Thesis Abstracts

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Sub-Quaternary Himalayan tectonics inferred from luminescence thermochronometry

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Luminescence thermochronometry is a very low-temperature thermochronometer that allows reconstruction of the thermal histories of the upper first few km of the Earth's crust within the last few 100 kyr (late Quaternary); a spatial and temporal scale hitherto at the sensitivity limit of other methods. Despite the potential of this method for deriving changes in landscape and subsurface evolution, it has until now never been applied to a large-scale study area, or been validated as a multi-thermochronometer approach.

I calibrated the multi-luminescence measurement protocol for feldspar thermochronometry by analysing three sets of samples (independently known thermal histories samples, synthetic thermal history samples created following irradiation at high temperature in the laboratory, and unknown-thermal history samples). As the reconstruction of a sample's thermal history depends on the thermal kinetic parameters extracted from isothermal decay experiments, I tested the validity of thermal kinetic parameters obtained from different combinations of isothermal holding data by trying to recover the sample's temperature. I found that the temperatures inferred from inverting the data vary depending on the combination of isothermal holding temperatures used for thermal kinetic parameter derivation, and that the inclusion of isothermal holding data above 250 °C result in kinetic parameters that underestimate modelled temperatures. For appropriate thermal kinetic parameter derivation, and thus accurate thermochronometric data, I recommended using a new protocol with four isothermal holding temperatures between 190 and 250 °C.

The improved multi-luminescence thermochronometry method was then used as a tool to constrain the late Quaternary exhumation history of the Himalayas, where two end-member competing models have been proposed to describe the kinematics of the central Nepal Himalayas in the last few Myr. They differ in their interpretations of which surface breaking faults accommodate current shortening and the kinematics responsible for driving rapid exhumation in the topographic transition zone around the Main Central Thrust (MCT). These locally higher uplift and erosion rates in the High Himalaya could reflect thrusting over a midcrustal ramp with the growth of a Lesser Himalaya duplex at midcrustal depth, or out-of-sequence thrusting along the front of the High Himalaya, possibly driven by climatically controlled localized exhumation. To address this debate, I successfully measured and analysed more than 100 rock samples with luminescence thermochronometry ($10^{4\text{-}5}$ yr), filling the temporal gap between GPS measurement, palaeoseimic ($\leq 10^2$ yr), Holocene fluvial terrace records ($10^{3\text{-}4}$ yr) and geological estimates ($\geq 10^6$ yr) of exhumation rates.

I first focussed on the Sub-Himalayas, the most frontal fold-and-thrust belt of the Himalayan orogen. Samples collected along six transects across the Siwalik foothills yield exhumation rates of ~ 3 – 11 mm/yr over the past ~ 200 kyr, which convert to thrust slip rates of ~ 6 – 22 mm/yr. Comparing these rates with geodetic convergence rates indicates that at least half of the Himalayan convergence is accommodated by the Sub-Himalayan fold-and-thrust belt, and particularly by the Main Frontal Thrust, since the late Quaternary, consistent with this fault being a high seismic hazard zone. Data also record exhumation rates on local Sub-Himalayan intra-wedge thrusts throughout the same time period, implying that internal deformation of the orogenic wedge and strain partitioning may have occurred, potentially endangering an entire population.

I then compared existing low and medium-temperature thermochronometric data ($^{40}Ar/^{39}Ar$ on muscovite, apatite and zircon (U-Th)/He, and apatite and zircon fission track), to newly acquired luminescence thermochronometry data from the High Himalaya of central Nepal. All of the thermochronometric data show younger ages and higher exhumation rates around the topographic transition and the MCT zone. For the higher temperature thermochronometers, a continuous trend towards younger ages from the Lesser Himalaya through the topographic transition and the MCT zone suggest that the duplexing model best describes the thermochronometric ages of this study area on Myr timescales. However, the luminescence thermochronometry data highlight a systematic sharp transition at the MCT, pointing to out-of-sequence activity at this tectonic boundary on 100-kyr timescales. Whether this difference in tectonic model between the two timescales is due to low resolution of the higher temperature thermochronometers, shallow isotherms deflected by fluid circulation and hot spring activity near the

MCT, or to a change in tectonic regime during the last 200 kyr, out-of-sequence activity of the MCT needs to be considered in seismic hazard models as it could put the local population at risk.

A PDF of this thesis can be obtained by contacting the author: chloe.bouscary@unil.ch

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Development of an Instrument for Spatially Resolved, Optically Stimulated Luminescence Dosimetry of Cobble and Dosimeter Surfaces

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Optically stimulated luminescence (OSL) dosimetry is a method used to determine the amount of energy stored within a crystalline insulator due to ionizing radiation. At its most fundamental, OSL dosimetry requires optical stimulation to induce a sample to emit luminescence, a light detection apparatus to collect the luminescence signal, and a calibrating radiation source to convert the acquired signal into an equivalent dose. Conventional instruments have successfully integrated these components to perform OSL dosimetry on sediment and dosimeters. In this dissertation, an instrument was developed that allows dose-mapping: LuCIDD (Luminescence instrument with Confocal and Imaging unit for Dating and Dosimetry) is based on the principles of a confocal microscope. This dissertation outlines the requirements for spatially resolved dosimetry mapping and describes the design and construction of LuCIDD. Tests of the integrated lasers' ability to perform spatially resolved stimulating measurements were made by measuring their focal spot size, power density, and penetration depth. Used for calibration, the built-in X-ray source's energy spectrum, uniformity, and dose rate were characterized. The minimum resolution and stimulation time for measurements were determined, quantifying the amount of time to complete a dose map of a sample's surface. Lastly, LuCIDD's ability to recover a known applied dose from single points was verified to provide a proof-of-concept for future dose-mapping measurements.