Luminescence dating –what is it, what can it do, and why is it important?

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The Earth’s surface is an archive of the history of our species and of our environment but to read and interpret the information recorded in this archive, we must have a means of knowing when the various records were preserved, and so when the events actually happened. Luminescence dating is an important and widely-applicable chronological tool used to date these records. The technique is not new, but recent developments have led to an explosion in applications, so that today it is one of the three most widely used methods in the geo- and archaeo-chronology of the last 500,000 years. This talk outlines the principles of the method, and discusses the advantages and limitations of the most widely-used form, optically stimulated luminescence (OSL) dating. Evidence for the precision and accuracy of the method is presented. The importance of the technique to studies of human evolution and migration, and to our understanding of past climate change is then illustrated using studies ranging in scale and time from the recent bioturbation of mudflats to late Quaternary ice advances in Eurasia. Finally, exciting new developments in rock surface dating are summarised.
It is concluded that OSL dating in its various forms is the most widely applicable dating tool available to earth scientists and archaeologists. It has grown from being relatively minor and unimportant to become one of the three pillars supporting modern archeo- and geo-chronology, and despite nearly 60 years of development, new signals, new techniques and new applications are constantly appearing. It continues to be a very exciting field in which to work.

Keywords: OSL dating, geochronology, quartz feldspar, rock surface dating

海浜カットアンドフィル堆積物の高分解能OSL年代測定：オーストラリア南西部Bengello Beachにおける海浜侵食履歴の評価
High-resolution OSL dating of cut-and-fill beach deposits for assessing beach erosion history in Bengello Beach at Moruya, SE Australia

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海浜や砂丘地などの露光しやすい環境では，石英の光ルミネッセンス（OSL）により，過去数十年程度の若い堆積物の年代を決定することができる．ごく稀に大規模なストームが発生すると海浜の砂が侵食されて海岸線が大きく陸側後退することがあり，そうした侵食の規模や頻度を理解することは海岸の保全に重要である．しかし，現在の海浜で行われている観測の期間は短く，そうした低頻度のイベントを経験的にとらえることは容易ではない．海浜堆積物は，過去の長期間に渡る堆積と侵食との繰り返しにより形成されるものであるが，それをもし連続的に年代測定することができれば，そこから海浜侵食の履歴を読み取ることができる可能性がある．ここでは，ベイズモデルを組み合わせた高分解能光ルミネッセンス年代測定と地中レーダ探査に基づく地質学的な海浜侵食履歴の評価方法を，オーストラリア南西部のBengello Beachを例に示す．Bengello Beachでは1972年以来定期的に海浜地形の観測が行われており，大規模なストームの後に海浜が後退しその後2〜3年以内にまた回復するという，カットアンドフィルと呼ばれる地形変化パターンを示すことが知られている．1974年に発生したストームにより海浜が50 mも後退したが，その後は海浜の後退量が30 mを超えるストームは発生していない．このため，1974の海浜侵食は50〜100年程度の再来周期を持つ低頻度のイベントであると考えられている．この海浜地形の観測は，海浜堆積物の上部の中で海浜侵食の直後の回復の期間に形成されたもののみが地層として保存されることを示している．つまり，海浜堆積物上部の年代は，過去に起こった大規模な海浜侵食のタイミングをほぼ表しているとみなすことができる．OSL年代の試料は，Bengello Beachの前置砂丘から内陸部120 mまでに発達する浜堤の地下から5〜10 mの水平間隔で採取した．ここで最も陸側の古い試料は510年前の年代を示すため，それ以降の正味の海岸線の前進速度は0.24 m/yとなり，中期完新世以降の平均値に等しい．得られたOSL年代は，350, 180, 130, 90年前の侵食イベントを示唆し，また1974年の侵食により形成された地形と整合的な結果となった．海浜の前進速度が0.24 m/yで一定だと仮定すると，これら4回のイベントでの後退量は 45〜55 mと見積もられ，1974年に匹敵する．350年前のイベントに続いて形成された幅約40 mの区間の海浜堆積物から採取された4つの試料はほぼ同じ年代を示し，そのすぐ海側の堆積物との間で150年間のギャップが認められ，180〜330年前においては大規模な海浜侵食が発生しなかったことを示唆している．以上の高分解能OSL年代測定により，Bengello Beachで1974年に匹敵する海浜侵食は，350年前以降50〜150年の間隔で発生していることが明らかになった．

キーワード：海岸、年代学、堆積学、第四紀学、ルミネッセンス年代
Keywords: coast, chronology, sedimentology, Quaternary science, luminscence dating

Luminescence characteristics and IRSL-chronology of extreme-wave event deposits recorded at the Shirasuka lowlands, Japan

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The location of Japan at the Pacific-Philippine-Eurasian subduction zones makes it vulnerable to earthquakes and subsequent tsunamis. Furthermore tropical cyclones cause destructive storm surges. Both natural hazards may generate extreme-wave events, which are a major threat for coastal communities.

The Shirasuka lowlands, sandwiched between a Mid-Pleistocene terrace and a coastal dune, record evidence for numerous extreme-wave events. Located along an important historical trade route, their impact history is well documented in written sources and a radiocarbon chronology has been developed for seven extreme-wave event deposits previously identified in this area (Fujiwara et al., 2006; Komatsubara et al., 2008). Therefore, this study area provides an excellent opportunity for testing the applicability of OSL dating to young (< 800 years) coastal, potentially incompletely bleached extreme-wave event deposits.

Quartz is preferred for dating such sediments, due to its faster rate of signal resetting. However, OSL measurements failed due to low signal intensities, absence of a fast component, and sensitivity to IR stimulation. Consequently, feldspar was used instead. The $IRSL_{50}$ signal has high signal intensities and resets quickly. However, thermal transfer affects these young feldspars. To minimise this effect and thus reduce recuperation, a second optical stimulation at 130 °C was included in Lx and Tx cycles of the $IRSL_{50}$ protocol.

Final dating was performed on single-grains of feldspars to (i) lower residuals, and (ii) account for potentially incomplete bleaching.

The resulting ages cover the known historical record of the extreme-wave events of the last 800 years at Shirasuka. Sand sheets can be correlated with tsunamis in AD 1361, 1498, 1605 and 1707. A poorly bleached equivalent dose distribution of the uppermost sand sheet hints at a different transport mechanism. The IRSL age range suggests a correlation with the Tonankai earthquake in AD 1944. Since the subsequent tsunami did not inundate the study area, a terrace slope failure due to intense shaking, is suggested for this sand sheet.

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Keywords: feldspar, single grain, tsunami deposits, storm surge deposits

ルミネッセンス年代測定による阿蘇火山のカルデラ決壊洪水発生時期の推定

Constraining the timing of the caldera outburst floods from Aso volcano

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The bouldery volcaniclastic apron sediment (Takuma gravel bed) west of Aso volcano and the overlying tephric loess were studied by Tsukamoto et al (2013) and a preliminary luminescence age constraint of 72-89 ka for the timing of the caldera outburst flood event, which built the volcaniclastic apron, has been reported. In this study we collected additional samples to further constrain the timing of the caldera outburst flood event. Samples were also taken from the Aso-4 ignimbrite, Hotakubo gravel bed consisting of the lower volcaniclasic apron along the Shirakawa River, and the tephric loess deposited above the gravel bed. The luminescence measurements of the tephric loess samples were performed using two post-IR IRSL (pIRIR) protocols with the pIRIR stimulations at 225˚C and 290˚C. The two pIRIR signals gave consistent ages and the result indicates that the gigantic caldera outburst flood event probably occurred shortly after the Aso-4 eruption, ~86 ka, and the another bouldery Hotakubo gravel bed, which is of cut terrace deposits derived from Takuma gravel bed or of other possible flood event occurred at ~47 ka. The ages will be further compared with the pIRIR ages from the gravel beds themselves. Interestingly, the Aso-4 ignimbrite using the pIRIR signal at 225˚C was dated to a much younger age (~40 ka) than the reported eruption age at ~87 ka (Aoki, 2008). This probably indicates that a very long time was needed for the sampled Aso-4 ignimbrite until the temperature reached to the effective closure temperature of the signal (~60-80˚C, King et al., 2016).

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キーワード：ルミネッセンス年代測定、post-IR IRSL、テフリックレス、火山性緩傾斜扇状地堆積物
Keywords: luminescence dating, post-IR IRSL, tephric loess, volcaniclastic apron sediment

