Potential of optically-stimulated luminescence (OSL) dating to improve Quaternary geology in Japan

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The optically-stimulated luminescence (OSL) dating has become a versatile and common method for determining depositional ages of Late Quaternary sediments worldwide over the last 15 years like the radiocarbon dating. The major advantage of this method, compared to the radiocarbon dating, is its applicability to ubiquitous minerals including quartz and feldspar in a wider age range, from several decades to a million years. Its disadvantage in contrast is problems in accuracy and reliability that are derived from uncertainties in the dose rate during burial and from regional variations in luminescence properties of mineral grains. The OSL dating is therefore regarded as an alternative, but still very effective, method where the radiocarbon dating does not work for some reasons. On the contrary to the recent expansion worldwide, the application of the OSL dating to sediments in Japan has been limited yet. The main reasons for this include unfavorable luminescence properties of quartz, especially of volcanic origin, and less importance of the OSL dating due to well-established Late Quaternary tephrochronology in Japan. However, some modified or even standard protocols of the OSL dating, especially those using K-feldspar, have been proved to effective for Japanese sediments, and there are still many cases in which the OSL dating is expected to have a critical role. We review the recent application of the OSL dating to Japanese coastal sediments, including in coastal dunes, beach ridges, tsunami deposits, raised marine terraces, and alternations of loess and tephra, and summarize their achievements and problems.

Keywords: Quaternary, geology, coast, luminescence dating

Optically stimulated luminescence dating of marine sediments: a review

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Optically stimulated luminescence (OSL) dating determines the time that has elapsed since sediments were last exposed to sunlight; the technique is widely applicable to late Quaternary sediments. An OSL age is calculated by dividing the radiation dose that has been absorbed by mineral grains during burial by the rate of energy absorption from ionizing radiation during burial (dose rate). The dose is measured using luminescence techniques and the dose rate is calculated from a knowledge of the concentration of natural radionuclides (U- and Th-series and ^{40}K) in the sediment matrix. A prerequisite for obtaining an accurate luminescence age is that all grains have been exposed to sufficient sunlight to empty the prior trapped charge prior to burial.
In contrast to studies on land, the application of OSL dating to marine sediments has been limited. The main reasons appear to be difficulties during sample collection (ensuring light shielded condition), the usually fine-grained nature of the material and the evaluation of the life-time burial water content. Here we give an overview of luminescence dating applied to marine cores, discuss the recent methodological advances and the upper and lower age limits. Finally, we show the potential of OSL dating of marine cores when high sampling depth resolution is available.

Keywords: optically stimulated luminescence dating, Quaternary

Luminescence dating of last Pleistocene marine terrace

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The marine terrace formed during sea-level highstand is important to understand the tectonics in the coastal area, Japan. To estimate the formed age of marine terrace is a key to reconstruct the uplift rate which is one of the most important tectonic information. In previous works, there were some uncertainties depending on indirectly age determination based on tephrochronology of terrestrial sediment, distribution of marine terraces in that area and so on. To determine the age of marine terrace directly, Post-infrared infrared stimulated luminescence (pIRIR) dating which can be used for sand samples from Late Pleistocene to present, was applied to the marine terrace. On the other hand, pIRIR signal was also applied to modern beach sands to know the difference of signal stabilities between difference areas and residual dose which was one of the most important factors in pIRIR dating. In seven outcrops of marine terraces of MIS5e, 7, 9 and 11 at Kamikita coastal plain, pIRIR ages were determined by using K-rich feldspar from subtidal sediments. Each age had no age difference between each subtidal facies of same outcrops because of measurement precision. However, considering error range, the average ages of samples from all subtidal facies of same outcrops were relatively concordant with expected ages of marine terrace which were based on Koike and Machida (2001). On the other hand, the luminescence characteristics of pIRIR signal such as signal stability were difference between each sampling area in Japan. This difference influenced the suitable choice of pIRIR protocols which had several differences between measurement temperatures. As a result, it suggested that we could apply pIRIR protocols to other marine terraces in Japan too, considering the signal stability depending on sampling area.
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Koike K. and Machida H., 2001. Atlas of Quaternary Marine Terraces in the Japanese Islands. University of Tokyo Press, ISBN 4130607359 (in Japanese).

Keywords: pIRIR dating, Marine terrace, Late Pleistocene

Luminescence chronology of the Middle Pleistocene marine and fluvial terraces in northern Japan using pIRIR dating

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In nothrern Japan, it has been difficult to construct a detailed chronology of marine / fluvial terraces of the Middle Pleistocene, due to the lack of the marker tephra layers and to the deformation of original landforms by strong past periglaciations. The lack of age constraint has prevented studies of precise geomorphic development and palaeoenvironmental reconstruction in this area. This study applies a post-IR IRSL (pIRIR;Thomsen et al., 2008; Buylaert et al., 2009) SAR protocol using polymineral fine grains to marine and fluvial terraces at Tonbetsu plain and Gifu Terraces along the Sea of Okhotsk coast area in northern Hokkaido, at Setana plain in southeastern Hokkaido.
In Tonbetsu plain, northern Hokkaido, the pIRIR ages from the higer marine terraces are ca.340 -370 ka, which yielded ages corresponding to MIS 9, respectively. In Setana plain, in southeastern Hokkaido, the pIRIR ages from the Oyachi marine terraces are MIS 7. In addition, pIRIR ages from upper Setana formation, basement of Tonke-gawa fluvial terraces, are ca. 400 ka. These pIRIR ages indicate that upper limit age of Setana formation and development of landforms after the Middle Pleistocene in Setana plain. I will also introduce pIRIR dating results and it’s meanings of marine / fluvial terraces of the Middle Pleistocene, northern Honshu Island.
Reference
Buylaert et al., (2009) *Radiat. Meas*. 44, 560–565.; Thomsen et al.(2008) Radiation Measurements, 43, 1474-1486.

Keywords: pIRIR dating, northern Japan, marine terrace, fluvial terrace, Middle Pleistocene

Potential and problems of K-feldspar optically stimulated luminescence dating of tsunami deposits

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In active tectonic region (e.g. the Japanese islands), quartz is often not suitable for optically stimulated luminescence (OSL) dating because of a lack of fast component and/or fading. Although OSL dating of feldspar is also disturbed due to fading and necessity of longer sunlight exposure for bleaching, stronger infrared stimulated luminescence (IRSL) relative to quartz OSL accepts for single grain OSL measurements and dating of young samples. This study was undertaken in order to confirm potentials and problems of OSL dating of K-feldspar on tsunami deposits using the 2011 Tohoku-oki tsunami deposits at Soma and Minami-soma city and Jogan tsunami deposits (A.D. 869) at Minami-soma city, Fukushima Prefecture, northeastern Japan.
Equivalent dose ratio of the conventional IRSL signal (IR_{50}) and post-IR IRSL signal ($pIRIR_{150}$) indicated both the 2011 Tohoku-oki and Jogan tsunami deposits were probably unexposed sunlight during transport processes. Although this condition was not favorable for OSL dating, single grain K-feldspar IRSL measurements of the 2011 Tohoku-oki tsunami deposits were feasible to extract the bleached grains indicating true depositional age. It is interpreted the 2011 Tohoku-oki tsunami deposits include K-feldspar grains bleached just before the tsunami transportations. On the other hand, single grain K-feldspar IRSL measurements of the Jogan tsunami deposits were only able to extract one grain showing true depositional age out of the 199 grains in five samples, and about half of the equivalent doses of K-feldspar grains exceeded 200 Gy (saturation level). The results indicated main sediment sources of Jogan tsunami deposits were different from the 2011 tsunami deposits at Minami-soma city, and therefore it caused different amounts of the K-feldspar grains bleached just before the tsunami transportations.
This study indicates it is important for estimating accurate depositional age of tsunami deposits using OSL dating to consider sediment sources and to select grains which have received sufficient sunlight exposure just before tsunami transportations.

Keywords: optically stimulated luminescence dating, post-IR IRSL dating, single grain IRSL dating, K-feldspar, tsunami deposits, Fukushima Prefecture

Journey of sand grains from river to deep marine estimated from bleaching percentage (BLP) of feldspar grains

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Optically stimulated luminescence has two remarkable properties, (1) the intensity of mineral grain luminescence increases with the amount of ionizing radiation absorbed by the grain; and (2) sufficient exposure to sunlight results in resetting of the luminescence signal (bleaching). Using these properties, evaluation for sand grain transport with the content of completely bleached grains (bleaching percentage: BLP) was established. Several case studies from riverine sand (Shirai et al., 2008; Shirai and Hayashizaki, 2013) to deep marine turbidite sand (Shirai and Hayashizaki, 2013) and sand grain transport processes inferred from these results are introduced.

Keywords: IRSL, bleaching, transport process

Red thermoluminescence (RTL) dating of Pleistocene volcanic quartz

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The Red thermoluminescence (RTL) method using tephra quartz has been widely used to date Pleistocene volcanic activity. The RTL method has some useful advantages explained as follows; long trap life time (more than 10^7-10^9 years at room temperature 300K), little effect of anomalous fading and exceeding ability of dose response (Yawata and Hashimoto, 2004). The great potential of RTL method is realized when it is used for the dating of tephra products covering Pleistocene land forms in Japan. Additionally, single quartz grain RTL dating using SAR method (Wintle and Murray, 2003) was also employed for late Pleistocene tephra and succeeded in giving more accurate ages (Ogawa et al., 2011).
RTL research we have been carrying out using some tephra quartz grains in middle Pleistocene (ex. Hakkoda 1st stage pyroclastic flow) showed three type RTL emission patterns; mono-peak type, double-peak type and broad type.
A broad type with double peaks at around 300 and 360°C showed a quite different pattern when compared to the typical shape of a mono-peak type being commonly used for RTL dating, such as a late Pleistocene Toya tephra (Ganzawa et al, 2005).
The broad type of RTL emission is originating in ignimbrite, suggesting a high emplacement temperature over 800°C. Heating quartz grains up to 1000°C, using Hakkoda aquatic pyroclastic flow fixed at a temperature lower than 200°C, clearly showed a change of the RTL emission pattern from a mono-peak type to a broad type in accordance with temperature increment. The RTL pattern heated at 800°C agreed well with the pattern of the Hakkoda ignimbrite, presumably showing the emplacement temperature of 800°C in the volcanic products.

Keywords: Red thermoluminescence dating, Pleistocene tephra, RTL emission pattern

The comparison of Red Themoluminescence dating and Radiocarbon dating

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A widespread tephra layer is often used as a "time marker bed" in geology and geography. They can be dated by radiocarbon method on organic materials to determined the timing of volcanic events occurred up to ca.50 ka. However lacking of suitable material (e.g. burial wood) for radiocarbon dating is often become an obstacle to directly estimate the timing. Alternative option is using the K-Ar method, yet considerable uncertainties for dating of younger samples (< 100 ka) and limit of the dating materials, namely the requirements of high K contents minerals, also prevent from the methods ubiquitously be applicable for tephra dating. Although the period between 50 to 100 ka is very important for various studies such as Paleoclimatology and Archaeology, the chronological “gap” has been existed.
A trapped radiation charge dating technique will potentially solve these problems. We focused on development of the Red Thermoluminescence (RTL) dating for tephra since we observed that it captures stable and high intensity RTL signal. We established the dating protocol to deal with tephra to conduct RTL dating. Comparing with ages of tehphras dated by radiocarbon and K-Ar agreed very well with RTL dates showing reliability of our newly developped experimental protocol. Uncertainties of the RTL ages were much reduced and they were comparable to the radiometric dating results.

Keywords: AT ash, radiocarbon dating, Red thermoluminescence dating, widespread tephra

Characteristics of various feldspar IRSL signals and their applications

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Recent studies have revealed various recombination processes of feldspar infrared stimulated luminescence (IRSL) signals measured at different preheat and stimulation conditions. These different IRSL signals have very diverse thermal, athermal and bleaching properties. The post-IR IRSL (pIRIR) signals measured at 150°C ($pIRIR_{150}$), 225°C ($pIRIR_{225}$) and 290°C ($pIRIR_{290}$) are most commonly used for dating sediments. However, no widely accepted criteria exist to select preheat and stimulation temperatures for samples with different age ranges and from different depositional environments. It has been known that the pIRIR signal with higher stimulation temperatures is more thermally and athermally stable than the lower temperature signal, however, the higher temperature pIRIR signal is much more difficult to bleach. Therefore the higher temperature pIRIR singal (e.g. $pIRIR_{290}$) is less suitable for dating sediments from difficult-to-bleach environments. The pulsed IRSL signal is also known to be more stable than the conventional IRSL signal. Since the pulsed measurement is performed at a low stimulation temperature, this signal appears to be much better bleachable than the pIRIR signal and therefore more suitable to date waterlain sediments. In the presentation I will also introduce newly developed OSL thermochronology using multiple IRSL signals stimulated at different temperatures, which have different thermal stabilities.

Keywords: luminescence dating, feldspar, OSL thermochronology

Thermoluminescence dating of calcite: Application to calcite vein deposited from groundwater in Luzon, Philippines

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Advantages of calcite thermoluminescence dating are (1) effective range of dating is from thousands to one million, suitable to quaternary research, and (2) the radioelement in sample is not necessary, therefore applicable to variety of materials. Thus, thermoluminescence dating can be applied to calcite as well as ^{14}C dating and/or uranium disequilibrium. TL dating has been applied to various calcites, for example, inorganic carbonates such as limestone and stalagmite, and biogenic calcite such as shell, coral and snail plate. However, thermoluminescence dating of calcite is sometimes problematic; e.g., sensitivity change occurred through repeated heating of samples, difference in characteristics of luminescence response against different kinds of radiation (e.g., alpha-ray, beta-ray, gamma-ray and X-ray). This study applied TL dating to calcite vein deposited from high alkaline groundwater originated probably from the serpentinization of mafic rocks in Luzon, Philippines. High alkaline groundwater has been circulating along cracks in a rock and bentonite layers. Age of calcite contribute to determine the timescale of fluid-bentonite interaction in a geological framework, which is an important knowledge for a deep geological repository of radioactive wastes, for bentonite plays an important role to prevent an outflow of the contaminated groundwater to the environment.

For paleodose measurement, SARA (single-aliquot regeneration and added dose) method was applied to evaluate sensitivity change of calcite occurred through repeating heating of samples. To know the difference in characteristics of luminescence response against different kinds of radiation, we measured thermoluminescence of sample induced by alpha-ray, beta-ray, gamma-ray and X-ray, and the ages of calcites were calculated with these results.

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Keywords: Thermoluminescence, Calcite

