— Report —

Marine sediment coring in the dark side: a method of complete optical covered sampling onboard for the optically stimulated luminescence dating of deep sea-bottom sediment

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Optically stimulated luminescence (OSL) dating provides an absolute age control for marine deep-sea sediment. Optical history of target minerals such as quartz and feldspar in the sediment is critical for the OSL dating that includes not only natural processes but also artificial exposure process to the daylight during sediment coring and sampling. An onboard complete optical covered procedure for marine sediment coring from deep-sea bottom for the OSL sample was developed in order to avoid any optical exposure during the sediment sampling. The methods includes: (1) a black-colored inner tube is set up in the outer core barrel of sediment corer before sediment coring, (2) the black inner corer is carefully drawing out from outer core barrel after returning of the corer on deck, (3) both ends of section (top and bottom parts of the section) are covered by opaque caps just after sectioning of the core, (4) splitting of the whole-rounded core is carried out during the night on deck. The section is moved in the dark room and split into half-semicircle pillar-shaped core by using wire in the room, (5) split sections are pack into large opaque plastic bag and store in refrigerator (3 degree Celsius) before sampling, (6) aliquot sample for the OSL is taken from each section in the dark room and stored in small opaque plastic bag before analysis, (7) any sample preparation for the OSL is performed in the dark laboratory. By following the methods, only top and bottom parts of the section and outer rim of the sediment core may be affected by light exposure during the core processing, but the central part of the aliquot slice of the section is completely safe by exposure to daylight and available for the OSL measurement. The sediment coring in the complete dark side following the method results in fine OSL dating. The proposed procedure of this study will be a methodological standardization of optical covered sediment coring of deep-sea sediment.

Keywords : Optically stimulated luminescence, Marine sediment coring, Deep sea-bottom sediment

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1. Introduction

Optically stimulated luminescence (OSL) dating has a high potential for obtaining an absolute age control of marine sediment (Murray and Olley, 1999, 2002, Stokes et al., 2003; Jakobsson et al., 2003; Kortekaas et al., 2007; Madsen et al., 2007). The OSL dating makes uses of the OSL signal originated from electron charge trapped between the valence and electron band inside of crystal structure of minerals such as quartz and feldspar in the case of geological materials. As the trapped charge stores by ionization of the crystal by natural radiation of radioactive elements (mostly K, U, Th, and Rb) in burial sediments, the total duration of subsequent deposition and burial of the minerals is measured as the age. When the minerals are exposed to daylight, all or most of trapped charge is released, that is, the OSL 'clock' is rest to zero under daylight. The 'clock' starts when the minerals are intercepted from the daylight such as deposition of clastic minerals after being transported by wind, river, sea-ice, and ocean current. The OSL age is calculated from an equation: the OSL age = (equivalent dose rate (De) / radiation dose rate). Where, the radiation dose rate is calculated from measurements of the radioactive elements (K, U, Th and Rb) in the sediment (Aitken, M. 1985, 1998). The equivalent dose rate is determined by exciting specific minerals extracted from the sediment with light and by measuring the subsequent OSL emission.

In this basic principle, the optical history of target mineral in the deep sea-bottom sediment is critical for the OSL dating. This optical history includes not only natural process such as transportation, reworking and deposition, but also artificial exposure processes to the light during sediment sampling or sample preparation. During marine sediment sampling using sediment corer, a transparent inner tube is used for taking marine sediment core from the sea-bottom by sediment corer onboard of research vessel. However, it may have an optical problem for OSL measurement because the recovered sediment core will be exposed under sunlight during core processing on deck. In this reason, we have

(a)

(b)

(c)

Fig. 1. Marine sediment coring facilities. (a) Research Vessel (R.V.) Yokosuka (JAMSTEC). (b) Piston corer (on R.V. Mirai, JAMSTEC). (c) Gravity corer with a trigger.

developed an onboard complete optical covered procedure for the OSL samples from deep-sea marine sediments in order to avoid any optical exposure during the sediment sampling. In this paper, we present the procedure of the methods with fine OSL dating results.

2. Marine sediment coring

Deep sea-bottom sediment is usually taken using sediment corer such as piston, gravity, and multiple corers from a research vessel (Figs. 1 and 2). The sediment corer is operated through wire-line from the vessel with pilot corer. The corer slowly takes down above a few to 10 m above sea-bottom with a pilot corer. A trigger releases the corer with freefall penetration when the pilot corer hit sea-bottom. Recovered sediment core after returning of the corer onboard is sectioning into 1m-long core section on board. The 1m-long whole-rounded section then splits into half-semicircle pillar-shaped half cores (archive and working halves) (Fig. 2). In this normal sediment coring procedure, a transparent inner corer that is plastic columnar shape liner tube is used for taking marine sediment core from the sea-bottom with outer core barrel of sediment corer onboard of research vessel. The core processing on deck includes : a drawing inner corer from outer core barrels, a dividing inner core into sections, and splitting whole-rounded core. These procedure into half-semicircle pillar-shaped core. These procedure is usually performed under sunlight.

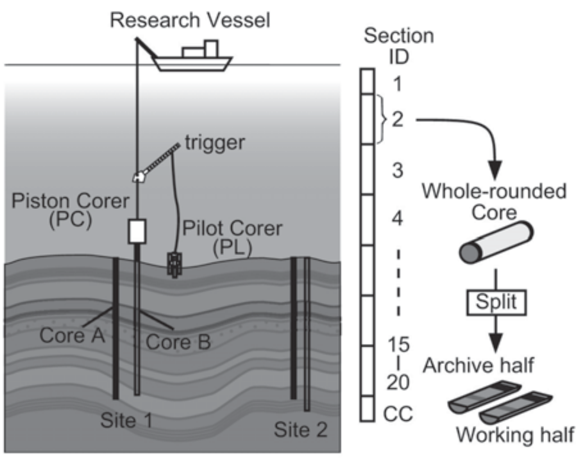

Fig. 2. Schematic view of standard sediment coring operation. (Left) The corer is operated through wire-line from research vessel. (Right) Recovered core is subdivided into 1 or 1.5-m sections with section ID. Each whole rounded section split into half-semicircle pillar-shaped sections (usually called as archive and working halves). Cc: core catcher.

3. Procedure of onboard optical covered sediment coring

For avoiding any optical exposure of sediment samples for the OSL dating during core processing onboard, we have developed a procedure for marine sediment coring from deep-sea bottom with complete optical covering (Fig.3). The procedure has conducted and tested during the research cruises MR0604 (R.V. Mirai, JAMSTEC) and YK0712 (R.V. Yokosuka, JAMSTEC, Sakamoto et al., 2008) in the central Okhotsk Sea. In these both cruises, a number of sediment cores including multiple, gravity, and piston cores has been recovered. In this development, we took notice that the procedure should not take much time and special step on normal sediment coring operation.

We constructed the following procedure: (1) a black-colored inner tube made by polycarbonate is set up in the outer core barrel of sediment corer before sediment coring (Figs. 4a and 4b). A handling of the sediment corer is as same way as normal sediment coring onboard. (2) After corer is returned on deck from the sea-bottom, the black inner corer is carefully drawing out from outer core barrel (Figs. 4c). (3) Immediately after sectioning of the long corer into 1-m long sections (Figs. 4d and 4e), both ends of section (top and bottom parts of the section) are covered by opaque caps (Fig. 4f). (4) Splitting of the whole-rounded core is carried out during the night on deck (Fig 4g). Core splitter is cut the black liner only in the edge of the plastic core liner without any affection of the sediment itself. The section is moved in

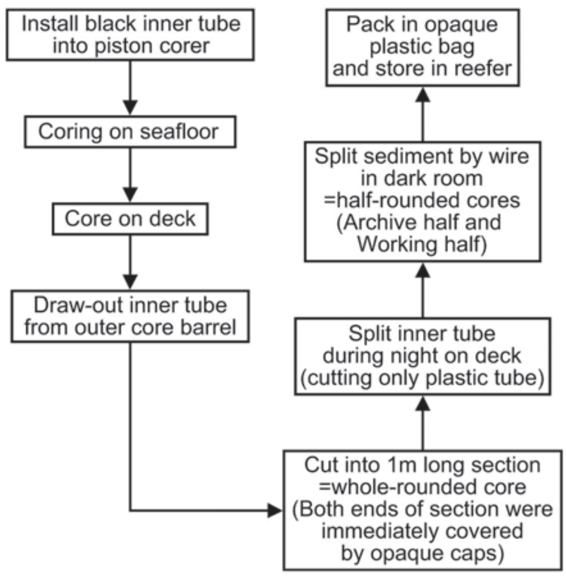

Fig. 3. Workflow of onboard complete optical covered sampling of deep sea-bottom sediment for OSL dating.

(a)

(b)

(c)

(d)

(e)

(f)

(g)

(h)

(i)

(j)

Fig. 4. Procedures of onboard complete optical covered sampling of deep sea-bottom sediment for OSL dating in the case of the piston corer system. (a) A stocked black-colored inner tube. (b) Setting of a black-colored inner tube in the outer core barrel of sediment corer before sediment coring onboard. (c) Drawing out of the black inner corer from outer core barrel. (d) Sectioning of the sediment core by inner tube-cutter. (e) Sectioning of the sediment core into 1-m long sections by spatula. (f) Both of ends of section (top and bottom parts of the section) are covered by opaque caps just after sectioning the core into 1m-long sections. (g) Splitting of the whole-rounded core during the night on deck. The image is just demonstrating the procedure under the light. (h) Opaque optical cover plastic bag for 1m-long core section. (i) Opaque optical cover plastic bag for aliquot samples. (j) The dark room for sample preparation.

the dark room and is split into half-semicircle pillar-shaped core by using wire in the room. (5) Split sections (archive and working halves) are pack into large opaque optical cover plastic bag and store in reefer (3 degree Celsius) before sampling (Fig. 4h). (6) Aliquot sample for the OSL is taken from each section in the dark room and stored in small opaque plastic bag before analysis (Fig. 4i). (7) Any sample preparation for the OSL is performed in the dark laboratory (Fig 4j).

During the core processing on deck, only a few cm of the top and bottom part of the section may be affected by optical exposure by sectioning process (Figs. 4d, 4e, and 4f). Outer rim of sediment in core barrel may be also optically affected by core splitting process (Fig. 4g). The outer rim parts should be discarded because it should be vertically contaminated during penetrating process into the sea-bottom. In this reason, both top and bottom parts of the section and outer rim of the sediment core are not used for the OSL measurement. Only the central part of the aliquot slice of the section is used for the OSL measurement (Fig. 5).

Fig. 5. Schematic view of sample separation for the OSL measurement. (a) Whole-rounded core section split into half sections. (b) Split core section subdivided into a series of slices in 1 or 2 cm intervals vertically. (c) After removing outer rim of each slice, central part of the slice is taken for the OSL measurement. Other part of the slice is for dose rate and other kind of measurements.

In the case of taking sea-bottom surface sediment, a black-colored core liner (60cm long) is directly set up in penetrating chamber of multiple corer system (Fig. 6a and 6b). Aliquot sample is taken directly from core tube in the dark room.

4. Results of the OSL dating by the new procedure

We test the quartz OSL dating in application of the new sampling method a 19 m marine core (MR0604-PC4A) taken from the south-western Sea of Okhotsk. Fine-grained quartz (4 to 11μm) was chosen as the dosimeter, because these grains are small enough to ensure complete penetration by all type of radiation, α, b, γ from the radioactive nuclide in the same horizon. A single-aliquot regenerative-dose protocol

(a)

(b)

Fig. 6. Procedures of onboard complete optical covered sampling of deep sea-bottom sediment for OSL dating in the case of multiple corer system. (a) Multiple corer for recovering sea-bottom surface cores. (b) A black-colored inner tube directly set up in multiple corer system. In comparison with recovered transparent inner tube informs about the expected recovered sediment in the opaque core tube.

was used for the determination of equivalent dose (De), with stimulation by both infrared and blue light. The resulting ages lie in the range up to 25 ka, and appear to be consistent with available radiocarbon ages from the same core (Fig. 7). The high-resolution chronology allowed us, for the first time, to quantify precisely the changes in sedimentation rates in this area before, during and after the last glacial maximum.

Another test was conducted in core MR0604-PC7 located at the central part of the Sea of Okhotsk where much slower sedimentation rate was expected in comparison to that of the core MR0604-PC4A (Sugisaki et al., 2008, this volume). The reliable absolute age of the last interglacial period (marine isotope stage 5e) was successively obtained for the first time by the OSL dating of fine-grained quartz from the sediment core.

Both results show that the OSL dating can be a powerful method for establishing high-resolution marine chronologies, especially in sediments with little biogenic carbonate.

5. Concluding remarks

In this paper, we present the onboard complete optical covered procedure for marine sediment coring for OSL measurement. This procedure is no doubt on optical exposure of the samples during the coring and sample preparation. The OSL signal, therefore, includes only natural optical history. The OSL dating results (Sugisaki et al.,

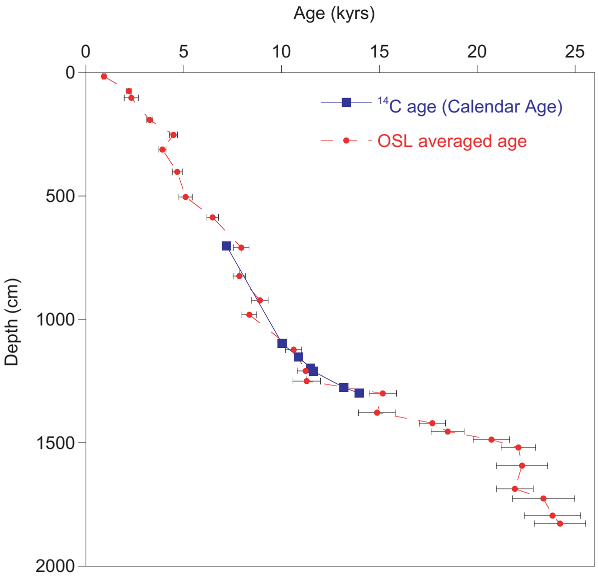

Fig. 7. Age-depth profile of the OSL dating and AMS radio carbon (^{14}C) dating of the Core MR0604-PC4 in the south-western part of the Okhotsk Sea.

2009) of deep-sea sediment samples following our procedure shows good agreements with independent age control by radiocarbon dating or marine oxygen isotope stratigraphy. The methodology of this study would be one of standard method for marine sediment coring for the OSL dating. .

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