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Lithological features of cored sediments from the northern part of Lake Tonle Sap, Cambodia

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ABSTRACT

Lake Tonle Sap situated in the central part of Cambodia is the largest lake in the Indochina Peninsula. Unique sedimentary processes due to drastic changes in its water area between the rainy and dry seasons are expected in the lake. It is also expected that regional environmental and climatic changes are able to be reconstructed over the period based on analyses of the lake-bottom sediments.

As the first step in a series on pursuing the above-mentioned subjects, two cored sediments obtained from the northern part of the lake were examined mainly from lithological point of view. Both cores, about one metre in length, are composed mainly of homogeneous and/or bioturbated mud, and a marked lithological change in sediment colour and grade of sediment compaction was recognized at a horizon of 47 - 48 cm below lake floor in both cores. Sediments below the horizon are composed of greyish olive green coloured homogeneous and/or bioturbated compact mud, but they are light olive grey coloured homogeneous soft or soupy mud above it. A slight but clear decrease of mud contents is recognized at the horizon. Sedimentation rates estimated on results of the radiocarbon datings of sediments was markedly dropped from 0.4 - 1.2 to 0.1 mm/year at the horizon in both cores. Taking all these factors and results of radiocarbon datings into consideration, it is inferred that an obvious change of depositional environments, probably the completion of basin filling, took place in the northern part of Lake Tonle Sap about 5,000 - 5,600 years B. P.

INTRODUCTION

Lake Tonle Sap, the largest lake in the Indochina Peninsula, lies in central Cambodia. The lake is known as "the elastic water world (Lao, 1992)", because its water area expands more than threefold due to a great amount of water supply from the Mekong River via the Tonle Sap River that connects the lake with the Mekong River during rainy seasons. It is also known as "the mud ocean (e. g. Ishizawa, 1989)" which refers to deep brown colour of the water all year round due to a large amount of muddy suspended sediments contained in water. Such setting hold out a promising prospect for investigations of unique sedimentary processes in the lake under the control of seasonal water-level fluctuations due to alternating rainy and dry seasons, characteristics of the tropical monsoon region (Tsukawaki *et al.*, 1994).

In addition, two hundred and fifteen species of fishes that come under 127 genera and 47 families including balloon fishes and rays which are generally marine forms are known in the lake and the Mekong River System in Cambodia (Kottelat, 1985). Further, sponge spicules are usually present in the bottom sediments from the lake and the Tonle Sap River (Tsukawaki and Moriai, 1993, Tsukawaki and Lao, 1995b). The presence of such marine creatures suggests that the lake was closely connected with the sea perhaps during the last high stand period of the global sea level (Tsukawaki *et al.*, 1994). Thus, it is expected that environmental and climatic changes, and their relationships with isolation of above-mentioned marine creatures in the lake, can be

reconstructed over a certain period based on the analysis of the lake bottom sediments.

Only a limited limnological, geological and sedimentological investigations has been carried out in the lake and adjacent river systems (e. g. Mitusio *et al.*, 1970; Lao, 1992 and 1993; Tsukawaki and Moriai, 1993; Tsukawaki and Lao, 1995a and 1995b; Tsukawaki *et al.*, 1994; Tsukawaki and Okawara, 1995) due to the presence of the Cambodian political unrest since 1970's. However, since the Cambodian political situations has been restored in the last few years, it can be said that a series on pursuing the above-mentioned subjects is able to start (Tsukawaki, in press).

Two cored sediments were successfully obtained from the northern part of Lake Tonle Sap by the "*Tonle Sap '96*" project (Members: Shinji Tsukawaki (Leader, sedimentologist: Faculty of Engineering, Kanazawa University, Japan), Michio Kato and Takahiro Kamiya (micropalaeontologists: Faculty of Science, Kanazawa University, Japan), Masafumi Okawara (clay mineralogist: Faculty of Engineering, Iwate University, Japan), Dallas C. Mildenhall (palynologist: Geological and Nuclear Sciences, New Zealand), Sotham Sieng and Sambath Touch (regional geologists: Department of Geology and Mines, Kingdom of Cambodia)) in May, 1996. In both cores, about one metre in length, no obvious discontinuous surfaces were recognized. Radiocarbon ages at a number of horizons of both cores were reported (Mildenhall, 1996; Tsukawaki *et al.*, 1997). Consequently, it is expected that environmental and depositional changes in the northern part of the lake can be reconstructed over a certain period based on analysis of the cores. Preliminary results of palynological investigation for one of the cores are reported (Mildenhall, 1996), but it has been still under the investigation for clay minerals and micro-organisms such as diatoms and ostracodes within the cores. Thus, the present paper illustrates mainly lithological features of the cores as the basic data for the above-mentioned and further studies, and an environmental change of the northern part of the lake at about 5,000 - 5,600 years B. P. will be discussed based on both lithological observations and the results of radiocarbon datings of both cores (Mildenhall, 1996; Tsukawaki *et al.*, 1997).

SAMPLING METHODS AND SAMPLE TREATMENT PROCEDURES

A 130 cm-long stainless-steel pipe Phleger-type core sampler (Phleger, 1951) with a 16 kg weight was utilized to obtain cored sediments from Lake Tonle Sap. Two cored sediments TS96-1 and 2, both about one metre in length, were successfully obtained in the northern part of the lake (Fig. 1).

The core TS96-1 was cut first vertically into two halves by a fishing line immediately after the sampling. One of the cutting surface was shaved and brushed well by a stainless-steel spatula and a spraying water atomizer for detailed visual observations. After visual observations and core descriptions were made, a certain centimetres thick slices were sectioned for both clay mineralogical and palynological analyses, and radiocarbon datings.

On the other hand, the core TS96-2 was carried back to Kanazawa University, Japan, then the core was processed same as the TS96-1. After visual observations were made, an 8-mm thick and 20-cm long sliced sediment was cased in a plastic box from the cutting surface of the lower part for soft X-ray observation, and about 5 cm thick slices were sectioned for micropalaeontological analyses such as foraminifers, ostracodes and diatoms, mud content measurements, and radiocarbon datings. For X-raying, the cased samples of the core TS96-2 were placed on Fuji industrial X-ray film type 100. The source-to-sample distance on the X-ray unit was 70 cm. Voltage, amperage and exposure time were hold constant at 50 kV, 4 mA and 80 seconds, respectively.

Microscopic observations using a number of smear slides for muddy sediments and thin sections for sandy sediments conduced to the textural and compositional description of cored sediments at several horizons of both cores.

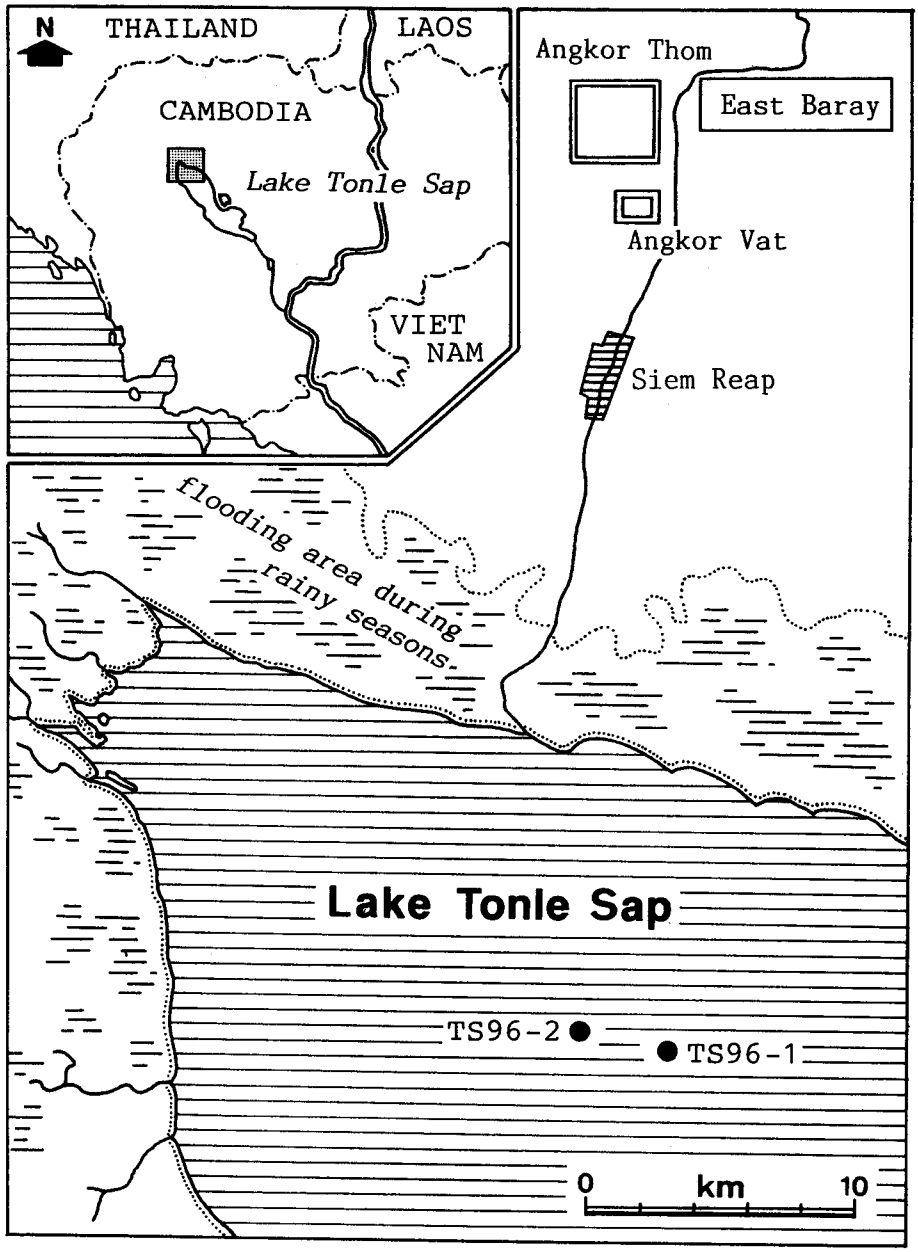

Figure 1 Locality of Lake Tonle Sap, central Cambodia (upper left), and samplings sites of cored sediments TS96-1 and 2 in the northern part of the lake. (after Tsukawaki et al., 1997)

LITHOLOGY OF CORED SEDIMENTS

TS96-1: This core, 125 cm in length, obtained from the northern part of Lake Tonle Sap at a water depth of 0.9 m, is composed of light olive grey soupy mud in the upper 22 cm and homogeneous or bioturbated muds in the lower (Fig. 2). In the lower part, a 25 cm thick light olive grey homogeneous mud overlies a 55 cm thick dusky yellowish green bioturbated mud, followed by an about 25 cm thick greyish olive green homogeneous mud. The lower bioturbated and homogeneous muds are relatively compact than overlain homogeneous mud. Parallel laminations are occasionally developed in part of the bioturbated mud. The sand is composed mainly of very fine-grained quartz, lateritic rock fragments and charred wood debris. The mud consists mainly of clay minerals with a small amount of biogenic materials such as diatoms and sponge spicules. A molluscan shell and shell fragments layer composed mainly of *Corbicula* sp. is intercalated at 26 cm below the lake floor.

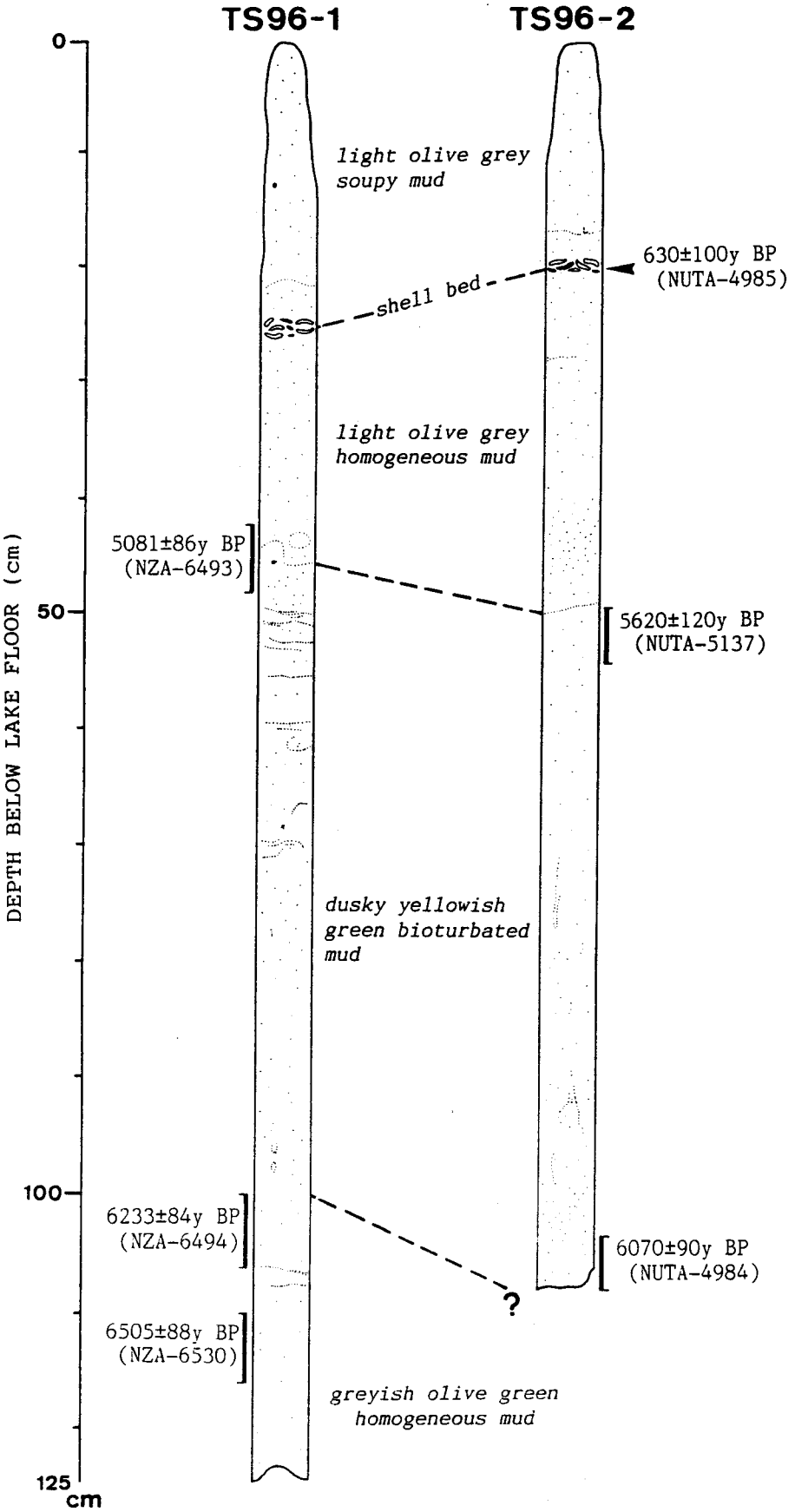

Figure 2 Lithology and radiocarbon ages of cored sediments TS96-1 and 2 from the northern part of Lake Tonle Sap, and correlation between them based on lithological features and radiocarbon ages. (after Tsukawaki et al., 1997)

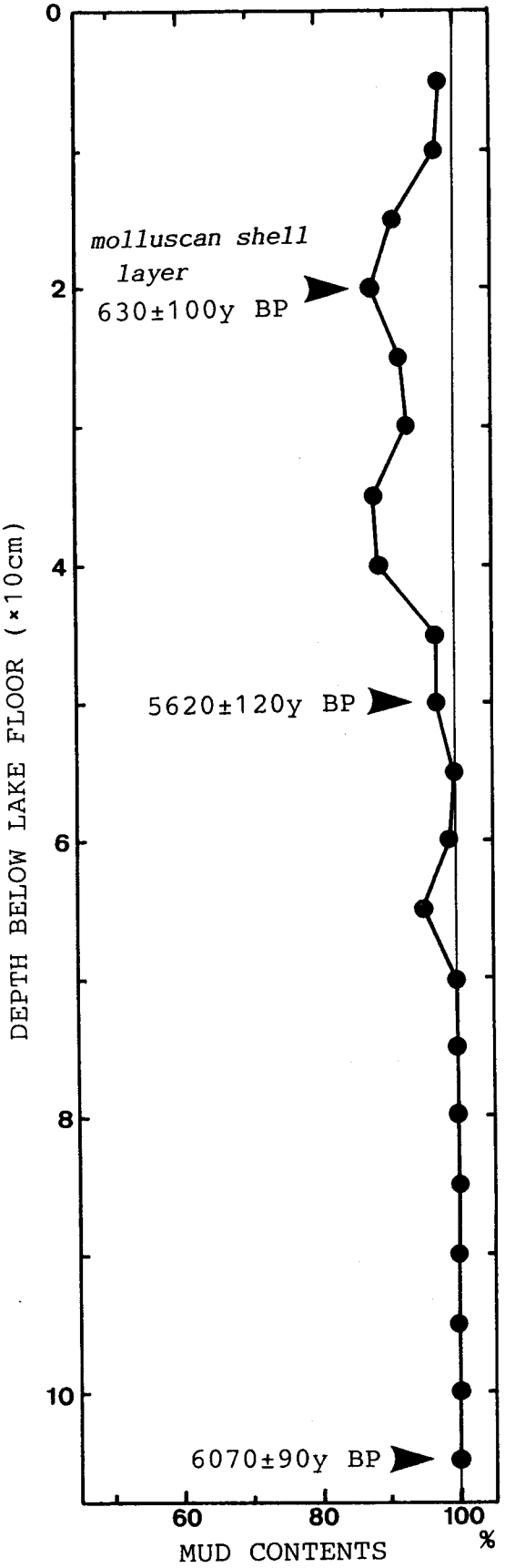

Figure 3 Vertical fluctuations of mud contents of the core TS96-2 from the northern part of Lake Tonle Sap.

TS96-2: This core, 108 cm in length, obtained about 4 km northwest of the site TS96-1 in the northern part of Lake Tonle Sap at a water depth of 0.9 m, is composed of light olive grey soupy mud in the upper 18 cm and homogeneous and/or bioturbated muds in the lower (Fig. 2). In the lower part, about 30 cm thick light olive grey homogeneous mud overlies a 58 cm thick dusky yellowish green bioturbated mud. The underlain bioturbated mud is relatively compact than the overlain homogeneous mud. The sand is composed mainly of very fine-grained quartz, lateritic rock fragments and charred wood debris. The mud consists mainly of clay minerals with a small amount of biogenic materials such as diatoms and sponge spicules. The mud contents are almost 100 % through the lower 50 cm, but they are about 90 % through the upper 50 cm of the core (Fig. 3). A molluscan shell and shell fragments layer composed mainly of *Corbicula* sp. is intercalated at 18 cm below the lake floor. No distinct internal sedimentary structures with exceptions of biogenic disturbance are recognized in soft X-ray radiograph observations through the lower part of the core.

DISCUSSION

Radiocarbon ages of sediments from 110-116, 100-106 and 42-48 cm below lake floor are 6,505±88, 6,233±84 and 5,081±86 years B. P. in the core TS96-1, respectively (Mildenhall, 1996). On the other hand, the ages of sediments from 103-108 and 48-53 cm below lake floor are 6,070±90 and 5,620±120 years B. P., respectively, and the age of a molluscan shell, *Corbicula* sp., collected from a shell layer 18 cm below lake floor is 630±100 years B. P. in the core TS96-2 (Tsukawaki *et al.*, 1997). On the basis of the radiocarbon ages of both cores with the exception of the age of the molluscan shell in the core TS96-2 that is an obvious reworked material, sedimentation rates in the northern part of Lake Tonle Sap during the last about 6,500 years can be estimated and they are summarized in Figure 4.

Tsukawaki *et al.* (1994) and Tsukawaki and Lao (1995a) prospected the sedimentation rate in the northern part of Lake Tonle Sap at a few centimetres per year based on the internal

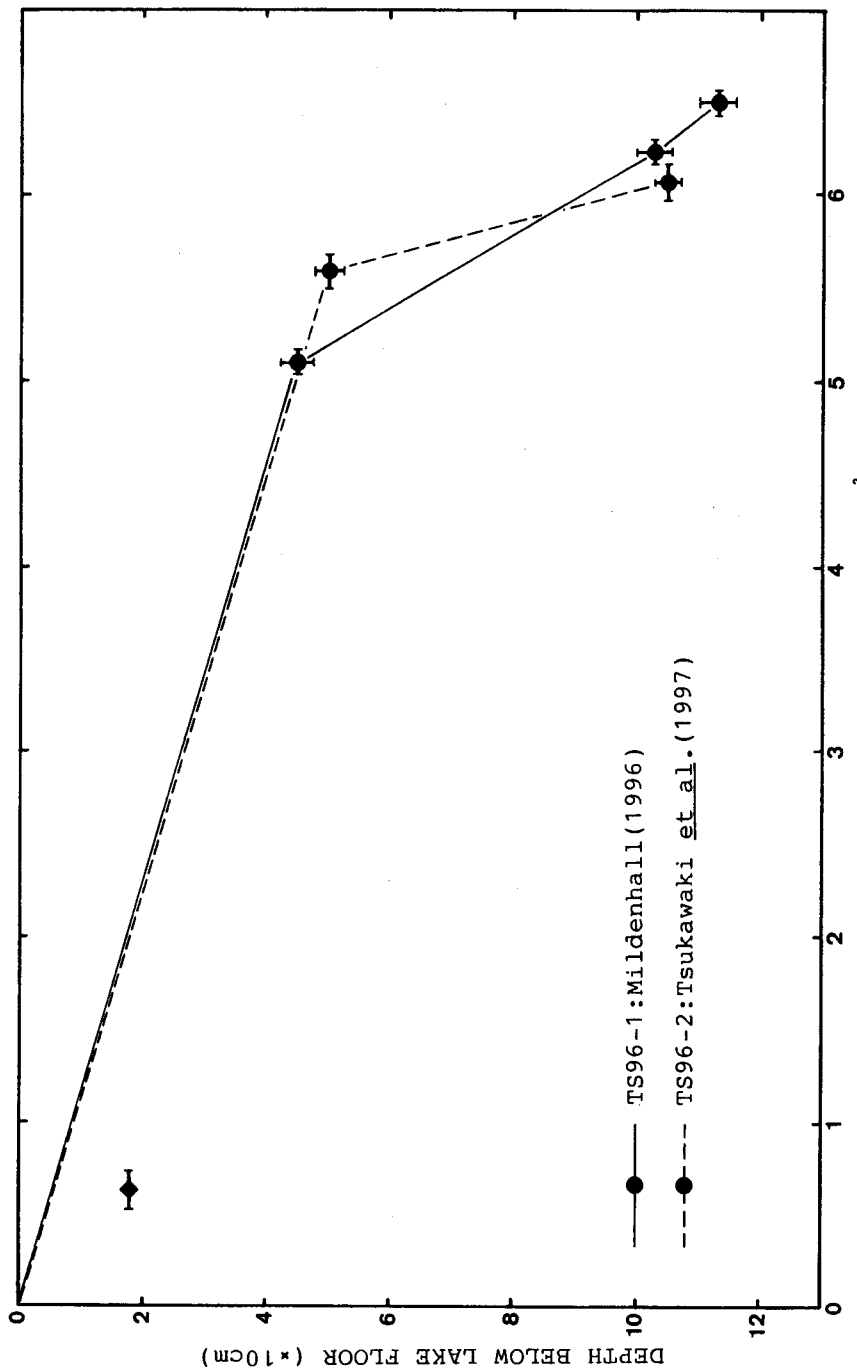

Figure 4 Estimated sedimentation rates of the northern part of Lake Tonle Sap based on the radiocarbon ages of sediments (Mildenhall, 1996; Tsukawaki et al., 1997). A lozenge indicates radiocarbon age of a molluscan shell, Corbicula sp., from a shell layer in the core TS96-2. Vertical and horizontal bars beside black circle indicate the sediment thickness for sampling and measurement errors, respectively.

structures of surface sediments obtained in the rainy seasons of 1992 and 1994. However, the estimated sedimentation rates in this study are much lower than the prospect of Tsukawaki *et al.* and Tsukawaki and Lao through the cores. At the sampling site TS96-1, sedimentation rates were about 0.5 mm/year since 6,505 to 6,233 years B. P. and 0.4 mm/year since 6,233 to 5,061 years B. P. On the other hand, the rate in the site TS96-2 located about 4 km northwest of the site TS96-1 was about 1.2 mm/year since 6,070 to 5,620 years B. P. Then, the rates have been drastically decreased to less than 0.1 mm/year since 5,061 and 5,620 years B. P. to the present in the sites TS96-1 and 2, respectively.

From the view point of lithological features, marked lithological changes in both colour and degree of sediment compaction are clearly distinguished at a horizon about 47 - 48 cm below lake floor in both cores. The sediments below the horizon are composed of greyish olive green or dusky yellowish green homogeneous and/or bioturbated compact mud, but above the horizon they consists of light olive grey homogeneous soft or soupy mud with an intercalation of molluscan shell layer. Further, a little but clear decrease in mud contents of sediments from 100 % to 90 % is recognized at the horizon in the core TS96-2.

Consequently, there is no doubt that a change of depositional processes took place around 5,000 - 5,600 years B. P. in the northern part of Lake Tonle Sap based on both lithological features and radiocarbon ages of the cored sediments. The lithological features and estimated sedimentation rates for both cores suggest that muddy sediments had been accumulated at 0.4 - 0.5 mm/year since about 6,500 to 5,000 years B. P. at the site TS96-1, and 1.2 mm/year since about 6,000 to 5,600 years B. P. at the site TS96-2, but muddy sediments with a small amount of sandy sediments have been accumulated at less than 0.1 mm/year since 5,000 - 5,600 years B. P. to the present in both sites.

Tsukawaki *et al.* (1994) illustrates that the present surface sediments contain about 2 % of sandy sediments at their site LTS-3 located about 5 km north of the site TS96-2, and they concluded that the sandy sediments in the present time are derived only from the alluvial plain around the lake, and no sandy sediments from the Mekong River via the Tonle Sap River are reached to the northern part of the lake even during flooding periods in the beginning of the rainy seasons. Thus, it may be inferred that the comparatively high sand contents in the sediments after 5,600 years B. P. and formation of a molluscan shall layer were resulted by the selected erosion for muddy sediments by the ebbing flow.

Taking all things into account, it is concluded that the sediment deposition that occurs mainly during flooding periods in the beginning of rainy seasons has been equivalent mostly to sediment erosion that occurs during ebbing periods in the beginning of dry seasons since about 5,000 - 5,600 years B. P. to the present. This equivalence has been resulted probably by the completion of filling up the northern part of lake basin.

CONCLUSIONS AND OPEN SUBJECTS

From the observation of lithological features and results of radiocarbon datings for cored sediments from the northern part of Lake Tonle Sap, it is concluded that a change of depositional environments, probably completion of filling up in the northern part of the lake basin, took place about 5,000 - 5,600 years B. P. Since, only two cores from the northern part of the lake were examined in the present study, systematic cored sediment sampling and examinations should be carried out over the whole lake in order to comprehend detailed depositional processes in the lake. Further, a long core sampling should be carried out in the central part of the lake in order to develop the environmental history of the lake over the last tens of thousands years.

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