The history of Lake Biwa drilling

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Sediments from Lake Biwa in central Japan preserve the paleoclimatic and tectonic history of the past 1 Ma of East Asia. In particular the uppermost massive clays are well suited to study high-resolution environmental change of the last 430 ka.

Lake sediments are important archives for understanding the environmental and tectonic history at regional to global scales. Located on the convergent margin of the Eurasian plate, the Japanese archipelago features many tectonic, volcanic, and coastal lakes well suited for paleolimnological studies. One of the most famous and most studied lakes in Japan is Lake Biwa. The first sediment core was retrieved in 1965 by Professor Shoji Horie and his team to study global climatic change and tectonic history of this convergent region. Since then, many more studies have been conducted on Lake Biwa. Here, I summarize the drilling history of Lake Biwa and put it in a broader perspective.

Southwestern Japan has been impacted by tectonic deformation throughout the Quaternary. The ca. 1.5 Ma old tectonic lake Lake Biwa (82 m a.s.l.) on south-central Honshu Island is the largest freshwater lake in Japan, measuring 22.6 km wide by 68 km long (Fig. 1). Lake Biwa is divided into two basins. The Northern Lake is a deep basin with a maximal depth of 104 m and average depth of 40 m. The much smaller Southern Lake is very shallow with an average depth of about 3 m.

Several attempts to recover core sediments from Lake Biwa have been made, mainly in the 65-70 m deep depression situated in the southern part of the northern Basin (Fig. 1). Horie et al. first recovered a six-meter long sediment core in 1965 and then an 11.5 m long piston core in 1967 (Horie et al. 1971). In 1971, with considerable effort, they managed to drill the sediments in the same depression (Fig. 1) and successfully obtained core samples totaling about 200 m (Horie 1984). Finally, in 1982 and 1983, they succeeded in recovering a 1400 m long core covering the entire sediment sequence. This record confirmed that the basin is filled with lacustrine and fluvial sediments about 800 m thick (Takemura and Yokoyama 1989; Horie 1991). Below 800 m the core is mainly composed of a ca. 100 m thick pebbles and cobbles layer, and Mesozoic-Paleozoic basement rocks. The uppermost unit consists of lacustrine clay and silt about 250 m thick, estimated to have deposited continuously during the last 430 ka (Takemura 1990; Meyers et al. 1993). In 1986, further samples of 141 m thick sediment were recovered

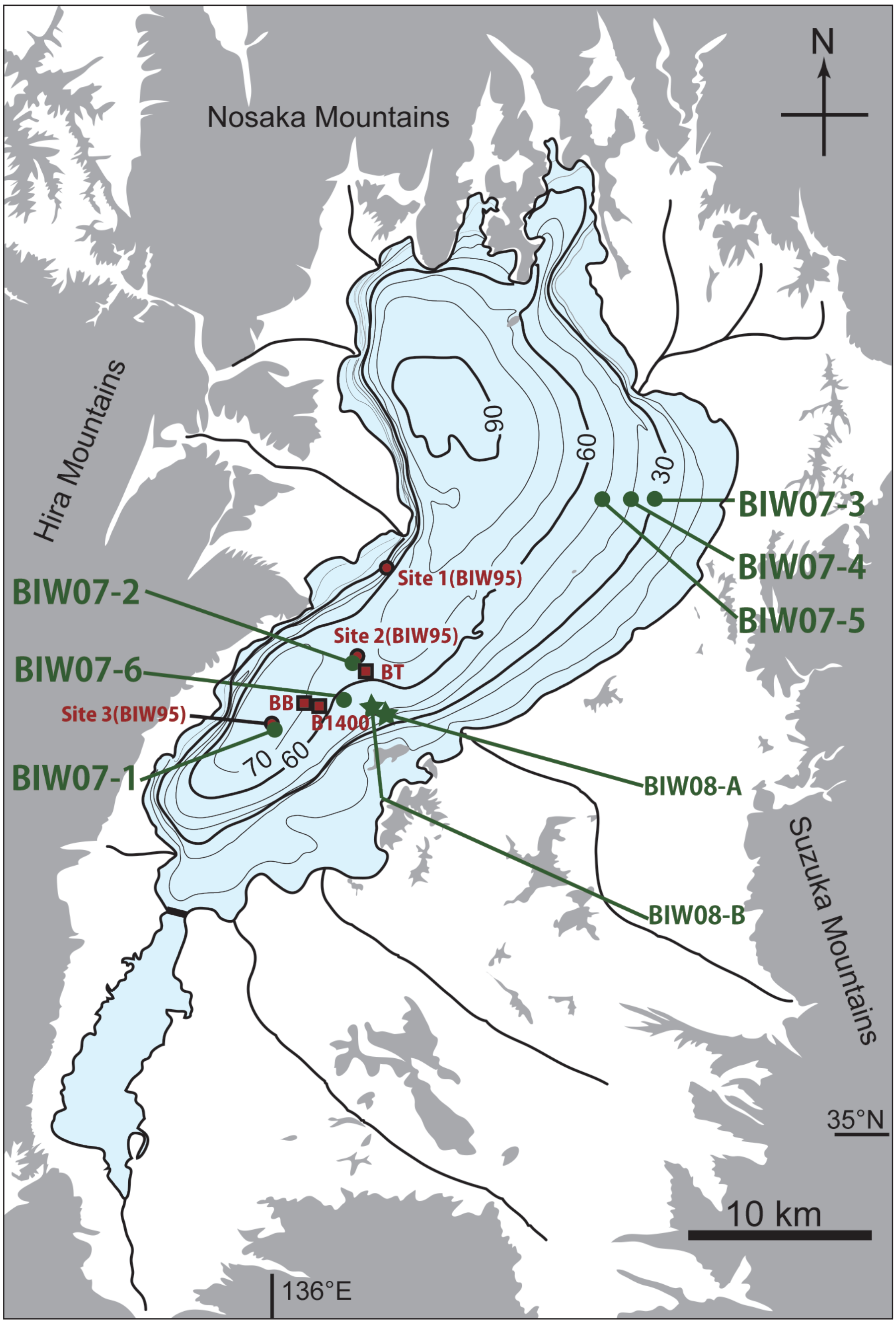

Figure 1: Map showing locations of principal coring sites in Lake Biwa (from Takemura et al. 2010). BB (200 m drilling in 1971; Horie 1984), B1400 (1400 m drilling in 1982-1983; Takemura 1990; Horie 1991), BT (141 m drilling in 1986; Yoshikawa and Inouchi 1991), Site 1, 2, 3 (BIW95; Piston cores in 1995; Takemura et al. 2000), BIW07-1 to BIW07-6 (Piston cores in 2007; Takemura et al. 2010), BIW08-A and BIW08-B (Drilled cores in 2008; Takemura et al. 2010).

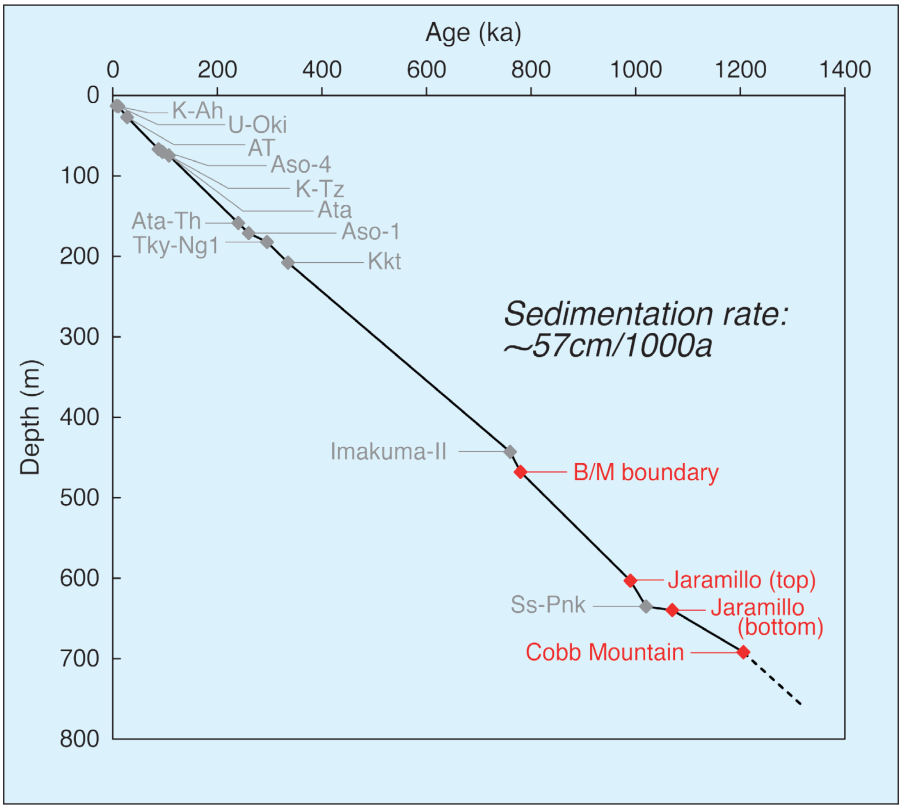

Figure 2: Summary of chronology of core B1400 based on the re-investigation of fission track ages, tephra identification and magnetostratigraphy (Danhara et al. 2010). Tephra horizons (gray): K-Ah, U-Oki, AT, Aso-4, K-Tz, Ata, At-Th, Aso-1, Tky-Ng1, Kkt, Imakuma II, Ss-Pink; Paleomagnetic information (red): B/M (Brunhes/Matuyama) boundary, top of Jaramillo event, bottom of Jaramillo event, Cobb mountain event.

about 5 km northeast of the older drilling sites (Fig. 1; Yoshikawa and Inouchi 1991).

Whereas the neighboring (ca. 20 km) basin of Lake Suigetsu has varved sediments of the past 150 ka, Lake Biwa has continuous sediments of a million years age. Therefore, together the two lake basin records will permit understanding the Quaternary climate and tectonics at annual to millennial time scales.

Initially, the scientific value of Lake Biwa sediments was not properly acknowledged because the first attempt of fission track dating gave a wrong Pliocene age to the basal part. This resulted in a significantly crooked sediment accumulation rate (SAR) curve, casting doubt on the continuity of the Lake Biwa sediment record. In 1993, based on a stratigraphic correlation of the Biwa core with marine data, Meyers et al. suggested that the fission track dates were erroneous. Then in 2005, improvements on the fission track timescale successfully identified the paleomagnetic reversal near the base as Jaramillo rather than Olduvai, estimating the time coverage of the Lake Biwa core as ca. 1.5 Ma (Danhara et al. 2010; Fig. 2). A highly linear SAR resulted for the 800 m deep Lake Biwa sediment record. This was evidence for the stable sedimentary environment of the basin, and the suitability of Lake Biwa as a paleoclimate archive. Moreover, progress in Japanese tephrochronology in recent decades enabled the identification of several marker tephras (Machida and Arai 2003) in and around the basin. Lake Biwa is, therefore, an ideal terrestrial site to explore paleoclimate and tectonic history during the past 1 Ma of East Asia.

Although the sediments of Lake Biwa have been analyzed by various methods, high-resolution studies have not yet been carried out. In most studies a single core was obtained at a single site. It was therefore difficult to evaluate the completeness of core recovery and disturbance of core samples. For example, we now know that in the deep drilling of 1982 and 1983, rotary coring caused disturbance of the upper sediment samples. For a detailed study of the sedimentary record, in 1995, we recovered seven piston cores (10-15 m long) at three localities (site 1, 2, 3) in the northern part of Lake Biwa (Fig. 1). We designed the coring plan (1) to take at least two cores from each site; (2) to take cores at three locations with different sedimentation rates; and (3) to recover the longest possible undisturbed sediment sequence. Analyses of the core samples include paleomagnetism, environmental magnetism, physical properties, organic and inorganic chemistry, pollen analysis and ^{14}C dating. We also demonstrated that magnetic susceptibility data are very useful to find microscopic tephra horizons, and establish correlation and age assignment of the core sediments from the different locations.

From the viewpoint of paleoclimatic change, Nakagawa et al. (2008) produced quantitative climatic reconstructions for the past 450 ka based on a long pollen record from Lake Biwa. Hayashi et al. (2010) reported a high-resolution pollen record covering the last 40 ka (BIW95-4) and found that they correlate with Dansgaard–Oeschger (D–O) cycles recognized from the anhysteretic remanent magnetization (ARM) record (Hayashida et al. 2007).

Drilling challenges are continuing for high-resolution studies on paleoenvironments and island arc tectonics. In 2007 and 2008, we obtained six new piston cores covering at least 50 ka, two longer cores covering 300 ka (Takemura et al. 2010), and 300 km long shallow seismic surveys. Various interdisciplinary analyses are expected to generate high-resolution records of the environmental change of the Asian monsoon and of the dynamics of the tectonic convergence.

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http://www.pages-igbp.org/products/newsletters/ref2012_2.pdf

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