Geomorphic History and Tectonic Movement of Lake Biwa during the Quaternary Period, Japan*

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Abstract

On the basis of the detailed mapping and correlation of the four terraces and three sublacustrine terraces in and around Lake Biwa, geomorphic history since 0.3 Ma has revealed. The distribution and characteristics of the buried basement topography and active faults of the bottom of Lake Biwa were made clear on the basis of the interpretation of the reflection profiles obtained by air gun and uniboom methods. Geomorphic development and tectonic movement of the Ohmi Basin including Lake Biwa since 2 Ma were discussed and paleogeographic maps of Lake Biwa in four stages (2, 0.4, 0.1 and 0.03 Ma) are shown. The tectonic history of Lake Biwa and its basin is divided into 3 stages based on the relation between paleogeography and tectonic movement: (1) down warping stage (2 Ma to 1.2 Ma), (2) fault angle basin stage (1.2 Ma to 0.4 Ma), (3) ramp structure overlapping fault angle basin stage (0.4 to the present).

Key word : Lake Biwa, Quaternary tectonics, geomorphic history, paleogeographic map

Introduction

As the largest and oldest lake in Japan, Lake Biwa has existed since 4 Ma in

* This paper was read at International Conference on Ancient Lake (ICAL), held at Lake Biwa Museum, Shiga (Japan), June, 27, 1997.

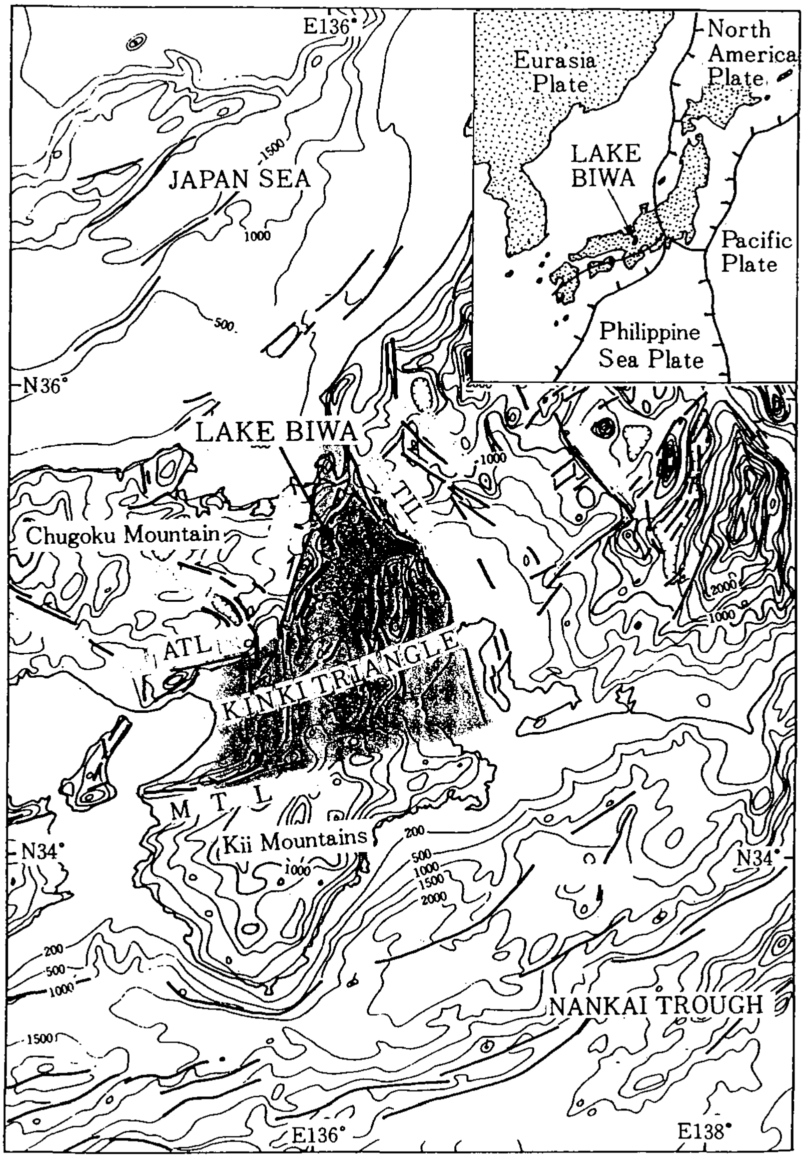


Fig. 1 Location of Lake Biwa and the Kinki Triangle province (dotted area).
Thick line : active fault, Contour interval : 200 m (500 m in the sea)
ATL : Arima-Takatsuki Tectonic Line, TIL : Tsuruga-Isewan Tectonic Line, MTL : Median Tectonic Line

Kinki Triangle tectonic province, south-west Japan (Fig. 1). The lake is characterized by broad water area (67.9 k㎡, water level is 84.5 m in altitude), long history and the existence of many endemic spices. Geomorphic development have been intensely controlled by tectonic movement, and situation of the lake basin has migrated from south to north drastically.

In this paper, geomorphic history and tectonic movement of the lake and its basin during the Quaternary period are summarized.

Terrace and sublacustrine terrace topography

The distribution of terrace around the lake and sublacustrine terrace of lake bottom is shown in Fig. 2. Terrace surfaces are classified into Highest, Higher, Middle and Lower in descending order. The terrace correlation is based on the wide-spread tephras, weathered soil and topographic features. Their deposits are mainly composed of gravel and sand bed in fluvial origin. But, Middle terrace is mainly composed of lacustrine or beach deposits meaning higher lake level.

Topography of lake bottom is mainly divided into the south, central and north lake basins (Fig. 3). Two laters are occupied about 90% of water area and have deep basins ranging from 60 to 90 m in depth. But, the first is only from 1 to 5 m in depth. Sublacustrine terraces are distributed off the shore, and classified into I (− 20 ∼ − 40 m in depth), II (− 10 ∼ − 20 m) and III (− 2 ∼ − 5 m) surfaces in ascending order. They are mainly composed of sand and gravel originated from the former delta or floodplain deposits and mean the submerged topography caused by intermittent subsidence. Therefore, terminal edges of sublacustrine terraces indicate the former lake level. In the offshore bottom of the large deltas as River Yasu, Hino and Ane, sublacustrine terraces are broadly distributed. The I surface as the deepest and oldest, is widely distributed all over the lake bottom and locally is called as BT terrace buried beneath the later sediments (Taishi et al, 1987). The I surface deposits are correlative with Lower I terrace dated about 25 ∼ 40 ka. The ages of II and III terraces deposits are dated about 15 and 1 ∼ 3 ka respectively by radiocarbondating and archaeologic remains (Uemura & Yokoyama, 1983).

Geologic Structure of lake bottom and development of lake basin

Many acoustic profiles were obtained by air gun and uniboom surveys directed by the Paleo-environment Laboratory of Kyoto University (Horie, 1983; Taishi et, al 1987). Fig. 4 and 5 show typical air gun reflection profiles by multi-channel method crossing the lake basins (survey lines are shown in Fig. 3). Fig. 4 indicates the correlation between the geologic column of 1400 m drilling core drilled in 1981and 1982 and reflec-

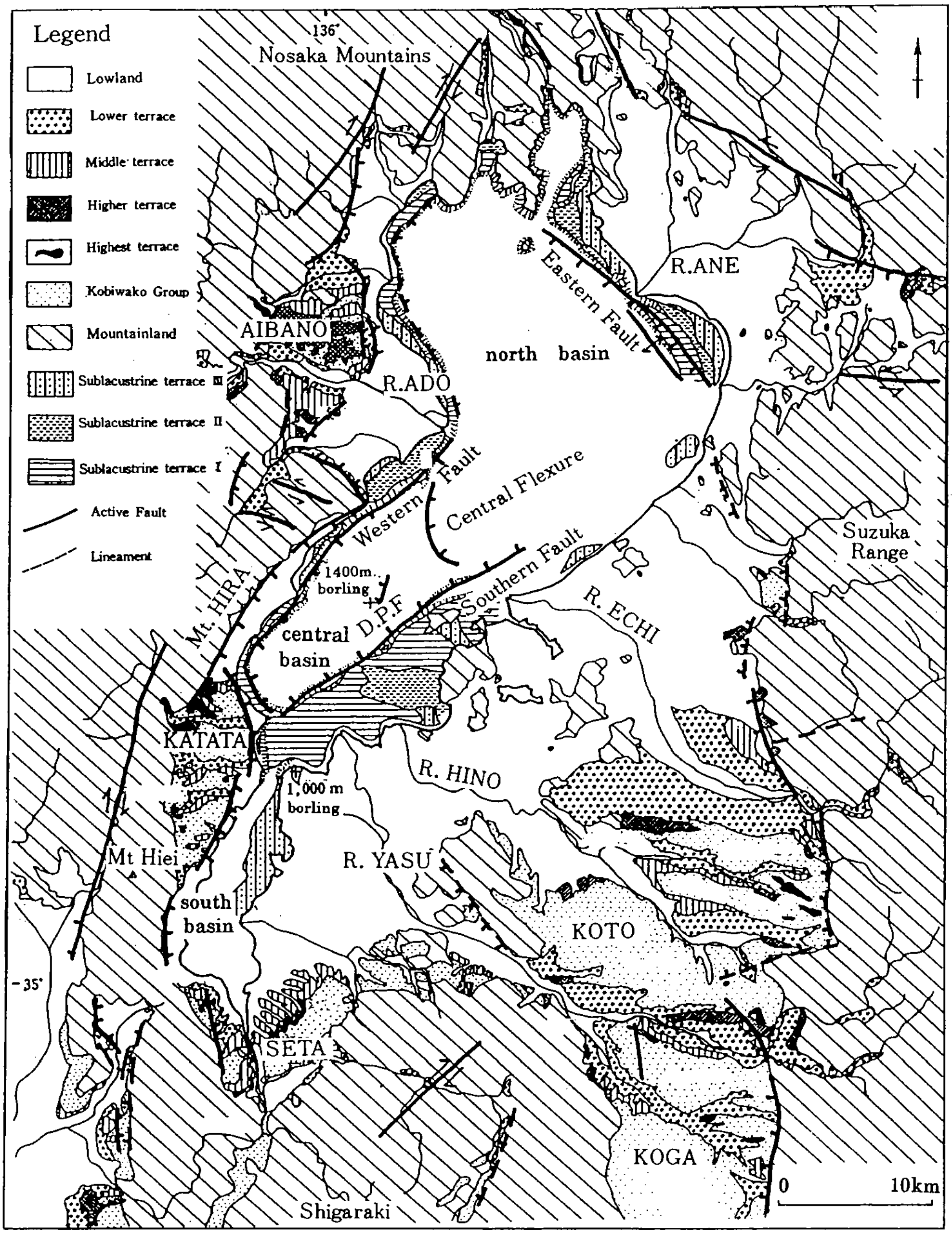


Fig. 2 Distribution of terrace, sublacustrine terrace and active faults of Lake Biwa and its surroundings. DPF : Drilling point fault
(Compiled and rewritten from Regional Geology of Japan part 6, KINKI, 1987)

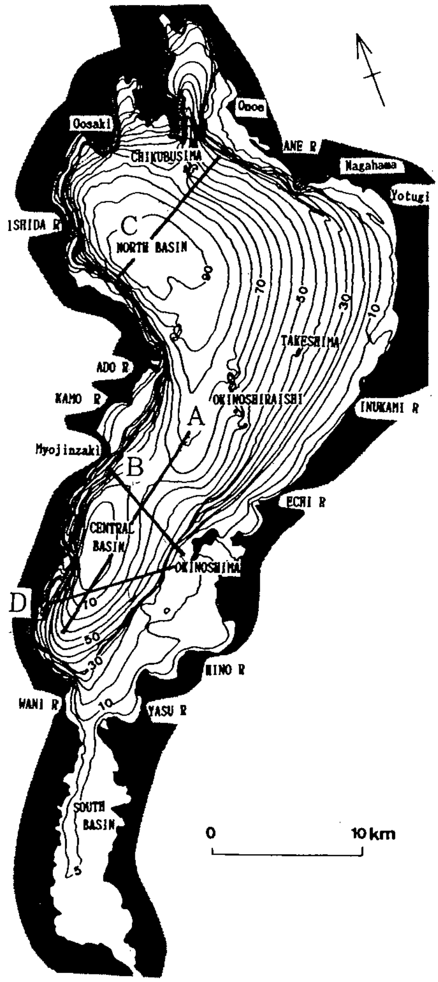


Fig. 3　Bathymetric chart of Lake Biwa, and survey lines of air gun (A, B and C) and uniboom (D) Contour interval : 5 m.

tion surfaces. Three reflection surfaces (TS, SR and BB) are correlative with the boundary of lithofacie changes of the lake bottom sediments. The buried rugged basement topography indicated by BB surface has large relief with 500～700 m in relative height. Some mountain-peaks without sediment cover are recognized as Okinoshiraishi (small reef) and subaqueous islands in lake. Isopach contour map of BB surface (Fig. 6 A) indicates the existence of ranges and valleys with north-south trending, and the arrangement of 4～5 km interval side by side. This is inferred to originated from fault topography similar to the Basin and Ranges province in United States. Some ranges and valleys are continuous to topography of the Nosaka Moun-

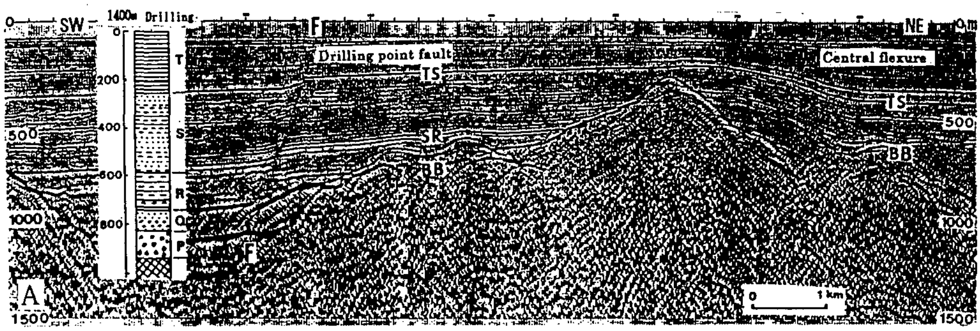
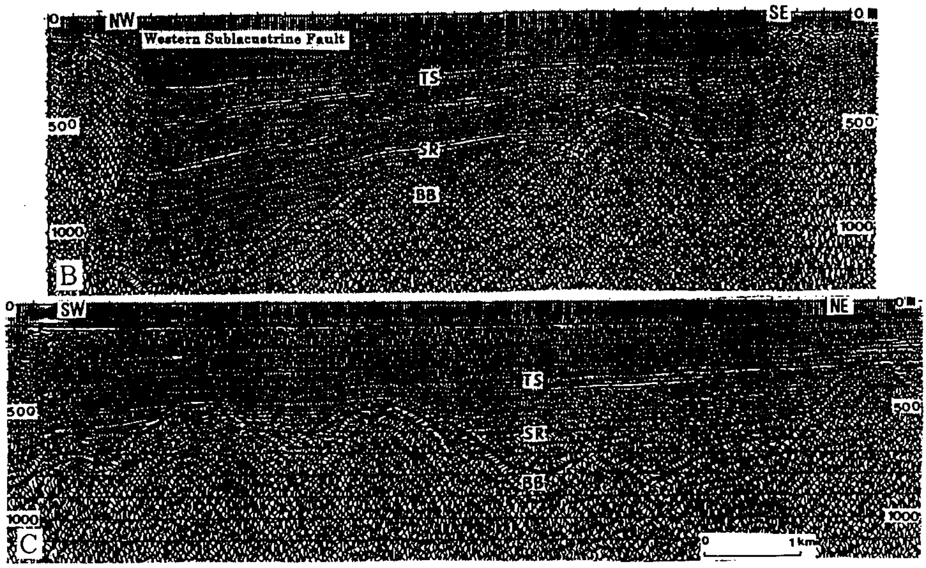


Fig. 4 Seismic profile of A line and geologic column of 1400 m drilling.
The sediments of lake bottom is divided into five facies called P, Q, R, S and T beds in ascending order.



B: Central Basin, C: North Basin

Fig. 5 Seismic profiles of B and C lines by air gun method.
B line is crossing the central basin, C line is crossing the north basin. Survey lines are shown in Fig. 3.

tains of northern area. The boundary between Q and P beds means the beginning of deposition of fluvial and lacustrine sediments in present lake basin and is dated about 2 Ma. The reflector between S and R beds is estimated about 1 Ma based on the F-T ages and the correlation of tephras. The TS surface are corresponds to the boundary between T and S beds in Fig. 4, and means the beginning of deposition of the Biwako clay bed. The deposition of T bed has started at 0.4 Ma (Yokoyama & Takemura 1989, Takemura 1990). Isopach map of TS surface is shown in Fig. 6 B.

Fig. 7 shows a uniboom profile crossing central basin (D survey line shown in Fig.

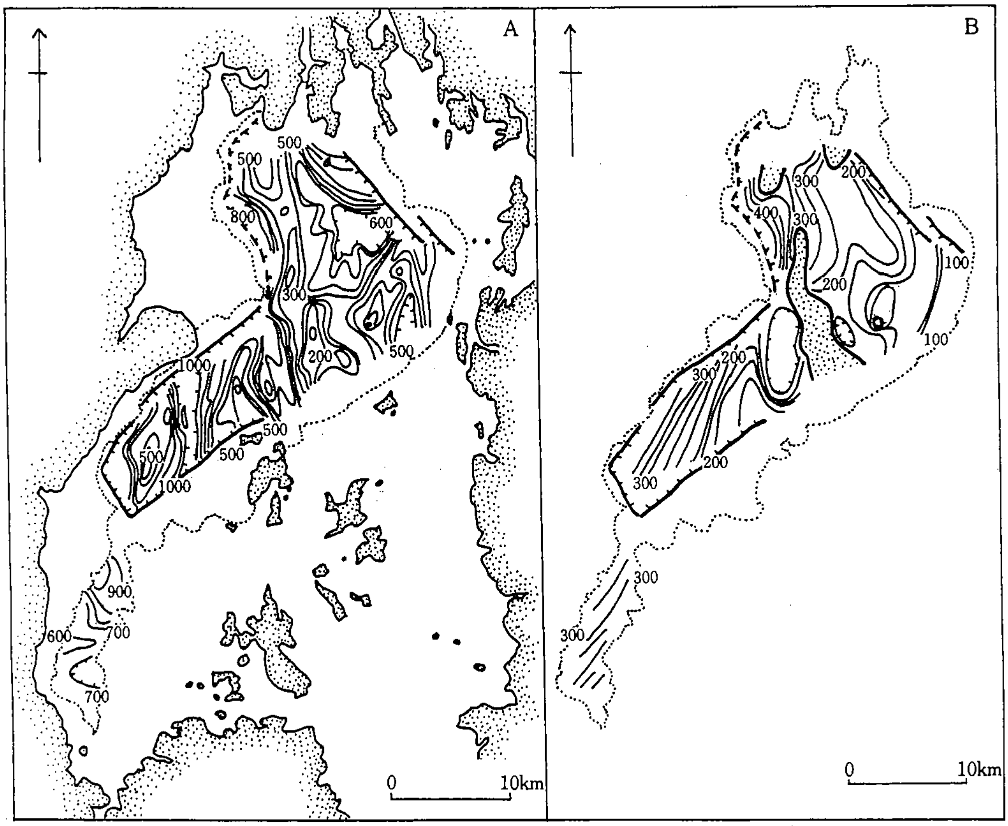


Fig. 6　Isopach contour maps of BB (A) and TS (B) reflection surfaces.
(A)　Contour interval : 100 m
Dotted : area of basement rocks
(B)　Contour interval : 25 m

3). The A, B and C reflection surfaces are correlative with the wide spread tephra beds as K-Ah (0.6 ka), U-Oki (0.9 ka) and AT (25 ka) respectively, and are traceable all over the lake bottom (Taishi et. al 1987 ; Uemura & Taishi 1990).

Sublacustrine active faults and flexure are distributed in the north and central basins (Fig. 2). The Western, Southern and Eastern sublacustrine fault are located along the edges of the deep lake basin over 50 m in depth. The Central flexure is located along the boundary between the north and central basins. The drilling point fault in the central basin has not any fault topogrphy because of overlaping by accumulation of clay bed. The Western, Southern and Eastern sublacustrine faults are reverse faults and accompanied with horizontal slip inferred from their en échelon arrangements. They are recognized as conjugate sets resulted from east-west horizontal compression of the upper crust. Therefore, the central and north basins are not

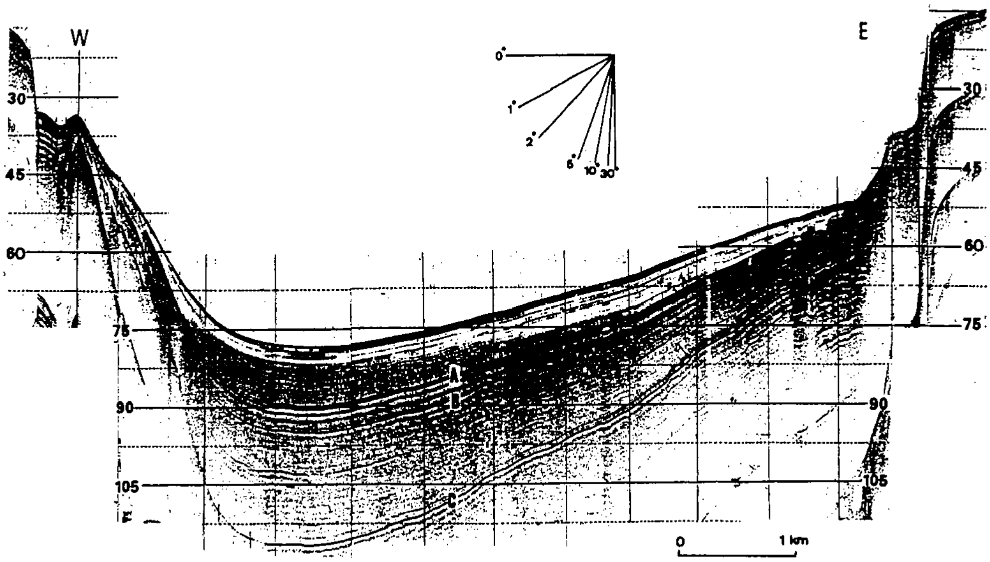


Fig. 7 Uniboom record of D line crossing central basin.
Survey line shows in Fig. 3. A, B and C refrectors are identical with volcanic ash beds.

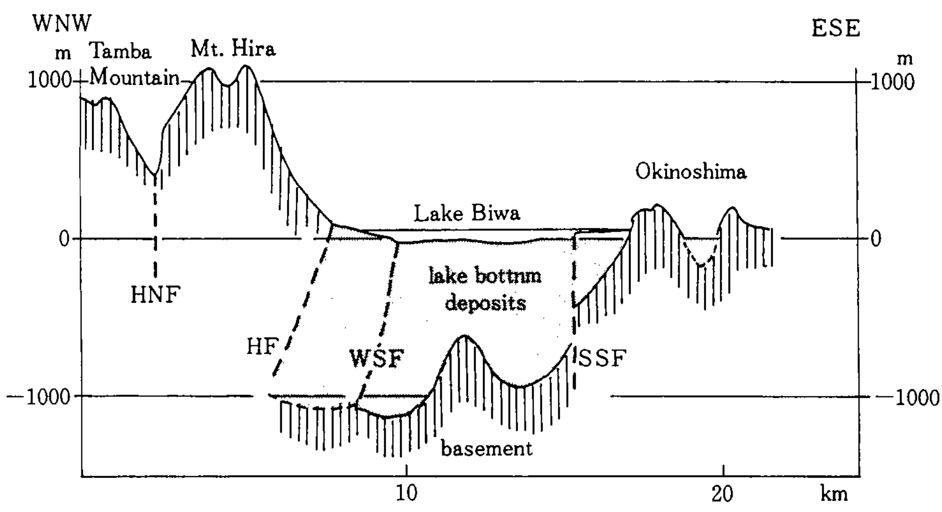


Fig. 8 E-W vertical section showing geologic structure of the central basin and Hira mountain.
HNF : Hanaore fault, HF : Hira fault, WSF : Western sublacustrine fault, SSF : Southern sublacustrine fault

graben due to extension but ramp valley bounded both sides by reverse faults (Fig. 8).

The west coast fault system including the western sublacustrine fault runs about 60 km in length with N-S trending. The vertical displacement of basement rock by this fault system attains about 2000 m (Fig. 8). This fault system has played role as

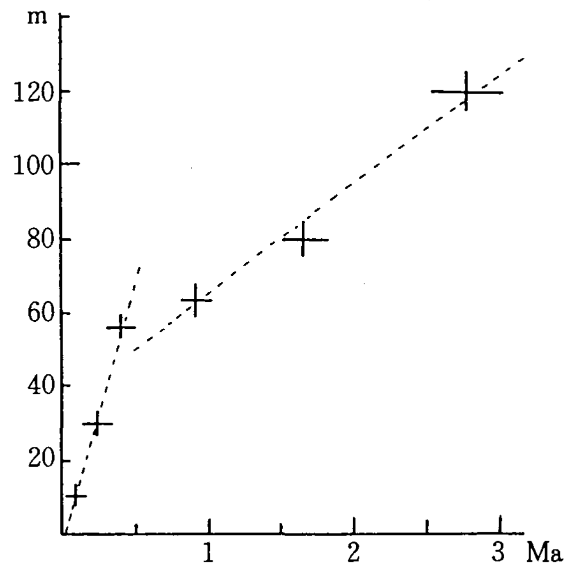


Fig. 9. Relationship between the amount of displacement and ages of key beds by the Drilling point fault.

the most important tectonic boundary between the Tamba mountain and Ohmi basin. Thrusting the Hira-Hiei Mountains over the Ohmi basin, lake bottom topography and style of sedimentation are controlled as fault-angle basin with west-ward tilting. The tilting has started around 1 Ma in the central basin, but since 0.4 Ma in the north basin, based on the examination on the dips of reflection surfaces of Fig. 4 and 5. The relationship between ages of key beds and their amount of displacement by the Drilling point fault is shown in Fig. 9. The mean slip rate of this fault has accelerated two times since around 0.5 Ma.

Paleogeography of Lake Biwa during 2 Ma

The four paleogeographic maps (A, B, C and D) of Lake Biwa and its surroundings are shown in Fig. 10.

A stage (before 2 Ma): Before the subsidence of the present basin, the ranges and valleys with N-S trending like basin and range topography had been existed in this area. Since 2 Ma, this area subsided by downwarping, and shallow sedimentary basin gradually developed and changed to the present location. So, rugged landforms has been buried beneath the sediments.

B stage (0.4 Ma): Since 1.2 Ma, activity of the west coast fault system has started

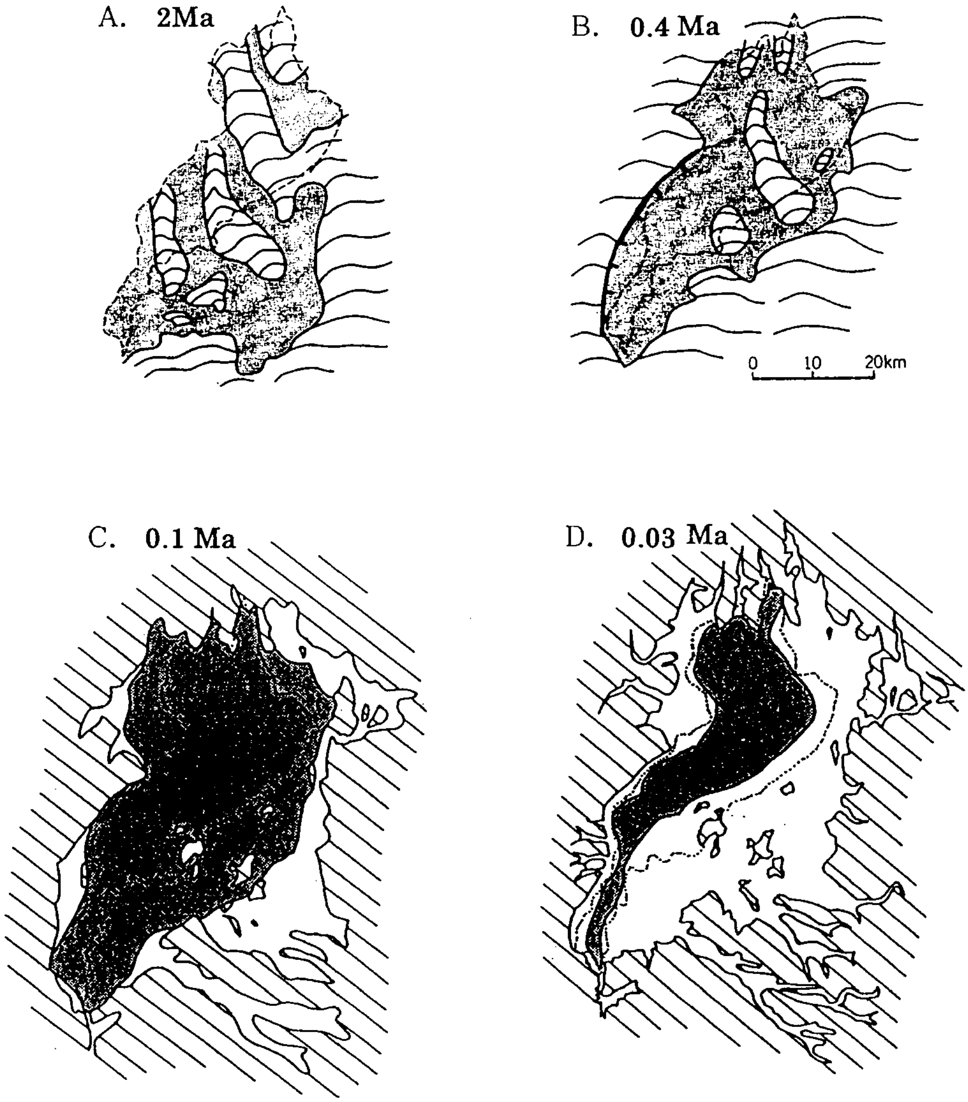


Fig. 10. Paleogeographic maps of Lake Biwa and its surrounding area during 2 Ma.
A : 2 Ma, B : 0.4 Ma, C : 0.1 Ma, D : 0.03 Ma

and the west-ward tilting movement has been dominated. As a result, the Katata formation (about 400 m in thick) of upper Kobiwako Group was rapidly deposited along the western margin of this fault angle basin. Since 0.5 Ma, Hira-Hiei mountains have rapidly uplifted by the activity of Hira and Hie active faults, so thick gravelly sediments deposited as the upper part of Katata formation. The Katata formation has uplifted by the activity of the Katata fault since 0.4 Ma. The Western and Southern sublacustrine faults have been simultaneously activated, and the central basin has been subsided rapidly as ramp valley. The Biwako clay bed has deposited about 250 m thick in this basin. But, the south lake basin without sublacustrine fault had been rapidly buried with sediments to shallow water condition. At same time, the north lake basin have rapidly subsided due to the activity of the northern part of the west coast fault system. Around 0.2 ～ 0.3 Ma, the Aibano and Kamidera active fault located along the eastern boundary of the Aibano and Taizanjino uplands have siverely activated, and these uplands have uplifted.

C stage (0.1 Ma): This stage is the middle terrace age and correlative with the last interglacial period (MIS 5). The lake level was relatively higher. Lacustrine terrace is distributed in Seta and Koto areas of southern part of Ohmi basin and the height of former shore line attains 105 ～ 120 m.

D stage (0.03 Ma): Lower I terrace and sublacustrine terrace I were formed as continuous terrestrial surfaces. Based on ^{14}C ages and the occurrence of cold conifer fossils, they are correlative with cold phase of the last glacial age (MIS 2). The Lake level fell down about 20 ～ 30 m lower than the present level and its water area had reduced. So the land area expanded 1.2 times as large as the present. After that, lake level has intermittently risen to the present level. Consequently, sublacustrine terraces II and III had submerged into the lake bottom.

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Accepted October 14, 1998