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Fundamental Problems in the Future Studies of the Philippine Sea

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Introduction

Remarkable progress has been made in the field of geological and geophysical study on the development of the Philippine Sea since the Geodynamics Project (GDP) started in Japan in 1972. However, as with all scientific works, many basic problems still remain unsolved.

For instance, many aspects have been studied about the geohistory of the ridges in the sea. "Remnant arc" and "died young" island arc character of the ridges, and their drifts have been investigated through GDP and the Deep Sea Drilling Project (DSDP-IPOD), as mentioned in several articles in this volume. However, as discussed by SHIKI in this volume, the geodynamics and origins of the arcs and basins of the Philippine Sea are still not completely understood.

Origin of the basins

There develop three relatively large basins in the Philippine Sea. They are the West Philippine Basin of late Mesozoic to early Tertiary age (HILDE and LEE, 1984), the Shikoku and West Mariana (Parece Vela) Basins of about 30–17 million years B.P. (KOBAYASHI and NAKADA, 1978; MROZOWSKI and HAYES, 1979), and the Mariana Trough of about 6–0 million years B.P. (HUSSONG and UYEDA, 1981).

The crustal structures of these basins are oceanic in character resembling those of the Pacific Ocean basin, and different from those of the arcs. However, the chemical composition of the basement basalts of the basins, except for that of the West Philippine Basin, appears to be slightly different from that of the Pacific Ocean. That is, only the basalts obtained from the West Philippine Sea have low concentration of incompatible elements and fall within the compositional range of the normal mid-oceanic ridge basalts (SATO, 1983). However, the larger depth of the sea floor for the genetic age and heat flow is the marked difference of the West Philippine Sea from that of the Pacific Ocean proper (ANDERSON, 1980).

There is a variety of hypotheses on the origin of these basins (e.g. TAYLOR and KARNER, 1983; UYEDA, 1984). It has been postulated that the basins in the Philippine Sea have been formed by a series of episodic extensional "Back-arc spreading" (e.g. KARIG, 1971). Recent studies on the back-arc spreading are focussed on the present opening of the Mariana Trough (HUSSONG and UYEDA, 1981), the Bonin Back-arc depressions (HONZA and TAMAKI, in press) and the Okinawa Trough (LEE *et al.*, 1980; KIMURA, 1983). Researches on topography, structure of sediments and nature of basement rocks, seismicity, heat flow,

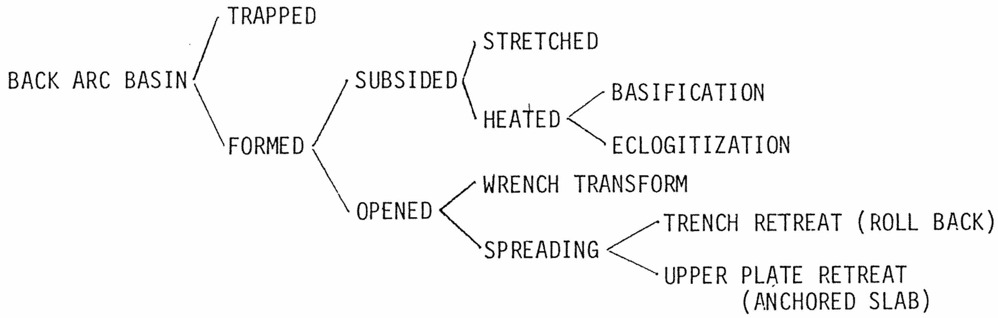

Fig. 1. Theories and hypotheses concerning the genesis of the back-arc basin.

magnetic anomalies, magmatism, hydrothermal processes, and mineralization, etc., of the regions in and around these troughs, are now being carried out actively by institutions from many countries, involving several international cooperative programs.

As for the West Philippine Basin, however, the model proposed by Uyeda and Ben-Avraham (1972) postulates that the basin is a trapped portion of a pre-existing ocean. The above geochemical character, together with the orientations of the magnetic lineations and the Central Basin Fault (possible remnant ridge of Paleogene spreading center) of the Basin which are almost at right angle to that of the Mariana Arc-Trench System, appear to support the trapped ocean model (Hilde and Lee, 1984).

Although the "back-arc spreading" is the most widely accepted process for explaining the origin of many back-arc basins in the continent-ocean transition zones, other possible mechanisms should not be ignored, as stressed by Uyeda (1977). It must also be pointed that, even for the cause of back-arc spreading many different mechanisms have been proposed: i.e. "roll-back" of the oceanic plate (Dewey, 1980), oceanward rotation of island arc crust (Otofuji and Matsuda, 1983) and landward motion of the upper plate (Chase, 1978; Uyeda and Kanamori, 1979; Uyeda, 1984), etc. as shown in Fig. 1. In order to determine which one of those mechanisms was effective, it is important to know whether the episodic spreading in the Philippine Sea took place by eastward migration of the arc (Seno and Maruyama, 1984) or by westward migration of the remnant arcs (Uyeda and McKabe, 1983). Furthermore, there are models in which back-arc spreading is more directly driven by subduction of oceanic lithosphere. Among these models, those which invoke the convective flow induced in the asthenospheric wedge are interesting (e.g. Sleep and Toksöz, 1973; Jurdy and Stefanick, 1983) Fig. 2 shows the results of experiments performed by Kinoshita *et al.* (1983), suggesting that convection can bring hot asthenospheric material to the base of the lithosphere behind the island arc, and generate tensional stress to cause the back-arc spreading. It would be one of the major targets to test if the tensional stress induced by this mechanisms alone is really strong enough to cause back-arc spreading.

Some dynamical aspects

"Motive or driving force" has been one of the most essential and difficult problems concerning the tectonics of the earth since the time of the "continental drift" theory. Con-

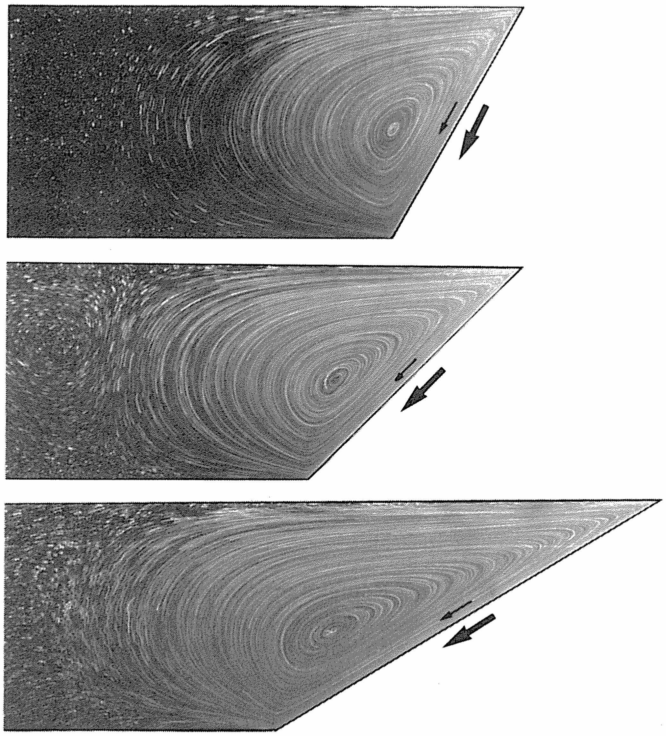

Fig. 2. Experiment of steady flow. Water glass was used as an operating fluid under the Reynolds number 3.9×10^{-4}. Flow patterns photographed by means of swiching on and light (KINOSHITA, ITO, and MASUDA, 1983)

vection current in the mantle beneath oceans was considered to be the driving mechanism of "Sea floor spreading" (DIETZ, 1961; HESS, 1962), the fore-runner of "plate tectonics". In these days, however, it seems that gravitational sinking of the oceanic lithosphere, namely the subduction, is the most important force to cause global plate motions (FORSYTH and UYEDA, 1975; CHAPPLE and TULLIS, 1977).

In "plate tectonics", it is considered, with some justification, that the lithosphere of higher density and higher rigidity overlies the asthenosphere of lower density and lower rigidity. Hence the lithosphere can subduct and behave as "rigid plate". However, it is evedent that lithosphere is not perfectly rigid. It is deformable. For a more realistic discussion on the tectonics of the earth, we must consider the more realistic physical and chemical properties of the lithosphere and the asthenosphere than hitherto made.

In this connection, we would like to refer to a study made by TOMODA, FUJIMOTO and MATSUMOTO (1983: Figs. 3a, 3b). The essential point of this study is that, if the lithosphere and asthenosphere are simulated by fluids of different density and viscosity confined in a box, inclined subsidence of the lithosphere and tensile state in the back-arc region can take place without any external diriving force except gravity. TOMODA and his colleague made similar numerical simulation on the interaction between a trench and a colliding seamount or a micro-continent (Fig. 3b), where a jump (transposition) of the trench to the ocean side of the colliding feature takes place. As stated above, the critical question in these type of approach is whether the material properties adopted are truely realistic

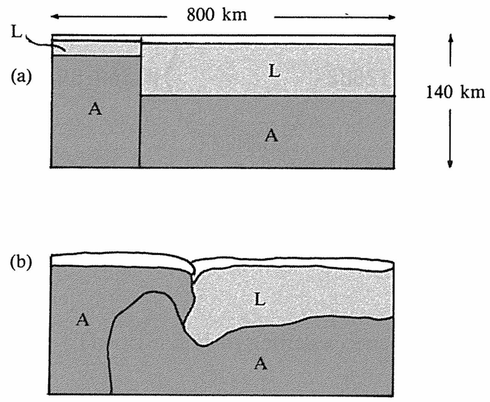

Fig. 3a. Result of the numerical simulation of the initiation of a trench at the Mendocino Fracture Zone. (a) Initial state. (b) 25 million years after the initial state. (TOMODA, FUJIMOTO, and MATSUMOTO, 1983).

L: Lithosphere 10^{23} poise
A: Asthenosphere 10^{21}

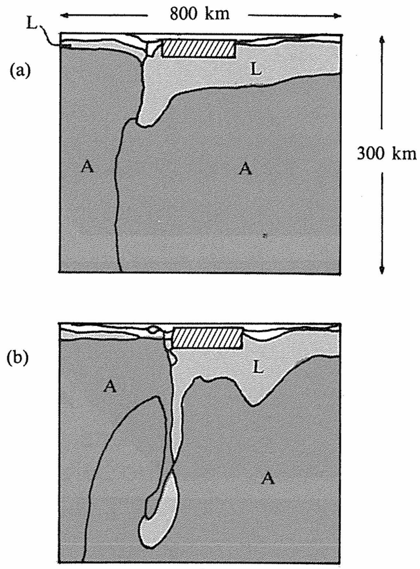

Fig. 3b. Result of the numerical simulation of the interaction between a trench and a seamount due to the collision of the two. (a) A seamount has collided aganinst a subduction zone. (b) 29 million years after the state of (a). (TOMODA, FUJIMOTO, and MATSUMOTO, 1983).

or not.

Another potentially important point is the relation between surface tectonic phenomena and earth's deep interior. Theories which postulate direct involvement of deeper processes, such as the whole mantle convection (e.g. ELSASSER, 1971), and deep thermal anomalies (e.g. BELOUSSOV, 1968; ARTHUSHKOV, 1983), have not been as widely accepted as the theories which assume that the upper mantle is more or less decoupled from the deeper mantle. However, if we want to understand the earth's history comprehensively, relationship with the deep interior can not be disregarded (e.g. RODNIKOV, *et al.*, 1982; NISHIMURA, 1982). Some important clue to such relation may be sought in the area of our interest, i.e. the Western Pacific continent-ocean transition zone where, for instance, notable geoid anomaly has been reported (e.g. BOSTROM *et al.*, 1983).

Concluding remarks

Study of the Philippine Sea was a major target of the International Geodynamics Project (GDP) and the International Phase of Ocean Drilling (IPOD). It will continue to be one of the major targets of the International Lithosphere Program (Dynamics and Evolution of Lithosphere Program, DELP) during the 1980's involving numerous national and international research campaigns. The Japan-Soviet Cooperative Project "Geotraverse across the Philippine Sea and the East China Sea" is one of these international cooperation programs and is now under preparation as a part of DELP. The main scope of the Geotraverse Project is to compile existing data on the Philippine Sea—East China Sea zone as extensively as possible and to make a comprehensive cross-section. Dr. RODNIKOV, Soviet Geophysical Committee, Academy of Sciences of the USSR is representing the Soviet participants on the Project while on of us (T.S.) is representing the Japanese side. For the success of the Project, strong support and cooperation of colleagues are most earnestly solicited.

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