Late Pleistocene Unconformity of the Tsushima and Korea Straits Revealed by Seismic Reflection Profiles

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Abstract

Four major seismic sequences (A, B, C, and pre Quaternary basement) and a major seismic sequence boundary (Reflector T) of an erosional unconformity were recognized in the Tsushima and Korea Straits as a result of shallow seismic stratigraphy. Subsequent sequences A, B, and C were interpreted as recent post-glacial marine transgression sequence, pre glacial marine regressive sequence, and Pleistocene pre-glacial sequence with topmost marine transgressive sequence, respectively.

We estimate that the Reflector T was probably formed by an erosion due to subaerial exposure of the sequence (sequences B or C or the basement) lying immediately below the Reflector T during the last glacial period (LGP) of isotopic stage 2. The existence of the erosional unconformity, the Reflector T, suggests that the Tsushima and Korea Straits were land and the Korean Peninsula was connected with the Japanese Islands during the LGP.

Key words: seismic stratigraphy, Tsushima and Korea Straits, erosional unconformity, last glacial period

I. Introduction

One of the interesting problems of Late Pleistocene geology in the east Asia is the paleogeography of the Tsushima and Korea Straits and their bearings on the paleoenvironments of the Japan Sea. The Straits have been of interests from a problem whether for some time of Late Pleistocene the Straits were land and the Korean Peninsula was connected with the Japanese Islands or not, in relation to sea level fluctuations (Katsura and Nagano, 1976, 1982; Ohshima et al., 1982; Park and Choi, 1986; Suk, 1989). The problem, however, is very controversial until now. The Straits might play a significant role as a watergate controlling water exchange of the Japan Sea with adjacent marginal seas, associated with Late Pleistocene paleoenvironmental changes of the Japan Sea. Moreover, the problem can be treated with geographical importance related to an influx of life from the Eurasian continent to the Japanese Islands.

In this paper we discuss the problem using seismic reflection profiles.

II. Hydrographic Setting

The study area is the Korea and Tsushima Straits which are continental shelf between the southeastern portion of the Korean Peninsula and the northwestern portion of Kyushu,
Japan. Most of the area is shallower than 200 metre in water depth except for the Korea Trough found in the Korea Strait of northwestern portion of Tsushima (Fig. 1). The Trough with a maximum water depth of 230 metre has an extension of northeastern
direction, and its slope shows a relatively steep gradient of 3.8° in nearshore, gradient of 1.2° in inner shelf, and increases rapidly up to 6.4° in the Korea Trough (Suk, 1989). The water column of the study area is characterized by the Tsushima Current, a branch of the Kuroshio Warm Current, which is passing towards the Japan Sea. The Tsushima Current of the Korea Strait has speed ranging between 1.0 and 1.5 knot whereas that of the Tsushima Strait between 0.5 and 1.0 knot (Hydrographic Department, Maritime Safety Agency of Japan, 1978a). Tidal current affected by the Tsushima Current has speed of about 0.5 knot between Iki and Kyushu (Hydrographic Department, Maritime Safety Agency of Japan, 1982).

III. Seismic Reflection Data

Within the study area, we interpreted sparker seismic reflection profiles which had been collected by the Hydrographic Department, Maritime Safety Agency of Japan (MSAJ) from 1977 to 1981. Locations of the representative seismic reflection lines (S1, S2, S3, S4, and S5) and their interpreted profiles are shown in Figs. 1 and 2, respectively. Reports of survey of the Hydrographic Department, MSAJ (1978a, b, 1982) are available for entire seismic lines. Especially, profile of seismic line S5 was taken from report of survey of the Hydrographic Department, MSAJ (1981b), and then re-interpreted.

In addition we interpreted air-gun single channel seismic reflection profiles, obtained as a result of the sea bottom survey which had been carried out by the Hydrographic Department, MSAJ in 1973. Locations of the representative seismic reflection lines (G1, G2, and G3) and their interpreted profiles are shown in Figs. 1 and 2, respectively. Entire seismic lines can be found in Katsura and Nagano (1976).

Previous works using the air-gun and sparker seismic profiles were already presented by Katsura and Nagano (1976), reports of survey of the Hydrographic Department, MSAJ (1978a, b, 1981a, b, 1982), respectively. Nevertheless, the seismic profiles were re-interpreted according to our particular interest.

IV. Interpretation

1. Sparker seismic reflection profiles (S1, S2, S3, S4, and S5)

In Fig. 2, interpreted profiles of seismic reflection lines S1 and S2 represent examples of subbottom structures beneath relatively shallow seabed between Kyushu and Iki. Sequence A unconformably overlies sequence B and pre Quaternary basement, and has acoustically strong, parallel reflectors. Within the sequence A, we can recognize a coastal onlap of landward prograding sediments. The sequence A is interpreted to comprise sediments of recent post-glacial marine transgression in which previous deposits were subjected to marine reworking and subsequent re-deposition. On the whole, maximum thickness of the sequence A does not exceed 30 metre.

Sequence B unconformably overlies the basement and has more transparent character compared with the sequence A. The sequence B also exhibits a parallel coastal downlap including pronounced parallel progradational foresets as shown in the line S2. The sequence B is interpreted as marine regressive sequence resulted from a sea level fall prior to the last glacial period (LGP) of isotopic stage 2. We estimate that the sequence B is mainly composed of relict coastal sediments deposited prior to the LGP.
Fig. 2 Interpreted profiles of the sparker and air-gun single channel seismic reflection lines S1, S2, S3, S4, S5, G1, G2, and G3 whose locations are represented in Fig. 1. Thickness of the seismic sequence was determined by assuming that seismic velocity in sediments is equal to 1,500 m/sec. See text for explanation of seismic sequences.
A reflector, indicated as "Reflector T", of strong, continuous character is identified as a seismic sequence boundary between the sequences A and B, or between the sequence A and the basement. The reflector is interpreted as an erosional unconformity. Top portions of the sequence B and the basement are truncated against the erosional unconformity, the Reflector T.

Seismic lines S3 and S4 represent seismic profiles further offshore. Sequence A unconformably overlies sequence B, sequence C, and pre Quaternary basement, and represent an irregular, hummocky (S3) or discontinuously parallel (S4) reflection patterns. Within the sequence A, we can observe a buried sand wave-shaped structure whose top portion was suffered from erosional truncation ascribed to probable recent strong currents and/or wave action. The sequence A is interpreted as the recent post-glacial marine transgressive sequence, judging from general spatial distribution of the sequence in the study area, although it does not represent the same clear coastal onlap as the seismic sections the S1 and S2. As a whole, maximum thickness of the sequence A does not exceed 20 metre.

Sequence B shows acoustically weak, transparent internal structure. Within the sequence B, we can recognize progradational foreset and truncated sand barrier-shaped structure. The sequence B is interpreted as a marine regressive sequence deposited prior to the LGP.

Sequence C represents an acoustically semi-transparent, moderately weak, discontinuously parallel reflection patterns. The sequence C is interpreted as Pleistocene pre-glacial sequence with topmost marine transgressive sequence formed by sea level rise prior to the LGP.

Alternating and subsequent phases from sequences C to A may be regarded as a good indicator of successive sea level fluctuations, namely, rise, fall, then rise.

The Reflector T of strong, continuous character is also identified as a seismic sequence boundary between the sequences A and B, or between the sequences A and C, or between the sequence A and the basement. The reflector is interpreted as an erosional unconformity against which top portion of the sequences B, C, and the basement are truncated.

In the interpreted profile of seismic reflection line S5, relatively thin sequence A is identified. As a whole, maximum thickness of the sequence A does not exceed 10 metre. Sequence B shows pronounced parallel progradational foresets, and sequence C shows a coastal onlap. The sequences A, B, and C are interpreted as recent post-glacial marine transgression sequences, pre-glacial marine regressive sequence, and Pleistocene pre-glacial sequence with topmost marine transgressive sequence, respectively, as in the other seismic lines mentioned above. The Reflector T of strong, continuous character is interpreted as the erosional unconformity against which top portion of the sequence 2 is truncated.

(2) Air-gun single channel seismic reflection profiles (G1, G2, and G3)

In the seismic reflection lines G1, G2, and G3 of Fig. 2, sequences A and B are identified. We can also recognize an acoustically strong reflector, "Reflector T" which is seismic sequence boundary between the sequences A and B. We consider that the sequences A, B, and the strong reflector correspond to sequences A, B, and the Reflector T of an erosional unconformity of the sparker seismic profile, respectively although the air-gun
seismic profiles have relatively poor resolution of seismic data. On the profiles G1 and G2, the Reflector T seems to extend continuously from Tsushima forward the Korean Peninsula.

V. Discussion

We can recognize four major seismic sequences (A, B, C, and pre Quaternary basement) and a major seismic sequence boundary (Reflector T) of the erosional unconformity as a result of shallow seismic stratigraphy. The Reflector T may be caused by an erosion due to either strong tidal currents and/or wave action during the Holocene or subaerial exposure of the sequences lying beneath the reflector during the LGP. We can, however, recognize that top portions of the pre Quaternary basement were clearly truncated against the Reflector T as shown in the seismic lines S1, S2, and S3. This supports that the Reflector T was probably formed by the erosion due to subaerial exposure of the sequence (sequences B or C or the basement) lying immediately below the Reflector T during the LGP. In general, thickness of the sequence A from seabed to the Reflector T represents northward or offshore decrease, approximately, not exceeding 30 metre between Kyushu and Iki, 20 metre between Iki and Tsushima, then 10 metre off eastern Tsushima. Reports of survey of the Hydrographic Department, MSAJ (1978a, b, 1981a, b, 1982) are available for detailed isopach map of the thickness of the sedimentary layer corresponded to the sequence A of present study. In most part of the study area, as a consequence, the Reflector T is observed with regional variation of depth (ca. 0 to 30 metre) between the seabed and the reflector. The erosional unconformity indicates that the Tsushima and Korea Straits experienced subaerial erosion and desiccation during the LGP.

A similar reflector of the erosional unconformity was recognized in many embayments and on the inner shelf floor of the southern coast of the Korean Peninsula at the depth of about 20 to 25 metre below the sea floor from interpretation of seismic reflection profiles (Chough, 1983; Park et al., 1987; Suk, 1989). This suggests that the Reflector T of the study area extends continuously forward the coast of the Korean Peninsula. On the other hand, the similar reflector has been recognized globally by numerous researchers (McMaster, 1984; Knebel and Scanlon, 1985; Chronis et al., 1991; Evans et al., 1992).

The existence of the erosional unconformity, the Reflector T, suggests that the Tsushima and Korea Straits were subaerially exposed and the Korean Peninsula was connected with the Japanese Islands during the LGP. Connection of the Korean Peninsula with the Japanese Islands may give rise to no water exchange between the Japan Sea and the East China Sea through the Tsushima and Korea Straits. Based upon the interpretation of the sparker and air-gun seismic reflection profiles, paleogeography around the study area during the LGP is inferred as shown in Fig. 3. We estimate that a subaerial land route via Iki and Tsushima played an important role in the connection of the Korean Peninsula with the Japanese Islands as a main passage.

We do not, however, have any available absolute chronological data about the seismic sequences and the Reflector T as well as high resolution seismic reflection data connecting directly Tsushima and the Korean Peninsula although there are suggestions based upon
VI. Conclusions

(1) Four major seismic sequences (A, B, C, and pre Quaternary basement) and a major seismic sequence boundary (Reflector T) of an erosional unconformity were recognized in the Tsushima and Korea Straits. The sequences A, B, and C are interpreted as recent post-glacial marine transgression sequences, pre-glacial marine regressive sequence, and Pleistocene pre-glacial sequence with topmost marine transgressive sequence, respectively.

(2) We estimate that the Reflector T was probably formed by an erosion due to subaerial exposure of the sequence (sequences B or C or the basement) lying immediately below the Reflector T during the LGP of isotopic stage 2. The unconformity indicates that the Tsushima and Korea Straits experienced subaerial erosion and desiccation during the LGP. The existence of the erosional unconformity, the Reflector T, suggests that the Tsushima and Korea Straits were land and the Korean Peninsula was connected with the Japanese Islands during the LGP.

Acknowledgement

The air-gun and sparker seismic profiles were provided by Japan Oceanographic Data Center (JODC). We would like to thank Dr. H. Tokuyama of Ocean Research Institute, University of Tokyo, for his useful suggestions. We also thank an anonymous reviewer for thoughtful reviews and comments that helped improve this paper.

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音波探査記録によって明らかになった対馬海峡および朝鮮海峡の後期第四紀不整合

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対馬海峡および朝鮮海峡の音響層序から、4つのseismic sequences (sequence A, sequence B, sequence Cおよびpre Quaternary basement)と1つのseismic sequence boundary（反射面 T）を認めることができ、その反射面 T は侵食不整合面であることがわかった。sequence A, sequence Bおよびsequence Cはそれぞれ最終氷期以降現在までの海進作用、最終氷期以前の海退作用、海進作用に伴って形成されたと解釈される。

また、侵食不整合面（反射面 T）は最終氷期の間、海底の陸化によって形成されたと推定される。従って、最終氷期のある時期、朝鮮半島と日本列島は陸続きであったと示唆される。

キーワード：音響層序、対馬海峡および朝鮮海峡、侵食不整合面、最終氷期

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