Bathymetry and Morphotectonic Elements in the Ulleung Basin, East Sea of Korea

Bong-Chool Suk[1], G. I. Anosov[2], V. P. Semakin[3], and A. S. Svarichevsky[4]

[1] Korea Ocean Research & Development Institute, Ansan P.O. Box 29, Seoul 425-600, Korea

[2] Institute of Volcanology, FEBRAS, Petropavlovsk, Kamchatsky 683006, Russia

[3] Institute of Marine Geology & Geophysics, Yuzhno-Sakhalinsk 693002, Russia

[4] Pacific Oceanological Institute, Vladivostok, Russia.

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Abstract

A detailed bathymetric map is used to construct a morphotectonic map of the Ulleung Basin. The definition of "morphotectonics" and the procedure of the morphotectonic mapping are described in detail. The morphotectonic structural elements of various orders and ranks are also determined using echo-sounding and other geophysical data.

Preliminary analysis shows that the newly determined morpho-structural elements coincide with the locations of deeper tectonic features established by the geophysical evidences of the inner sedimentary and/or crustal sections. Therefore, the tectonic zone of the Ulleung Basin has imprinted the patterns of the inherited evolution since Neogene.

1. Introduction

Tectonic mapping of an investigated region of the earth's surface is the necessary stage in establishing a theory of the region's evolutionary development [*Spizharsky*,1973] . For the mapping of structural formation folding is usually applied to continent as a rule. On the other hand, the morphostructural approaches of tectonic mapping based on the formative features and detection of the systems of the geological bodies from past geological and geophysical evidences are strongly applied to the oceanic type of earth's crust.

The morphostructural features within tectonic mapping of the oceanic crust are very important not only because various information about the relief of sea(ocean) floor has been accumulated but also the relief that reveals the condition of underwater denudation and smoothing is sufficiently coupled with the inner structures of the earth's uppermost crust. The sea floor relief of the marginal seas would reflect the influences of both continental and oceanic features as well as endogenetic and exogenetic processes.

Morphotectonics is the tectonic interpretation of the morphological, or present topographic features, of the earth's surface. It deals thus with their tectonic or structural relations and origins, rather than with their more obvious origins by surficial processes of erosion and sedimentation. Analysis of the relationships between the large-scale and small-scale elements of up-to-date relief of seafloor-elevations, directions, macro-and micro-dismemberments, and ages of rocks are fundamental to construct the morphotectonic maps. From the results, the morphostructures of various orders and ranks are defined, whose relation with junctions of the intersections are crucial to the analyze of tectonic movements.

Among the great variety of morphotectonic dislocations we distinguish two main types: relative "rises" and "depressions", which may be considered as "positive" and "negative" morphotectonic dislocations, respectively. Rises and depressions may be plicated, disjunctive or injective (or be represented by a combination of two types), simple or complex, and of various sizes, i.e., various "orders" or "ranks".

This paper focuses on the construction of a morphotectonic map using the detailed bathymetric and geophysical data in the Ulleung Basin to give basic information on basin evolution and tectonic process in the East Sea.

2. Bathymetric Data

The East Sea(Sea of Japan) is comprised of three deep basins: the Japan, Ulleung and Yamato basins; all of which are separated by ridges and banks(Yamato Ridge, Korea Plateau, Kita-Oki bank, Oki bank, and Oki Ridge)(Fig. 1). The Ulleung basin is outlined as a basin with an average water depth of 2,000m and a width of about 150km(Fig. 2). It is separated by the Ulleung Interplain Gap(U.I.G.) of two subbasins [*Chough*, 1983] : one on

the northeastern edge and the other on the southwestern edge, respectively. The northeastern Ulleung subbasin is bordered by the steep slope of the Korean Plateau, Yamato Ridge(including Kita-Yamato Trough), Kita-Oki and Oki banks(Fig. 1). It is likely that the southwestern extension of the subbasin has been progressive, but gently uplifted toward the WSW direction. This rising, however, is prevented by the Ulleung Interplain Gap which is represented to the elevation of seafloor as a small subbottom rise caused by buried volcanic swells [*Chough*, 1983] . The elevation of subbottom mounds is not more than 100m. The control outline of the isobath is 2,200m(Figs. 2 and 3), and has extended the subbasin continuously toward the WSW direction.

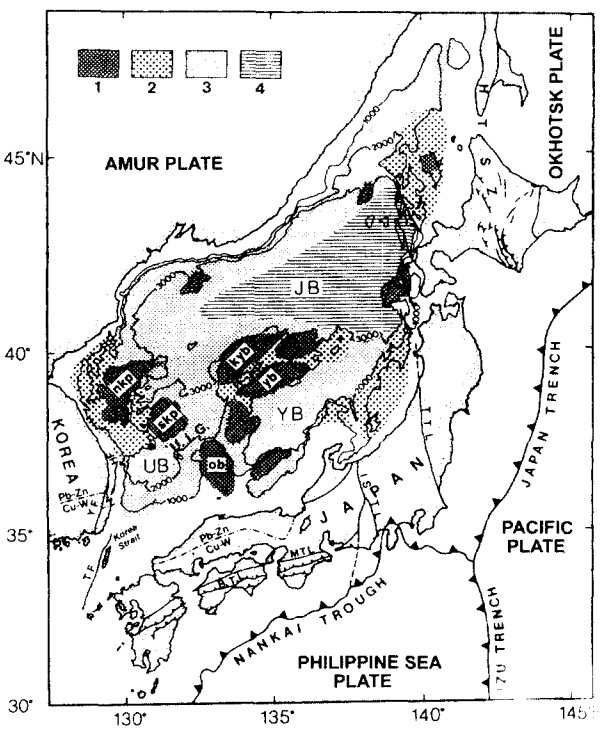

Fig.1 Major physiographic and tectonic features of the East Sea. Modified from *Tamaki* [1988] , *Jolivet et al.* [1991] and *Yoon* [1994] . Key: 1 -continental blocks, 2 -thinned continental crust, 3 -extended continental crust, 4 -oceanic crust, BTL-Butsuzo Tectonic Line, HF-Hupo fault, HTSZ-Hidaka Tertiary shear zone, ISTL-Itoigawa-Shzuoka Tectonic Line, JB-Japan Basin, MTL-Median Tectonic Line, TF-Tsushima fault, TTL-Tanakura Tectonic Line, U.I.G.-Ulleung Interplain Gap, UB-Ulleung Basin, YB-Yamato Basin, YF-Yangsan fault, kyb-Kita Yamato Bank, nkp-North Korea Plateau, ob-Oki Bank, skp-South Korea Plateau, yb-Yamato Bank. Pb-Zn and Cu-W represent the metallogenic belts offset by the Yangsan and Tsushima faults [*Sillitoe*, 1977] . Bathymetry in meters.

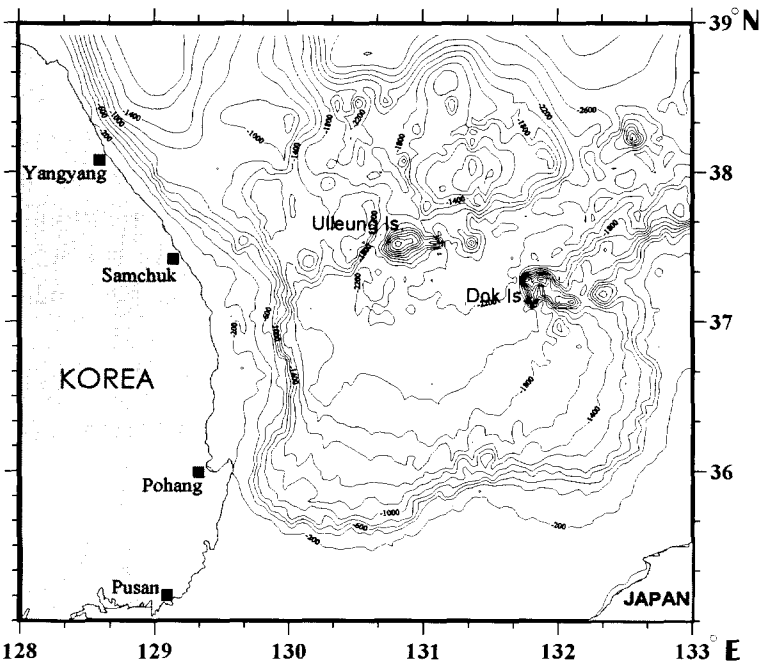

Fig.2 The bathymetric features of the Ulleung Basin region. Bathymetry in meters.

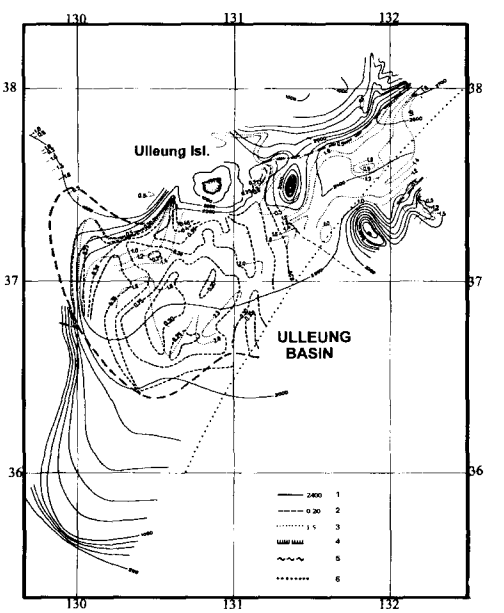

Fig.3 Map showing the areal distribution of the seismic facies Unit 1-1, the acoustic basement and bathymetry(in meters), in the Ulleung Basin. Key: 1 -isobath, 2 -thickness of Unit 1-1 in TWT(sec), 3 -depth of occurrence of acoustic basement(km), 4 -interface of type acoustic basement, 5 -change of the sedimentary cover section type(Unit I-Unit III), 6 -axis of spreading zone according *Hilde and Wageman* [1973].

The Ulleung Basin is bordered by the continental shelves of the Korean Peninsula and southwestern Japan with a steep slope of the Oki bank structure. The Korea Strait located at southern enterance of the basin seems to play an important role to form the basin. Both Korean Peninsula and southwestern Japan shelves are represented by the narrow strips of about 25~30km in width. The shelves are generally smooth; upper part of continental slope is gentle at most area, whereas middle part of the slope shows a steep gradient(Fig. 2). The inner shelf zone has developed a great number of inner rises, broad mounds and valleys, and faulting-thrusting structures exhibited by the smoothness of sea-floor.

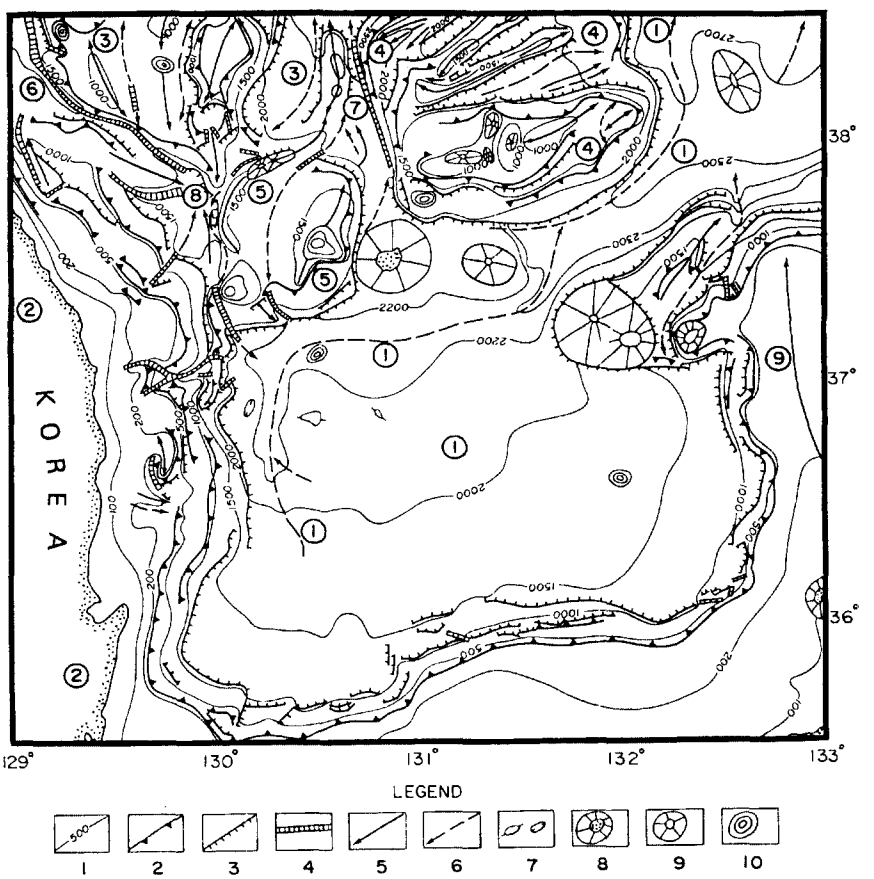

Fig.4 Morphotectonic map of southern part of the East Sea(Sea of Japan). Key: 1. Isopleths of the "summit" surface(the numbers are depth in meters), 2. Brows of flexures and tectonic scarps, 3. Foots of flexures and tectonic scarps, 4. Bottom of narrow grabens and V-shaped depressions, 5. Axes of relative morphotectonic rises, 6. Axes of relative morphotectonic depressions, 7. Local rises(a) and depressions(b), 8 Above-water-underwater volcanos, 9. Underwater volcanic structures, 10. Isolated underwater mountains and eminences of unknown origin. Marked by the numbers: 1 -Ulleung Basin; 2 -Korean Peninsula Rise; 3~8 -the complicated underwater rise of the Korea Plateau, (3~8): 3 -Wonsan Plateau Rise, 4 -Ulleung Plateau, 5 -rise to the west from Ulleung Island, 6 -Wonsan Trough, 7 -Ulleung Trough, 8 -Mukho Plateau; 9 -Oki Rise.

It seems important to understand how the northwest and north-northeast boundaries were constructed in the Ulleung Basin. The deep subbasins of the Ulleung Basin are bordered by the strip of the Korean Plateau(Fig. 4). As the characteristic structure the Korean Plateau consists of a north branch(Wonsan Rise near 39°N in latitude) and a south branch(the Ulleung Rise near 38°N in latitude). the both branches are separated by a deep narrow channel, Ulleung Trough. The Wonsan Rise is about 100km wide and 250km long with northeastern trend. The Ulleung Rise is wider than 150km and is 200km long with eastern trend. The Ulleung Trough trends east-northeast. All of these structures are separated by a narrow deep bathymetric channel with northeastern border. This channel is situated between the main rises and ridges of the East Sea. Buried powerful fault zones possibly reveal the surface manifestation.

3. Morphotectonic Map Compiling

Morphotectonic maps are the figurative model of morphotectonic dislocations(i.e. morphotectonic objects). Cartographic analysis of the neotectonics proposed by *Ufimtsev* [1974, 1984] and *Ufimtsev and Khudyakov* [1976] has been adopted to make a morphotectonic map in the Ulleung Basin. The basis of the morphotectonic map compiling using this method is derived from mapping and interpretation of the summit surface of the earth's crust [*Ufimtsev*, 1984] .

For compiling the morphotectonic map, we use the "summit surface" of the sea floor as the original "structural" surface, which is mapped by absolute isolines with reference to present sea level. The acoustic basement, "structural" surface, allows to map the morphotectonic dislocations of the sea floor.

Tectonic scarps(i.e., morphotectonic faults-surface image of fault zone) and flexures are expressed on the maps of the summit surface by zones of large gradient isopleth, which permit mapping the brows, feet of flexures, and tectonic scarps. However, it is impossible to separate flexures and tectonic scarps from bathymetric data at this stage.

On the morphotectonic map, the brows, flexures, and tectonic scarps has been drawn using the geomorphological evidence. The axes of relative morphotectonic features comprise the local rise and depressions. The map also includes above-water-underwater and underwater volcanic structures, isolated seamounts, and eminences of unestablished origin.

Thus, morphotectonic map complied mainly with geomorphological evidence shows morphotectonic dislocations of the sea floor, which is the statical model of the morphotectonics. The shape and constructing technique of this map differ slightly from a neotectonic model of the onland regions [*Semakin*, 1966, 1969] . The morphotectonic map is mainly constructed using the geomorphological characters and morphotectonic structural units of different orders from bottom topographic data which reveal to newest tectonic

movement in the Pliocene-Quaternary ages. Therefore, morphotectonic map is always based on the bathymetric or geomorphologic maps.

The relief of the sea floor of the East Sea has been gathered from hydrographical surveys by the Japan and the Russia(the USSR) since the middle of the last century but most intensely within the past thirty years. The first attempt of geomorphological mapping of the East Sea was performed by *Zencevitch* [1961], who detected three relatively independent parts. One of the parts is in the southern area from 44°N in latitude and coincides with boundaries of the Ulleung Basin.

The schemes of Zencevitch were based mainly on the morphometric (bathymetric) data. The newest echosounding bathymetric data with recently acquired geophysical and geological evidences are available to make a morphotectonic map in the Ulleung Basin [*Ludwig et al.*, 1975; *Chough*, 1983; *Likht*, 1986; *Park et al.*, 1995; *Suk et al.*, 1996].

4. Morphotectonic Elements

In study area, the main morphotectonic structure units of conventionally first order(Fig. 4) is as follows: (1) the Ulleung Basin, (2) the Korean Peninsula Rise, (3-8) the complicated underwater rise named the Korean Plateau, and (9) the Oki-Bank Rise.

In the south, the Ulleung Basin(1) is limited by the relative rise coincided in space with the Korea Strait. Tsushima Island is a member of this rise, which may be conventionally named after the Tsushima Rise. The west side of the southern part of the Ulleung Basin border on the complicated above-water morphotectonic(neotectonic) structure is limited by the Korean Peninsula Rise(2). In the north and north-west, the Ulleung Basin(1) borders on the Korean Plateau(3-8), which is limited by the Oki-Bank Rise(9) in the east.

The Ulleung Basin is parted with the above rises by the sets of tectonic scarps which are the morphologic image of young morphotectonic faults. The southern part of the Ulleung Basin is represented by an asymmetrical depression, the axis of which is shifted in the west and north. The depression extends in the latitude direction with a broad and gentle southern flank. To the north of the underwater volcanic swell of Dok-Ulleung Islands(see U.I.G.), the Ulleung Basin(subbasin) extends in the north-western direction as a morphotectonic graben and broadens towards the deep basin of the East Sea in the north.

The northern and north-western parts of the Ulleung Basin(to the north of Ulleung Island) is the Korean Plateau Rise which consists of three complicated rises(Fig. 4): (3) the Wonsan Plateau, (4) the Ulleung Plateau, and (5) the Rise situated to the west of Ulleung Island.

The Wonsan Plateau(3) is limited to the west by the Wonsan Trough(6) and to the east by the Ulleung Trough(7). The Ulleung Trough(7) separates the Wonsan Plateau(3) and the

Ulleung Plateau(4). The Rise(5) located on the west of Ulleung Island is limited in the west by the narrow depression, conventionally named as Mukho Trough(8). The Rise and the Wonsan Plateau(3) are complicated by the submeridional rise and depression of the higher order, and extend mainly in NE direction.

The Oki-Bank Rise(9) is situated in the eastern part of the study area(Fig. 1). It extends to the meridional direction in the limit of the east and the southern part of Ulleung Basin. In the study area, underwater volcanic structures are easily distinguishable in some places, especially southeast of the Ulleung Basin.

The results of the single channel and multichannel reflected seismic survey(Fig. 3) show that the major morphotectonics features, brows, concord to the outcrop of the acoustic basement and the feet of continental slope. The isobath "-2200 m" which overlap the deepest part of the Ulleung basin also coincides with contours of maximum thickness of sedimentary strata. These are serious indications to consider the inheriting evolution of those parts of the Ulleung Basin.

5. Conclusion

Detailed bathymetric maps combined with various geomorphological evidences can be used for the construction of morphotectonic map in the Ulleung Basin. These geophysical data help establish to apply morphotectonic statical models and to express dislocations in the sea floor.

Morphotectonic dislocations on the sea bottom, just as the newest (neotectonic) geological structures forms on land, have evidently been developed as the feature of the separated summit surface on the sea floor mainly in the Pliocene-Quaternary.

Comparisons of morphotectonic maps with geological and geophysical data especially by SeaBeam data allow to determine the nature of isolated floor-relief bodies such as volcanic domes and caldera. The morphotectonic maps, maps of "structural" surfaces provide the sufficient inheritance degree of structural elements on various geological levels. The map also give the information of nature of basin(structures and ages of acoustic basement and summit surface of the sea floor and etc.). The conformity of some sea floor relief forms to definite geological bodies(volcanic constructions, for instance). Therefore, it is possible to forecast locations of different geological bodies and their structures in the regions where geological and geophysical survey(seismic data, in particular) has never been performed or has been conducted without sufficient detail.

It must also be noted that the morphotectonic rises and depressions, in general, coincides with the sedimentary structure elements established by the seismic data, in that they are inherited tectonic elements in this part of the East sea(Sea of Japan).

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