

3D gravity modelling for Anyongbok Seamount in the East Sea

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Abstract A seamount chain with an approximately WNW trend is observed in the northeastern Ulleung Basin. It has been argued that these seamounts, including two islands called Ulleung and Dok islands, were formed by a hotspot process or by ridge related volcanism. Many geological and geophysical studies have been done for all the seamounts and islands in the chain except Anyongbok Seamount, which is close to the proposed spreading ridge. We first report morphological characteristics, sediment distribution patterns, and the crustal thickness of Anyongbok Seamount using multibeam bathymetry data, seismic reflection profiles, and 3D gravity modeling. The morphology of Anyongbok Seamount shows a cone shaped feature and is characterized by the development of many flank cones and flank rift zones. The estimated surface volume is about 60 km³, and implies that the seamount is smaller than the other seamounts in the chain. No sediments have been observed on the seamount except the lower slope, which is covered by more than 1,000 m of strata. The crustal structure obtained from a 3D gravity modeling (GFR = 3.11, SD 3.82 = mGal) suggests that the seamount was formed around the boundary of the Ulleung Plateau and the Ulleung Basin, and the estimated crustal thickness is about 20 km, which is a little thicker than other nearby seamounts distributed along the northeastern boundary of the Ulleung Basin. This significant crustal

thickness also implies that Anyongbok Seamount might not be related to ridge volcanism.

Keywords 3D gravity modelling · Anyongbok Seamount · East Sea · Ulleung Basin · Ulleung Plateau

Introduction

Continental fragments, Korea Plateau and Oki Bank, Ulleung and Dok islands, and small seamounts are distributed along the northern boundary of the Ulleung Basin (Fig. 1). Physiographical studies using a multibeam system (Han et al. 1998; NORI 1998) have been actively conducted around these areas since late 1990, and suggest that small seamounts around Dok Is. show a flat-topped summit and lie in a linear fashion from Dokdo Seamount to Isabu Seamount with a WNW trend (Fig. 2). 3D gravity modeling (Kang 2000; Kang et al. 2002) on Dokdo, Simheungtaek, and Isabu seamounts also shows that these seamounts have an independent volcanic conduit. Based on these results and petrological/age-dating analyses on Dok and Ulleung islands (Lee et al. 2002; Huh et al. 2005; Song et al. 2006), it has been suggested that these seamounts and islands were formed by a hotspot process during the time that Ulleung Basin was formed. This model implies that these volcanisms initially formed at the present location of Ulleung Is. and moved in an ESE direction with the eastward expansion of the entire Ulleung Basin. However, gravity modeling on the Ulleung Basin and 3D magnetic modeling on Anyongbok Seamount (Kim et al. 2002, 2005, Kim 2006; Park et al. 2006) proposes a spreading ridge extending from the center of the Ulleung Basin to near the Anyongbok Seamount with a NE-SW direction (Fig. 2), and suggest that seamounts distributed

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Fig. 1 Physiographic map of the East Sea. Box represents the Ulleung Basin shown in Fig. 2. The numbers with red dots denote ODP sites. UI: Ulleung Island; OI: Oki Island; TI: Tsushima Island; UP: Ulleung Plateau; OB: Oki Bank; KYR: Kita-Yamato Ridge; YR: Yamato Ridge

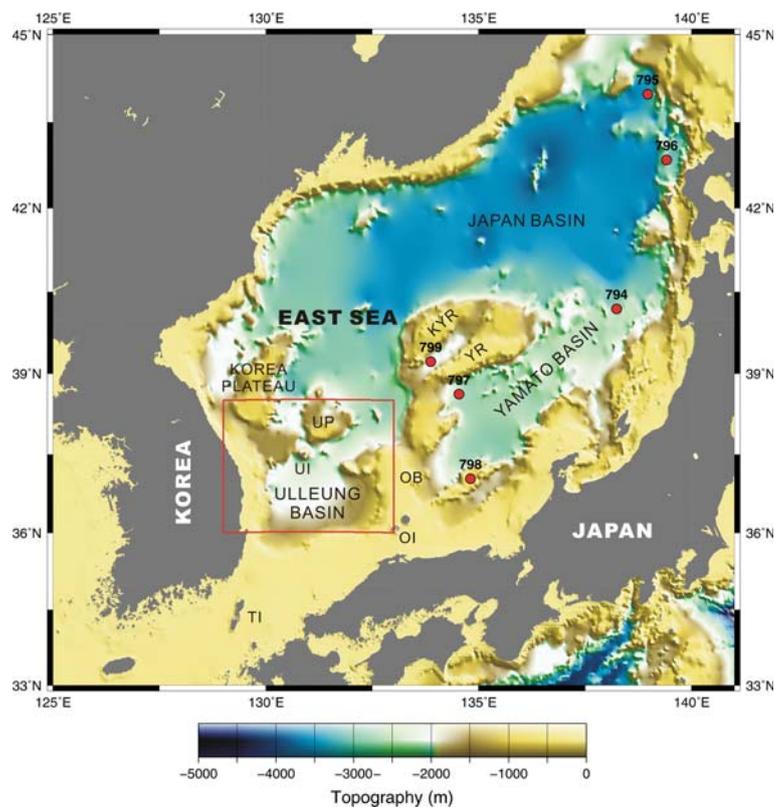
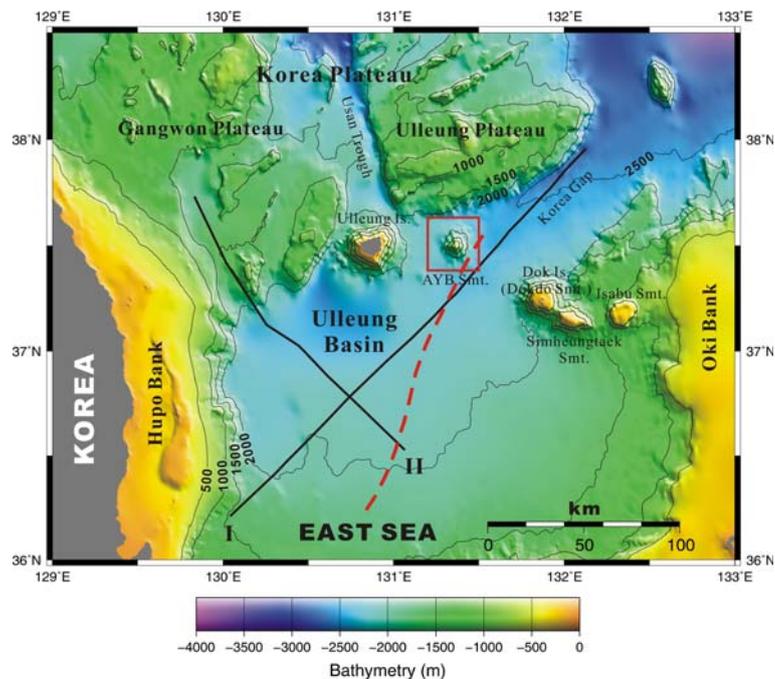


Fig. 2 Bathymetry map of the Ulleung Basin (NORI 1998). Contour interval is 500 m. Box represents the study area (Anyongbok Seamount) and thick solid lines with numbers are OBS seismic profiles (Suk et al. 1992; Kim et al. 1998). The under sea feature names are derived from NORI (2005). AYB Smt.; Anyongbok Seamount. Red dashed line denotes the spreading ridge proposed by Park et al. (2006)



in the northern boundary of the Ulleung Basin were related to the ridge volcanism rather than formed by a hotspot mechanism. However, these hypotheses have been made without analyzing the geological and geophysical characteristics of Anyongbok Seamount, which can provide the information for resolving this contro-

versy because it is located about 30 km away from Ulleung Is. and is adjacent to the proposed ridge crest. If the seamount was formed by ridge volcanism, the crustal thickness may be much less than the other neighboring seamounts, which are located far away from the proposed ridge.

There are a couple of methods for delineating the crustal structure such as OBS and gravity modeling. OBS data on a small seamount, however, is very hard to collect because of the high slope angles. Therefore, gravity data around Anyongbok Seamount was collected to do 3D gravity modeling for constraining the crust shape and thickness, and multi-channel seismic reflection and multibeam bathymetry data were also collected to identify the sediment distribution patterns and the exact shape of seamount.

Geological setting

The East Sea is a mature continental-margin backarc basin. Two formation models have been debated; the pull-apart model by the dextral Hidaka shear motion in the Early Oligocene (Jolivet and Tamaki 1992; Tamaki et al. 1992) and back-arc expansion model by upwelling of a mantle plume in Late Oligocene-Early Miocene time (Otofujii et al. 1986; Tatsumi et al. 1989; Hayashida et al. 1991; Lee et al. 1999). It is now in an early stage of compressive destruction or closure (Ingle 1992). The East Sea consists of three deep basins (Japan, Yamato, and Ulleung basins), separated by submerged continental remnants, including the Korea Plateau, Oki Bank, Yamato Ridge, and Kita-Yamato Ridge (Fig. 1).

The Ulleung Basin lies at the southwestern part of the East Sea, and its northern and northeastern parts are bounded by Ulleung and Dok islands as a volcanic island and submerged seamounts called Anyongbok, Simheungtaek, and Isabu seamounts (NORI 1998, 2005). These islands and seamounts were formed by volcanic activities, and lie in parallel to the initial opening trend of the East Sea between Korea Plateau and Oki Bank (Lee et al. 1999).

The width of the Ulleung Basin is about 200 km in the East–West direction and about 150 km in the North–South direction, and the water depth increases to the north and reaches about 2,300 m at the Korea Gap bounding the Ulleung Basin and the Japan Basin (Fig. 2). Sediment thickness interpreted from the multi-channel seismic reflection data (Lee et al. 2001) shows about 5 km at the north and about 10 km at the south. However, the origin of crust underlying the Ulleung Basin is still unclear whether it is an extended continental crust (Tamaki 1988; Tamaki et al. 1992; Chough et al. 2000), or an oceanic crust (Suk et al. 1992; Kim et al. 1998). Gravity modeling in the Ulleung Basin (Park et al. 2006) indicates that a buried fossil spreading ridge is located from the center of the basin to the Korea Gap.

Ulleung Is., as a cone shaped volcanic island, lies at the northern boundary of the Ulleung Basin, and is mainly composed of trachytes and trachy-andesites (Kim 1982;

Won and Lee 1984). Age dating results (Kr–Ar and Nd–Sr) on alkali volcanic rocks give values of the range of 2.7 Ma–0.01 Ma, indicating that the Ulleung Is. was mainly formed during Quaternary period (Xu et al. 1998; Kim et al. 1999; Song et al. 2006). To the east of Ulleung Is., Anyongbok Seamount is a narrow cone shaped feature with a height of about 1,500 m. Although there is no age data for this seamount, it is generally assumed that this body was formed before the formation of Ulleung Is. (Kim 2006). Regional 2D gravity modeling from the Ulleung Is. to the Oki bank suggests that the crustal thickness near the Anyongbok Seamount is about 15 km (Kim 2006).

Dok Is., which lies about 88 km away southeasterly from Ulleung Is., is also a small volcanic island having the same rock types of Ulleung Is. (Kim et al. 1987). The island is composed of two small islets with the height of about 90 m from the sea surface. K–Ar ages of volcanic rocks give in the range of 3.7–1.9 Ma, indicating that Dok Is. was mainly formed during the Pliocene (Sohn and Park 1994; Sohn 1995; Song et al. 2006). However, the estimated age may represent the final volcanic eruption because Dok Is. was formed by multiple volcanic eruptions, and a large volume of the volcanic body called Dokdo Seamount exists beneath the island. Dok Is. was interpreted as a remnant feature of Dokdo Seamount after wave-cut erosion (Han et al. 1998; Kang 2000; Kang et al. 2002). No aging data on this seamount has been reported. The other two seamounts called Simheungtaek and Isabu are developed with the trend of E–W. These seamounts are about 1,000 m in height and also show flat topped summits at about 300 m water depth. 3D gravity modeling (Kang 2000; Kang et al. 2002) suggests that these seamounts have a regional compensation with a root of 1 km thick in average.

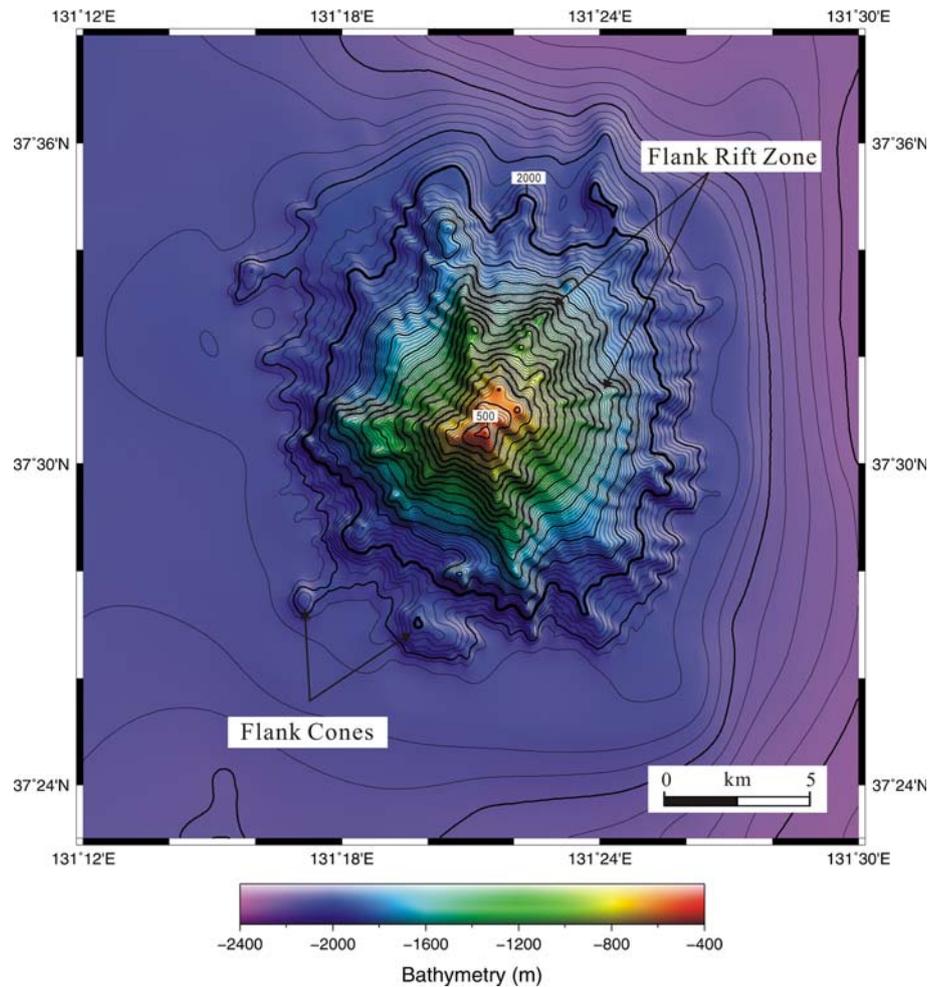
Geophysical data

Multibeam bathymetry, gravity, and multi-channel seismic reflection data were collected using *R/V Tamhae 2* in the area of 37° 23′ N to 37° 38′ N and 131° 12′ E to 131° 30′ E during the period of 2003 and 2004.

Bathymetry data

SIMRAD EM12S and EA500 multibeam echosounders were used to map the morphological features around Anyongbok Seamount. To minimize artifacts, rolling, pitching, heaving and yawing corrections were made in real time, and sound velocity measurements were also conducted at several places. The final morphological feature map (Fig. 3) was drawn after correcting position and depth using the data processing software called NEPTUNE.

Fig. 3 Detailed bathymetry of Anyongbok seamount illustrating major types of morphological features. Contour interval is 20 m. Thick solid contours represent 2,000 m isobath



Anyongbok Seamount shows a cone shaped feature with a basal width of about 12 km, and the summit can be defined at the 600 m isobath with a width of about 1.2 km. The peak of the seamount as a pointed cone developed about 100 m above the summit. Many flank cones and flank rift zones are also observed on the northeastern and the southwestern flanks. Vogt and Smoot (1984) reported that flank rift zones are associated with lava eruptions. Flatness and slope angle were estimated as 0.1° and 16° using Smith's routine (1988), and the calculated gross area and surface volume based on the 2,000 m isobath base are 130 Km^2 , and 60 km^3 , respectively. These morphological characteristic parameters are compared with the other seamounts distributed in the northeastern boundary of the Ulleung Basin (Table 1).

The morphological parameters as shown in Table 1 show that Anyongbok Seamount is a relatively small feature with a high slope angle compared to the other seamount. Its pointed cone shaped summit also implies that this seamount has never been exposed to the sea surface since it was formed.

Seismic data

Seismic reflection data were obtained using Western-Geco's Trilogy system. The data collected during 2003 used 144 channels with 18 segments (a segment length is 100 m) and a group interval of 12.5 m. As a sound source, two air-gun arrays composed of six guns in each array were implemented with a total volume size of $2,289 \text{ in}^3$ (37.5 l). The pressure was maintained at 2,000 psi and the shot interval was 25 m. In 2004, however, 80 channel data were collected using 10 segments and a single air-gun array with a $1,035 \text{ in}^3$ volume. Onboard data processing was conducted for all acquired data using the data processing software called GECOISEIS, and processed stack sections were used to interpret the sediment thickness and to define the acoustic basement (Figs. 4 and 5).

Seismic profiles crossing over Anyongbok Seamount show that sediments cover the seamount only on the flanks. Sediments are about 1 s (TWT) thick except the northern flank having 0.5 s (TWT) thick (Figs. 4 and 5). A sediment isopach map was constructed using the velocity data esti-

Table 1 Characteristics for seamounts distributed in the north of the Ulleung Basin

Seamount name	Shape	Basal depth (m)	Basal width (km)	Summit depth (m)	Summit width (km)	Peak depth (m)	Flatness (f)	Flatness (ζ_h)	ε	Slope angle (ϕ)	Basal area (km ²)	Surface volume (km ³)	Summit feature
Anyongbok Seamount	Circular cone	2,000	12.0	600	1.2	500	0.10	0.25	0.28	16°	130	60	Pointed cone
Dokdo Seamount	Circular cone	1,900	24.0	200	9.5	100	0.40	0.15	0.25	14°	470	420	Flat-topped
Simheungtaek Seamount	Elongated	1,100	22.0	300	13.0	200	0.59	0.08	0.20	11°	260	150	Flat-topped
Isabu Seamount	Dome	1,000	18.0	300	10.0	200	0.54	0.14	0.30	17°	410	200	Flat-topped

Flatness (f) = summit width/basal width, height-to-basal-radius ratio (ζ_h) = $2 \times \text{height}/\text{basal width}$, $\varepsilon = 2 \times \text{height}/\text{basal width}$, slope angle (ϕ) = $\arctan(\varepsilon)$

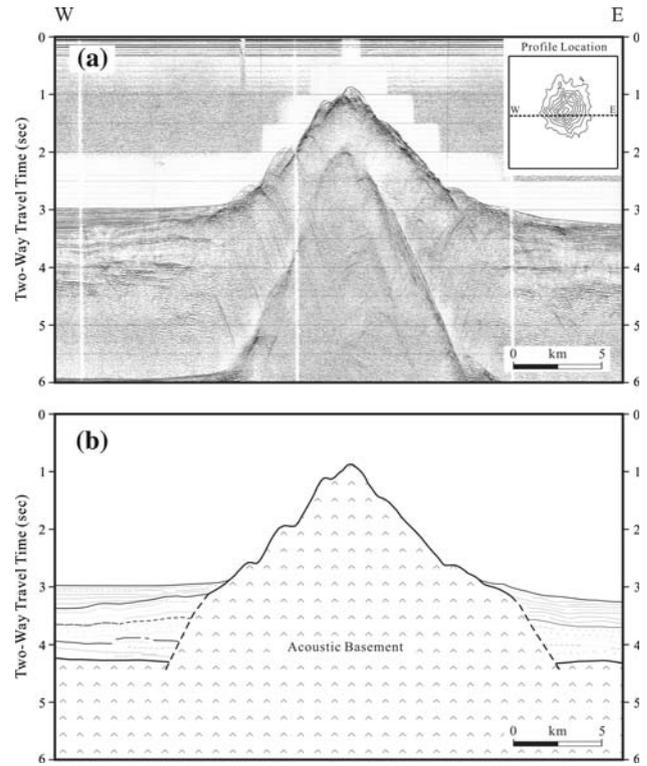


Fig. 4 Multichannel seismic reflection profile with an E-W direction (a), and interpreted section (b). Inset shows a location of the profile

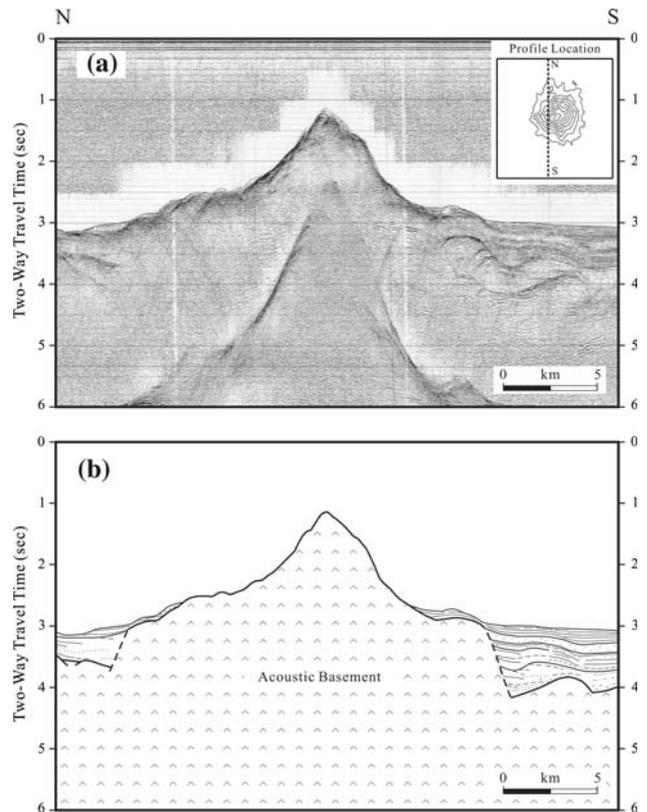
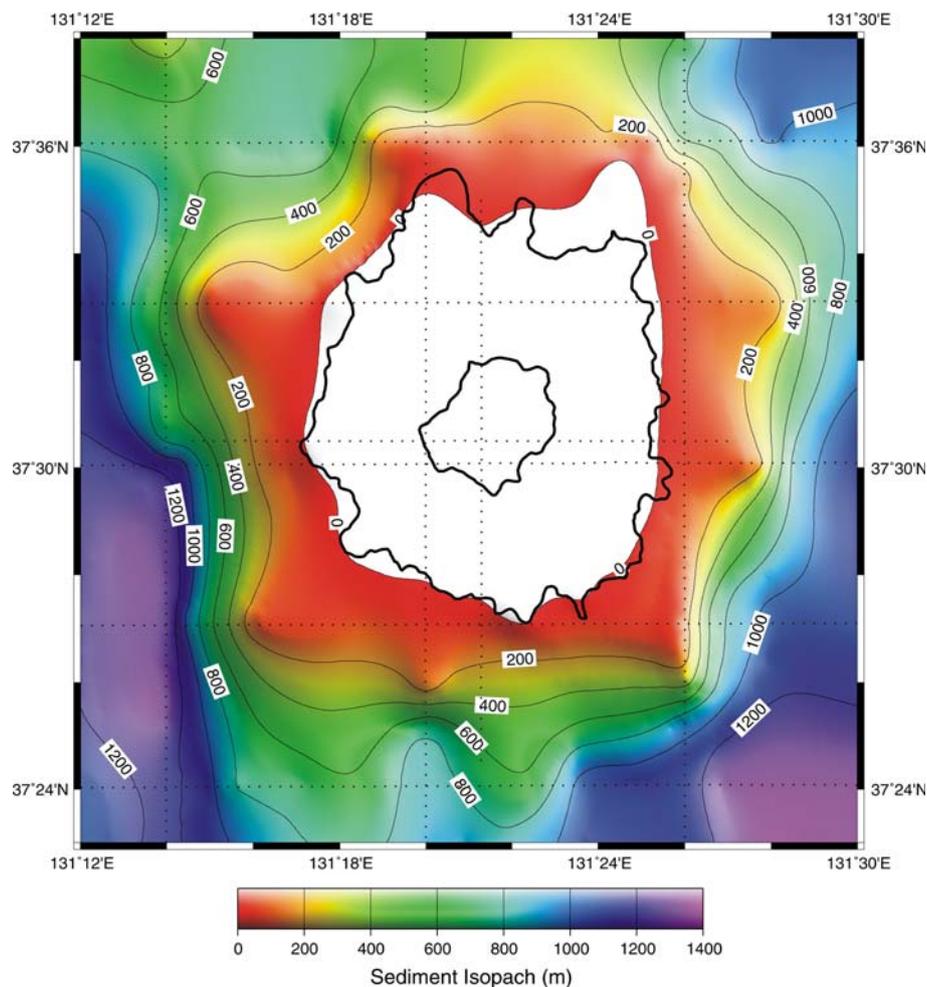


Fig. 5 Multichannel seismic reflection profile with a N-S direction (a), and interpreted section (b). Inset shows a location of the profile

Fig. 6 Isopach map of the sediment layer in the study area. Contour interval is 200 m. Dotted lines denote the seismic tracks used to constrain isochrons, and thick solid lines represent bathymetry contours of 1,000 m and 2,000 m



mated from stack velocities. The isopach map (Fig. 6) shows that sediments thicken rapidly away from the seamount and have thickness more than 1,000 m except the northern part, which has about 600 m thickness with a smooth variation in between.

Gravity data

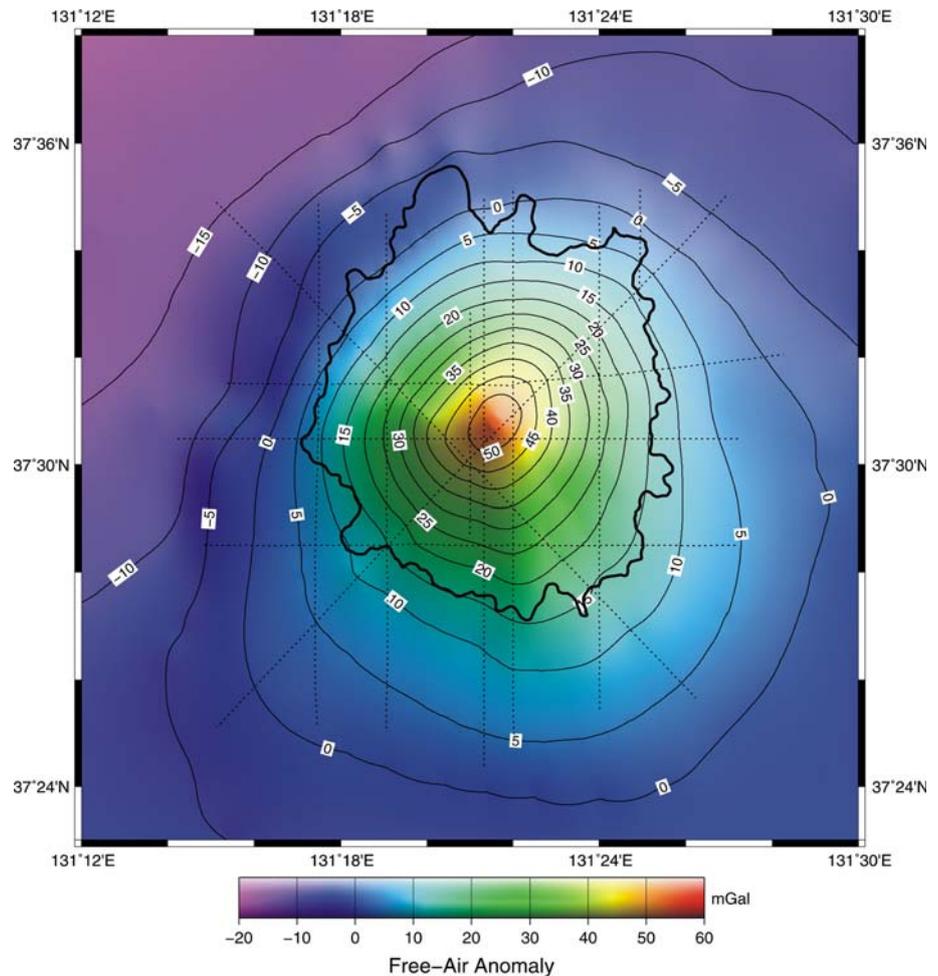
Gravity data were obtained using LaCoste-Romberg shipborne gravimeter. The S-118 meter is a relative gravity meter and cannot directly measure the absolute gravity value. Therefore, the acquired relative gravity values data must be converted to absolute gravity values to calculate the Free-Air gravity anomaly. For this process, the absolute gravity value at the International Gravity Station in Pusan National University, Korea was transferred to the home port of Tamhae 2. The effect of meter drift was also considered because S-118 gravity meter uses a fused-metal spring, and the length of spring can vary with time. The calculated meter drift value was -0.001 mGal/h and a linear meter drift correction was conducted. The Eötvös effect, which causes a large deviation of the observed data,

was also removed from the observed values based on a standard equation (Nettleton 1976). After correcting these effects, Free-Air anomaly was calculated from WGS84 Standard Gravity Formula (NIMA 2000). In the area outside the shipboard gravity data, however, satellite altimetry data (Sandwell and Smith 1997) were added because of limited shipborne gravity data.

Calculated Free-Air anomalies show 1.3 mGal RMS errors in 37 cross-over points. EZXover (Kang et al. 2006) program using a weighted linear interpolation algorithm (Mittal 1984) was used to minimize cross-over errors, and RMS errors reduced to 0.1 mGal, which is enough to make a Free-Air anomaly map with a 5 mGal contour interval.

Free-Air anomalies generally reflect the seamount bathymetry as shown in Fig. 7. The maximum value (about 50 mGal) is found at the top of the seamount, and the anomaly gradually decreases to 10 mGal at a water depth of 2,000 m and shows the minimum value (about -15 mGal) at the northwestern part of the study area. In general, gravity anomaly values at the southern part are relatively higher than the northern part, which differs from the water depth pattern. The maximum gravity value is also

Fig. 7 Free-Air gravity anomaly map of the study area. Contour interval is 5 mGal. Dotted lines denote shipborne gravity survey tracks used to constrain contour map, and thick solid contour represents a 2,000 m isobath



relatively smaller than the other seamounts such as Dokdo (120 mGal), Simheungtaek (90 mGal), and Isabu (70 mGal) seamounts (Kang 2000; Kang et al. 2002). This difference may be due to the smaller volume size of seamount.

3D gravity modeling

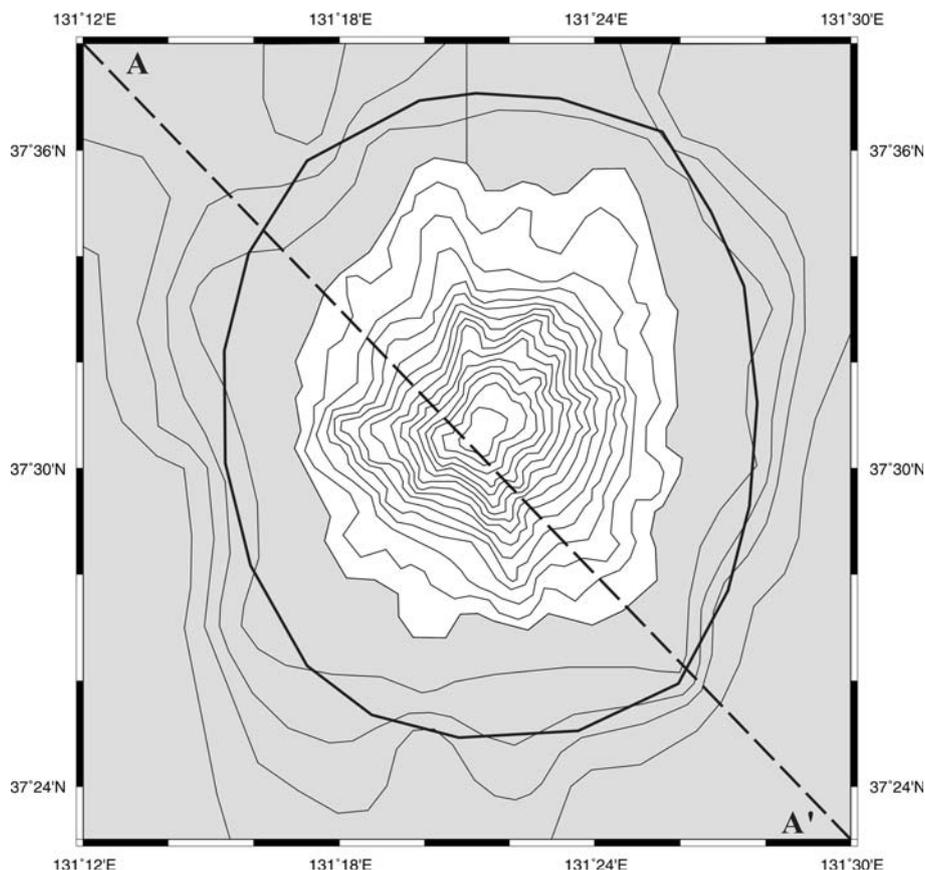
Method

One of key parameters for the gravity modeling is a density distribution, and there are many ways to estimate the densities of a seamount. However, 2D analysis for 3D features could over-estimate the body volume and may underestimate a body's density (Rose and Bowman 1974). Therefore, 3D linear least-squares inversion of observed gravity anomalies has been used for estimating densities of seamounts. The estimated averaged density of seamounts is typically in the range of 2.5–2.6 g/cm³ (Le Pichon and Talwani 1964, 1965; Schimke and Bufe 1968; Sager et al. 1982; Kellogg and Ogujiofor 1985;

Wedgeworth 1985; Freitag 1987; Kellogg et al. 1987; Wedgeworth and Kellogg 1987). However, a linear least-squares inversion has an assumption that observed gravity anomalies are only due to the body above the seafloor; i.e., it does not consider an isostatic root. Therefore, this method may not valid if a body has a local gravity root or a large magma chamber (Le Pichon and Talwani 1964). Consequently, determination of densities for the modeling of Anyongbok Seamount was relied on direct measurements because no data is available for the isostatic compensation.

The measured density of sediments in the East Sea (ODP Leg 128, Ingle et al. 1990) varies from 1.6 g/cm³ to 2.0 g/cm³ depending on the depth and lithologies, and these values were adopted within the given depth. Density of volcanic rocks was assumed as 2.5 g/cm³ for the first phase of gravity model since there are no directly measured densities from the seamount, and this value was changed until the residual gravity anomalies were minimized. Densities of water and upper mantle were assumed as 1.03 and 3.3 g/cm³, which are generally accepted values (Dehlinger 1978), and density of

Fig. 8 Polygonal prisms used for Model A. Polygons are spaced at 100 m depth intervals. Shaded area represents sediments and thick solid line indicates an isostatic root



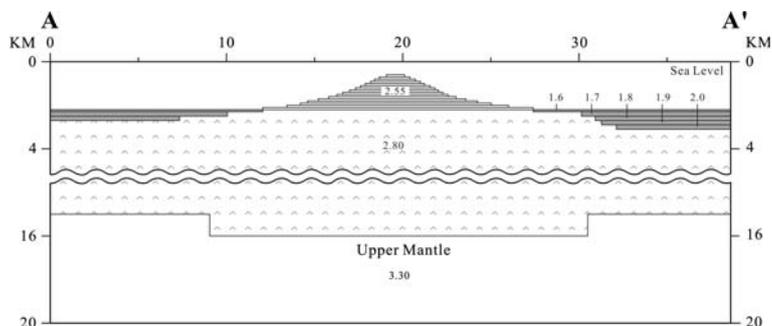
the crust was assumed to be 2.8 g/cm^3 based on density–velocity relationship (Den et al. 1969; Carlson and Herrick 1990, Eq. 2a).

Plouff's 3D gravity modeling method (1976) was used for this study because it is easy to apply for features like a seamount (Sager et al. 1982; Sager 1983; Han 1993). This technique utilizes a stack of polygonal prisms with vertical sides to approximate the shape of the body. To create an input dataset of gravity values, a grid with an interval of $0.15'$ (about 280 m) in latitude and of $0.2'$ (about 300 m) in longitude was used to digitize the gravity values. Observed gravity anomalies at 9,191 points were digitized and some of gravity values were interpolated where there are not enough gravity survey

lines, but this is appropriate because gravity varies smoothly over the seamount. To test the validity of the gravity model, residual gravity anomaly (observed minus calculated) and GFR (Goodness of Fit Ratio) value were also calculated.

Minimizing the residual gravity anomaly is one of the widely used methods for justifying a model. If residual anomalies show negligible amplitudes, it is generally accepted that the model reflects the actual body. The other criterion is GFR defining as the ratio of the mean observed anomalies to the mean residual anomalies (Richards et al. 1967). If GFR value is higher than 2.0, it is generally assumed that the model is reliable (Harrison et al. 1975; Sager 1983; Sager and Pringle 1987).

Fig. 9 Cross-section showing the density distribution used in Model A. Numbers denote the assigned densities (g/cm^3). Location of transect AA' shown in Fig. 8



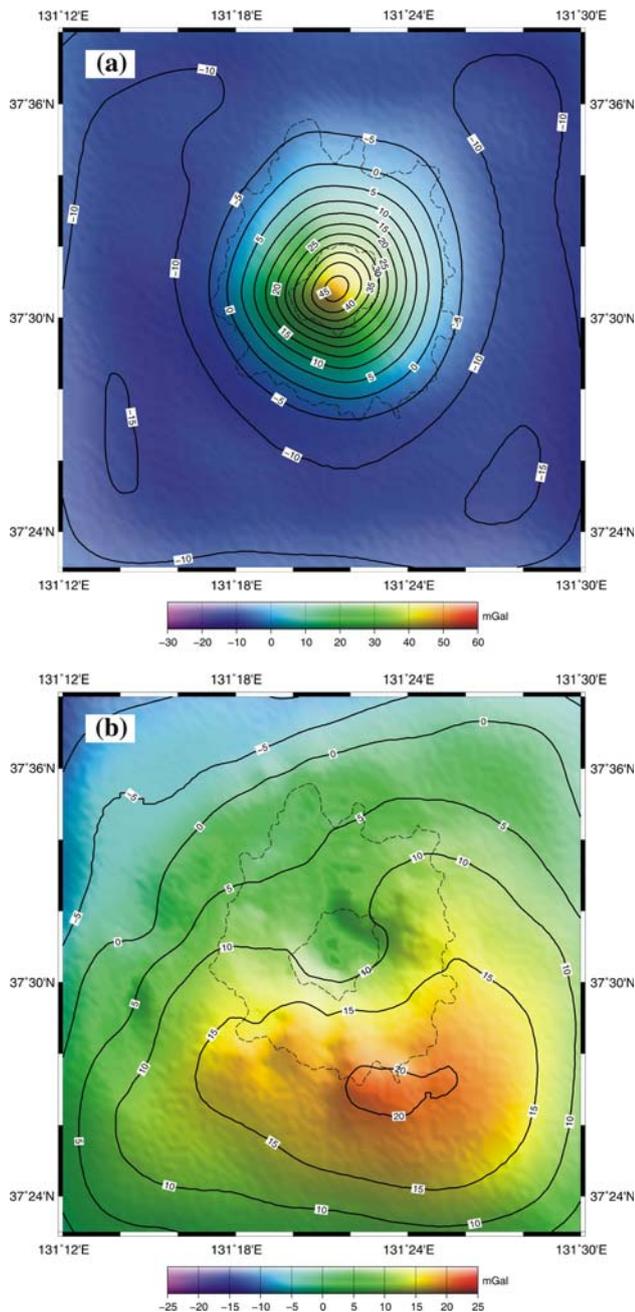


Fig. 10 Results of the gravity Model A showing calculated gravity anomalies (a) and residual gravity anomalies (b). Contour interval is 5 mGal. Dashed lines represent bathymetric contours of 1,000 m and 2,000 m

Model A

Polygonal prisms with a vertical side of 100 m thickness from the water depth of 600–2,200 m were constructed as a volcanic body, and polygons for sediments were extended from 2,200 m to 3,100 m water depth based on the seismic reflection data to avoid edge effects (Fig. 8). It was assumed that the boundary of the crust and upper mantle occurs at

about 15 km from the sea surface, based on OBS results (Suk et al. 1992; Kim et al. 1998), and that the regional gravity root with a 1 km thick is existed, based on the results from the other neighboring seamounts. The effect of volcanic conduit was also ignored because the seamount body is too small. All given parameters are shown in Fig. 9.

Calculated gravity anomalies based Model A show about 45 mGal at the top of the seamount, and gradually decrease along the slope and reach to -5 mGal at the 2,000 m isobath. The minimum values of about -15 mGal are observed at the eastern and western parts (Fig. 10a). Overall residual anomalies show a relatively large deviation from the observed anomalies, the low GFR value (1.06) and a relatively high standard deviation (10.71 mGal). Negative residual anomalies are shown to the northwest of the seamount and positive anomalies (>15 mGal) are found to the southeast (Fig. 10b). The asymmetry of the residual implies that Model A has a sloping density contrast, and the low GFR value implies that the given model does not properly reflect the shape of root.

Model B

The crustal structure of the northern boundary of the Ulleung Basin has not been analyzed. It is known that the crustal thickness of Ulleung Plateau as a continental fragment (Fig. 1) could be thicker than the Ulleung Basin consisted of an extended continental crust or an oceanic crust. Based on this information, several different types of models with the same parameters of Model A except for the root were tested. Model B was selected because this model showed the minimum residual gravity anomalies and the maximum GFR value. The gravity root for Model B was constructed with a thickness of about 15 km in the southeastern part of the model and gradually thickened toward the northwestern, eventually reaching about 31 km thick at the Ulleung Plateau, which is the normal thickness of continental crust (Figs. 11 and 12).

Calculated gravity anomalies are about 55 mGal at the top of the seamount and about 5–0 mGal at the 2,000 m isobath. Negative anomalies with about -5 to -10 mGal were calculated at the northwestern edge of the model (Fig. 13a). Residual anomalies are negligible in the whole area as shown in Fig. 13b, and high GFR (3.11) and low standard deviation (3.82 mGal) values imply that the Model B better reflects the crustal structure of Anyongbok Seamount.

Discussion

Topographic highs generally have a regional or a local compensation according to their size and duration of loading

Fig. 11 Polygonal prisms used for Model B. Shaded area represents sediments and thick solid lines indicate isostatic root

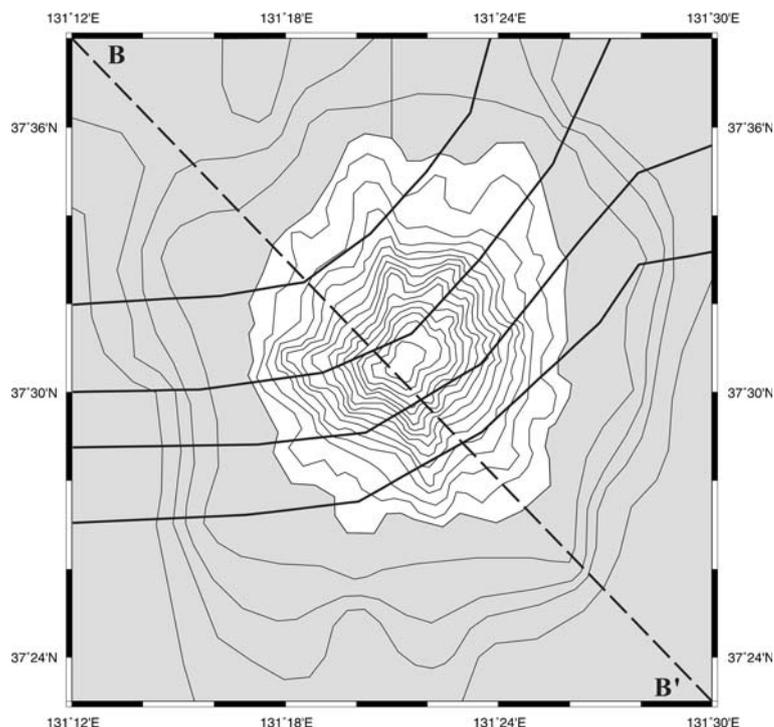
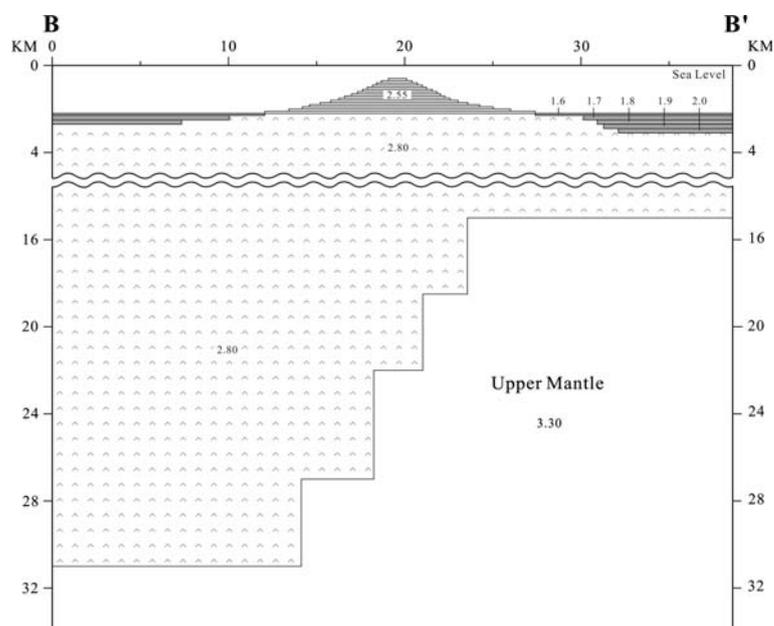


Fig. 12 Cross-section showing the density distribution used in Model B. Numbers denote the assigned densities (g/cm^3). Location of transect BB' shown in Fig. 11



(Watts and Cochran 1974; Dehlinger 1978). However, the gravity root of Anyongbok Seamount, based on the 3D gravity modeling, does not show a typical regional or a local compensation. Small changes of root shape and thickness of the model may expect similar results. However, the general sloping pattern of the root should be maintained, and it implies that the result is robust. What causes this kind of sloping bottom crust boundary? One possible explanation is that the seamount might be formed at the margin of the

Ulleung Plateau based on the crustal thinning from northwest to the southeast, and the other explanation is that the seamount was formed near the boundary of the Ulleung Plateau and the Ulleung Basin because the crustal thickness at the southern tip of the seamount is similar to the Ulleung Basin (about 15 km). However, the boundary of the Ulleung Plateau and the Ulleung Basin may not be tested because both crusts have a similar density structure. In either case, the modeling result implies that the boundary of the Ulleung

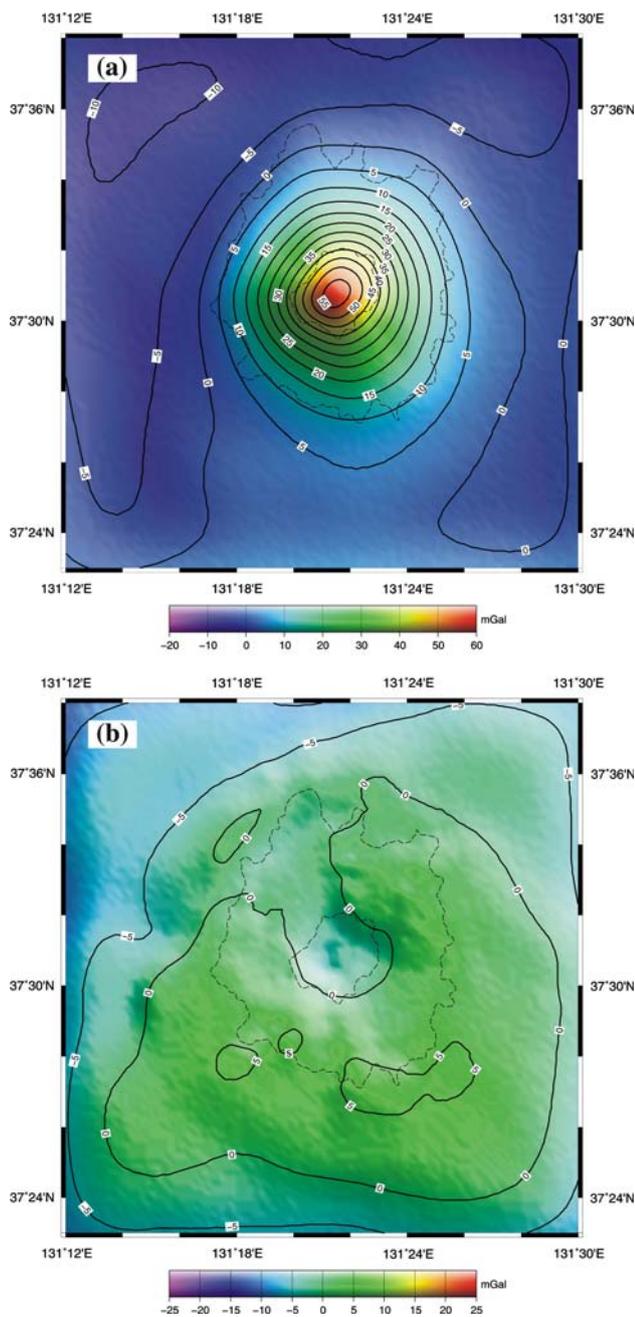


Fig. 13 Results of the gravity Model B showing calculated gravity anomalies (a) and residual gravity anomalies (b). Contour interval is 5 mGal. Dashed lines represent bathymetric contours of 1,000 and 2,000 m

Plateau, which is defined as a 2,000 m isobath based on the morphological point of view, can be further extended to the south (Fig. 14).

It is generally known that the East Sea started to open in Late Oligocene or Early Miocene, and has been in the closing stage since approximately 15 Ma when the rotation of Japan was completed (Otofujii et al. 1985). This kinematic process was reconstructed using a two-stage model

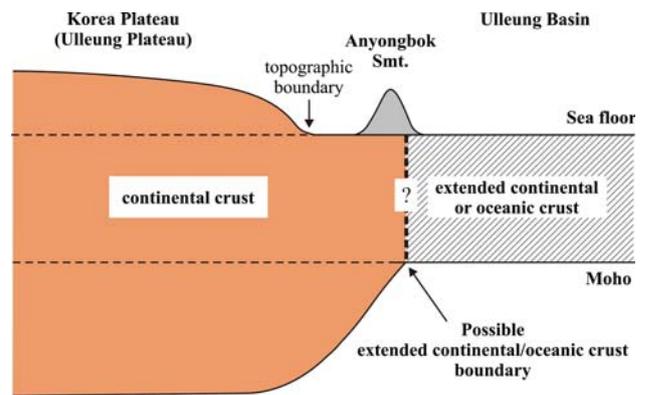


Fig. 14 Cartoon showing the crustal shape around Anyongbok Seamount

(Lee et al. 1999). Kaneoka et al. (1990) interpret that seamounts in Yamato and Japan basins were formed after the formation of the basins based on the formational age of seamounts (10–17 Ma). This interpretation, and ages (<3.7 Ma, Song et al. 2006) and rock types of Ulleung and Dok islands suggest that seamounts in the East Sea may have a similar formational environment, and it implies that Anyongbok Seamount was formed after the Ulleung Basin was fully developed.

Kim (2006) and Park et al. (2006) observed sub-parallel elliptical Free-air anomalies in the Ulleung Basin and proposed that an extinct spreading ridge may have existed from the center of the Ulleung Basin to the southwestern margin of Anyongbok Seamount. However, their interpretations near the seamount were based on only two track lines, and any peculiar anomalies cannot be observed in our dataset. Also, the estimated crustal thickness below Anyongbok Seamount is a little bit thicker than the seamounts at the northeastern boundary of the Ulleung Basin. If the seamount was formed by a ridge volcanism suggested by Kim (2006) and Park et al. (2006), the crust thickness should be much thinner than that of the other seamounts. Therefore, the proposed spreading ridge from the center of the Ulleung Basin to the Korea Gap (Kim 2006; Park et al. 2006) may not pass through the seamount, or may be terminated somewhere else in the Ulleung Basin.

Summary

Morphological characteristics, sediment distribution patterns, and the crustal thickness of Anyongbok Seamount were analyzed using multibeam bathymetry data, seismic reflection profiles, and 3D gravity modeling. A cone shaped Anyongbok Seamount has a basal width about 12 km, and a slightly flat surface is developed at the 600 m isobath and its

width is about 1.2 km. The peak of the seamount is a pointed cone, and extends about 100 m above this surface. Many flank cones and flank rift zones related to lava eruptions are observed at the northeastern and the southwestern flanks. The estimated flatness and slope angle were 0.1° and 16° , respectively. The calculated area (130 km^2) and surface volume (60 km^3) suggest that the seamount is smaller than other nearby seamounts distributed along the northeastern boundary of the Ulleung Basin. Seismic reflection profiles show that no sediments cover on the seamount, but sediments more than 1 km thick mantle the lower slope.

The crustal structure of Anyongbok Seamount based on the 3D gravity modeling shows a transition from the southern edge of the Ulleung Plateau to the northern boundary of the Ulleung Basin. This interpretation implies that the boundaries of both the southern part of the Ulleung Plateau and the northern part of the Ulleung Basin can be further extended to the center of Anyongbok Seamount. The crustal thickness of Anyongbok Seamount ($\sim 20 \text{ km}$) having a little bit thicker than the other seamounts also suggests that the seamount may not be formed by a ridge volcanism.

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