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Investigation of Subsurface Structure of Cheju Island by Gravity and Magnetic Methods

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ABSTRACT: The geologic structure of the Cheju volcanic island has been investigated by analyzing the gravity and magnetic data. Bouguer gravity map shows apparent circular low anomalies at the central volacanic edifice, and the maximum difference of the anomaly values on the island appears to be 30 *mgal*. The subsurface structure of the island is modeled by three-dimensional depth inversion of gravity data by assuming the model consists of a stacked grid of rectangular prisms of volcanic rocks bounded below by basement rocks. The gravity modeling reveals that the interface between upper volvanic rocks and underlying basement warps downward under Mt. Halla with the maximum depth of 5 *km*. Magnetic data involve aeromagnetic and surface magnetic survey data. Both magnetic anomaly maps show characteristic features which resemble the typical pattern of total magnetic anomalies caused by a magnetic body magnetized in the direction of the geomagnetic field in the middle latitude region, though details of two maps are somewhat different. The reduced-to-pole magnetic anomaly maps reveal that main magnetic sources in the island are rift zones and the Halla volcanic edifice. The apparent magnetic boundaries inferred by the method of Cordell and Grauch (1985) are relatively well matched with known geologic boundaries such as that of Pyosunri basalt and Sihungri basalt which form the latest erupted masses. Inversion of aeromagnetic data was conducted with two variables: depth and susceptibility. The inversion results show high susceptibility bodies in rift zones along the long axis of the island, and at the central volcano. Depths to the basement are 1.5~3 *km* under the major axis, 1~1.5 *km* under the lava plateau and culminates at about 5 *km* under Mt. Halla. The prominent anomalies showing *N−S* trending appear in the eastern part of both gravity and magnetic maps. It is speculated that this trend may be associated with an undefined fault developed across the rift zones.

INTRODUCTION

Chejudo (Cheju island) is a volcanic island located approximately 90 km south of the Korean peninsular and covers an area of about 1,800 km^2, 75 km eastwesterly and 31 km northsoutherly in the major and minor axial distances, respectively. The island is elongated in an *ENE* direction, and Mt. Halla which locates at the center of island rises to 1950 *m* and dominates the landscape.

The Cheju island belongs to the Circum Japan(East) Sea Alkali Rock Province of Cenozoic age which are widely distributed in the eastern Asia with relatively samall scale (Lee, 1982; Nakamura *et al.*, 1989; Nakamura *et al.*, 1990; Tomita, 1935). These volcanic centers are isolated, mostly distributed along the active deep continental faults (Zhou and Armstrong, 1982) and some of them are seemed to be related to the extentional rifting of the eastern Asia (Terman, 1977). The Cheju island is a shield volacano formed by central eruption in the vicinity of Mt. Halla during Upper Pliocene to Lower Pliocene. The geology of Cheju island is characterized by the Halla volcanic edifice, lava plateau and cinder cones. The island is composed mainly of large amounts of basaltic lava flows and minor pyroclastic rocks. The central volcanic edifice, which has the circular shape with a diameter of about 16 km, are mainly composed of Hallasan trachyte and Baekrockdam hawaiite. The rift zone composed of many cinder cones and lava flows are developed parallel to the long axis of the island. Altough basement rocks are not exposed in the Cheju island, a few granitic xenoliths are found in the pyroclastic rocks and lava flows in Beoldobong and Songaksan and these can be correlated with Bulkuksa granite widely distributed in the Korean peninsular (Lee,1982). In recent times, granite and tuff were confirmed under volcanic rocks from the deep drilling wells. There are currently two available geologic maps of the Cheju island: the maps made by Lee(1982) and KADC (Korean Agriculture Development Corporation). Fig. 1 is the

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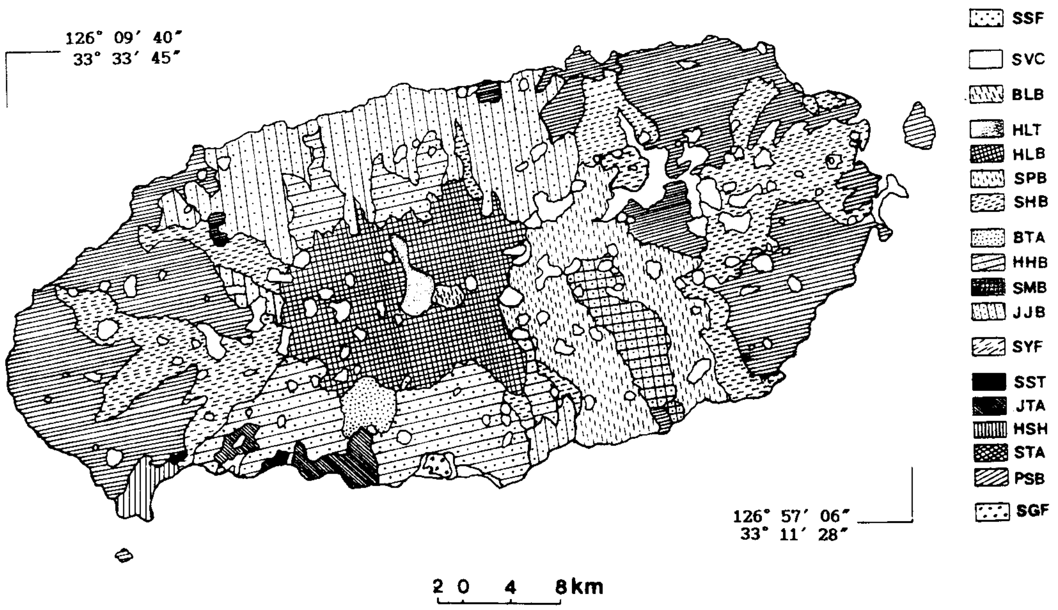

Fig. 1. Geologic map of Cheju island (after Lee, 1982).
SSF : Shell sand formation; BLB : Baeklokdam hawaiite; HLB : Hallasan basalt; SHB : Sihungri basalt; HHB : Hahyori basalt; JJB : Jeju basalt; SST : Sanbangsan trachyte; HSH : Hwasun-Songsan Hyaloclastite; PSB : Pyosunri alkali basalt; SVC : Scoria volcanic cones; HLT : Hallasan trachyte; SPB : Seongpanack basalt; BTA : Beobjeongri mugearite; SMB : Sumangri basalt; SYF : Sinyangri Formation; JTA :Jungmun hawaiite; STA : Seoguipo hawaiite; SGF : Seoguipo Formation.

geologic map provided by Lee (1982) which we mainly refer to in the course of our study.

A number of geological and geophysical studies have been conducted in the island, though most of which are related to the ground water exploration (Suh *et al.*, 1964; Nahm, 1966; Lee *et al.*, 1968; Won, 1976; Lee, 1982; Lee *et al.*, 1983; Yoon *et al.*, 1984; Lee *et al.*, 1988; Cho *et al.*, 1987, Cho *et al.*, 1988, Cho *et al.*, 1989, Cho *et al.*, 1990; Kwon *et al.*, 1992; Lee *et al.*, 1993). Geothermal possibilities in the Cheju island attract geologist's attention and some reconnaissance surveys are in progress. To delineate the ground water formations and investigate the geothermal sources, it is essential to interprete the regional subsurface structure of the island. Gravity and magnetic data may be the effective ones in modeling the subsurface structure for this purpose.

GRAVITY STUDY

Gravity studies have not been conducted actively in the Cheju island, mainly due to the rugged topograhy. Distribution of triangulations and leveling nets of the island, which are quite useful for gravity measurements, is also worser than that of inland. Furthermore, the slope of the Halla volcanic edifice is so steep that precise leveling on mountain area is almost impossible.

Lee *et al.* (1983) made gravity measurements at 290 points, whose heights were determined by using altimeters, and reported low Bouguer anomalies over the Halla edifice. They also suggested the presence of a graben-like structure and a volcanic plug in the vicinity of Mt. Halla by studyng both gravity and magnetic anomalies. Choi *et al.* (1993) studied geoidal undulation in and around the Cheju island based on the free-air anomaly map showing the maximum anomaly of 110 mgal over the summit of Mt. Halla, which is about 100 mgal higher than in coastal areas.

Data Acquisition and Reduction

Gravity surveys have been conducted by using a La Coste-Romberg gravity meter, of which accuracy is 0. 01 mgal. The distribution of 236 gravity stations are shown in Fig. 2. together with free-air anomalies. Most gravity measurements are made along the roads and elevation of the stations are measured by leveling. In areas such as coast or lava plateau, gravity measurements were made at bench mark or triangulation points. In the Halla volcanic edifice, however, there exist no bench mark or triangulation stations and leveling was also

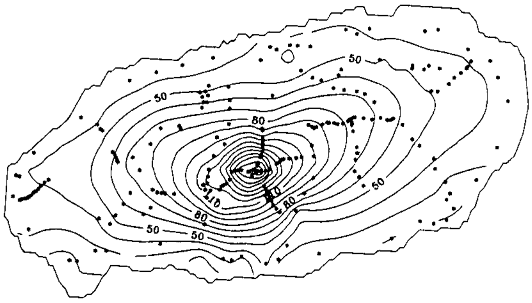

Fig. 2. Free-air anomaly map of Cheju island, showing the location of gravity stations. Contour interval is 10 mgal.

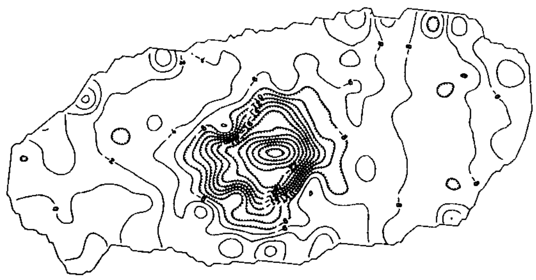

Fig. 3. Bouguer anomaly map of Cheju island. Contour interval is 2 mgal. The relative datum level of anomaly is reduce to 0 mgal for the purpose of gravity modeling.

impossible because of the steep gradient of terrain. Thus the elevation of stations were determined by using an altimeter. Since the altimeter readings are based on barometric variation, the observational error may exeed 10 m or more and the accuracies of gravity values in the area of Halla volcanic edifice are much worser than those of other areas.

The bench mark at Kwandukjung(an old wooden pavilion) in Cheju city was selected as the base station for the gravity survey and the base station reading was tied to the absolute gravity of the datum station located in Seoul National University. Tidal correction was made with g-factor of 1.2 as usual in Korea. Drift correction was also carried out in loop measurement with a period of a day. The mean density of 2.5 g/cm^3 based on laboratory measurments of rock samples was used in Bouguer and terrain corrections. Digital terrain data taken off from the topographic map at 1 km by 1 km and 250 m by 250 m grid stations in the areas of the lava plateau and Halla volcanic edifice, respectively, were used for terrain correction. The maximum radius enclosed the terrain data was maintained to be 20 km for every station.

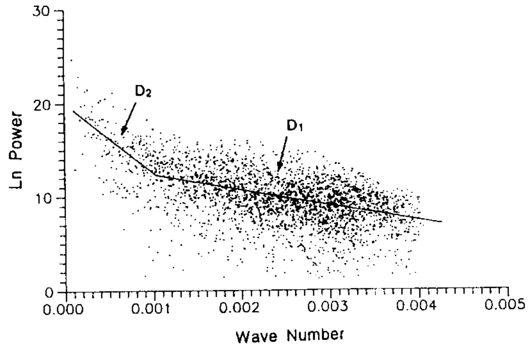

Fig. 4. Two-dimensional power specrum analysis of Bouguer anomalies. Two density discontinuities are inferred at the depths of 1.67 km (slope D_1) and 7.42 km (slope D_2).

Free-air and Bouguer Anomaly Maps

Free-air anomaly shown in Fig. 2 reflects the typical topographic features of shield volcano of Cheju island dominated by Mt. Halla. The anomaly values vary from 12 mgal at the coastal area to 190 mgal at the top of Halla volacanic edifice.

The Bouguer anomaly map(Fig. 3) shows a circular shaped low anomaly centered on Mt. Halla which is the predominant gravity characteristics of the island. This low anomaly was also noted by Lee *et al.* (1983), and they suggested a geologic model whose boundary surface of basement bends down in the the central volcanic edifice. The actual anomaly values vary in the range of $-4\sim26$ mgal, but the relative datum level of Bouguer anomaly was chosen to be 0 mgal for the purpose of gravity modeling of subsurface strucure of the island. The Bouguer anomaly increases westwardly at the rate of about 6 mgal/75 km (8 mgal/100 km), which is in close agreement with that of 4~6 mgal/75 km observed by Lee *et al.* (1983). This regional variation may be related to the gradient of interface between basement and upper volcanic rocks. It is also noticeable that low gravity anomaly zone is located in the eastern part of the island with $N-S$ trend.

Modeling of Gravity Structure

Two-dimensional power spectrum analysis and three-dimensional depth inversion of the Bouguer gravity data were attempted to delineate the subsurface strucure of Cheju island. In order to work on a computer, gravity values on grid points of 1 km interval were recomputed from original data set. Also to avoid the edge effect, which is generally arisen in the course of spectral ana-

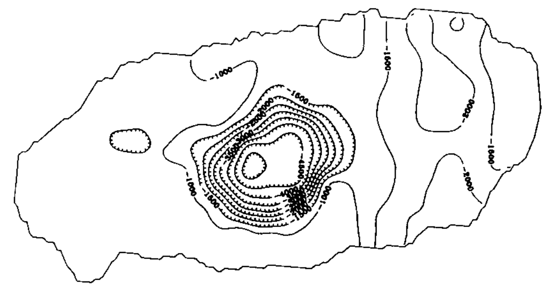

Fig. 5. Depth distribution of basement beneath the volcanic rocks obtained by three- dimensional depth inversion of gravity data. Contour interval is 500 m.

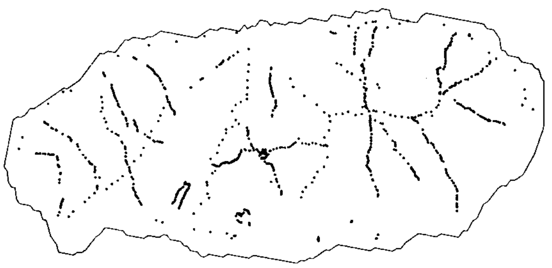

Fig. 6. Distribution of magnetic measurement points in the surface magnetic survey.

lysis, the new data set was expanded four times by using a folding method(Kwon and Yang, 1985). Fig. 4 shows the result of two-dimensional power spectrum analysis, in which two straight lines D_1 and D_2 indicating density discontinuities at depths of 1.67 km and 7.42 km are identified. The first discontinuity at the depth of 1.67 km seems to be interface between basement and upper volcanic rocks. The nature of the second interface at the depth of 7.42 km can not be interpreted at this time because no geological or geophysical information are available as to this discontinuity.

The Marquart-Levenberg inversion method(Levenberg, 1944; Marquardt, 1963) was adopted in three-dimensional depth inversion of gravity data using stacked grid of a rectangular prism with a horizontal cross section of about 2 km on a side. Initial bottom depth of each prism was set as mean depth of 1.67 km obtained previously by the power spectrum analysis. Densities of volcanic rocks were measured from many rock samples. The density of basement rock, which is inferred as granite and tuff, could not be directly measured. Thus it was assumed that the basement rock of the island was identical with that of continental shelf of the South Sea, where several deep oil wells had been drilled, and the density contrast of upper volcanic rocks to lower basement rocks were set to be $-0.3\,g/cm^3$.

Fig. 5 shows the result of gravity inversion. The base of volcanic rocks bends down in central volcanic edifice with the maximum depth of 5 km under the summit of Mt. Halla. Although there are not any geological information on density of the material forming central volcanic edifice, there is possibility that it is lower than that of other areas if fracture zones are developed inside the strucure of the edifice. But the model studies denies the assumption that fractures alone can make such a low anomaly. The $N-S$ trending anomalous zone in eastern part of the island is revealed in the inversion

Fig. 6. Distribution of magnetic measurement points in the

result with thicker volcanic layers.

Although the number of gravity stations is not sufficient to uncover all the detailed subsurface structure of the Cheju island, but the result of gravity inversion provides a relatively reasonable feature of the distribution of volacanic rocks in the island.

AERO AND SURFACE MAGNETIC STUDY

The aeromagnetic survey over the Cheju island was undertaken by Koo *et al.* (1986) using the Geometrics G-813 proton magnetometer. The flight height was kept to be 400 ft high above the ground level. The surface magnetic survey was carried out by geophysics research group of Department of Earth Science, Seoul National University with MP-2 proton precession magnetometers.

Data Acquisition and Reduction

The aeromagnetic data were reduced to residual magnetic anomalies by removing IGRF. The digital data of aeromagnetic map was resampled to grid point data with a grid size of 500 m by 500 m for the purpose of data processing. The total number of grid data are 7,815. The distribution of surface magnetic measurement points is shown in Fig. 6. The surface magnetic survey were generally carried out along the roads and total number of measurements was 747 points. During the magnetic survey period, the time variation of the magnetic field were recorded every 30 seconds for correction of diurnal variation, but it was not so serious during the field survey in comparison with the variation due to the lithology and geologic strucure. The surface magnetic data were also resampled to grid point data.

Fig. 7(a) and (b) show aero and surface magnetic anomaly maps of the Cheju island. In both maps, positive anomalies appear on the southern part and negative anomalies on the northern part of the island. This kind of anomaly pattern is the typical one when a ma-

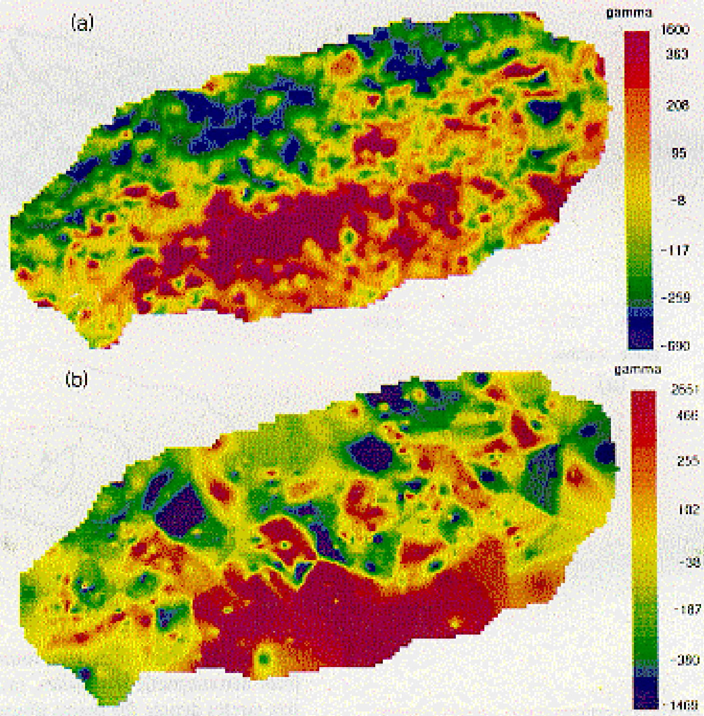

Fig. 7. Aeromagnetic anomaly map (a) (reproduced from aeromagnetic survey data by Koo *et al.* (1986) and surface magnetic anomaly map (b) of Cheju island, showing residual total field strength.

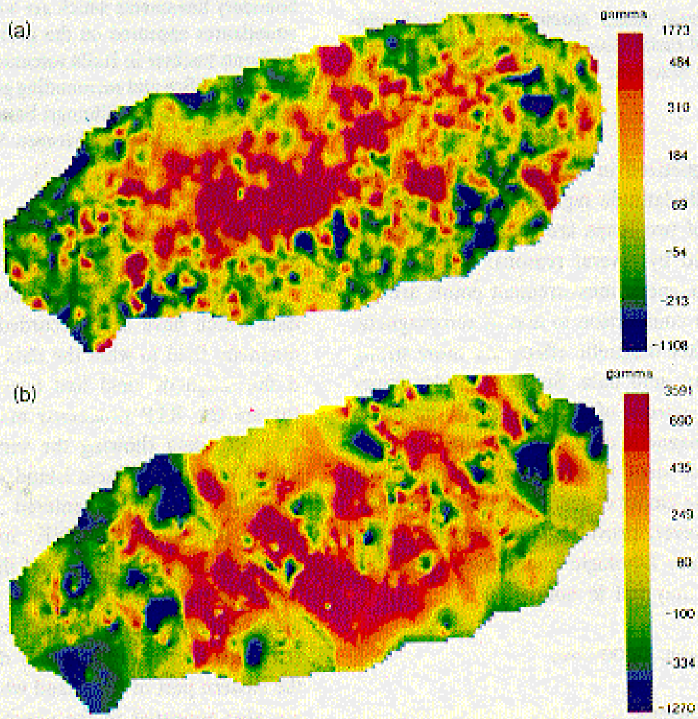

Fig. 8. RTP (Reduction to the pole) processed map of aeromagnetic data (a) and surface magnetic data (b).

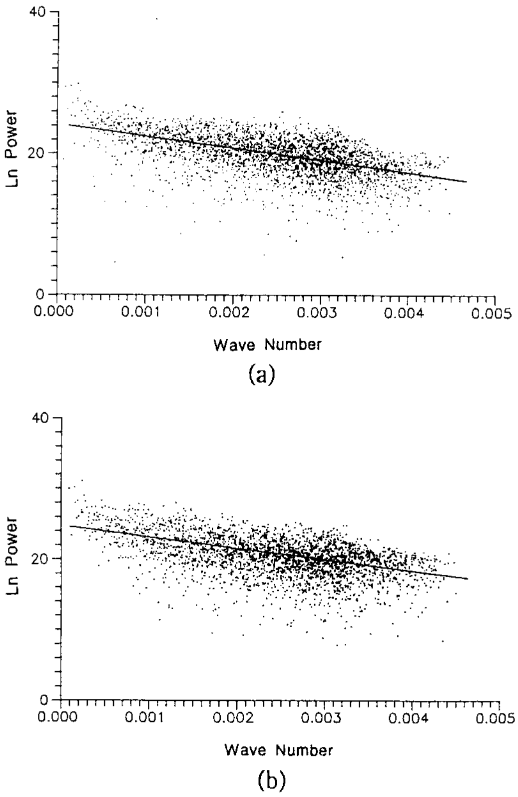

Fig. 9. Two-dimensional power spectrum analysis of aeromagnetic data (a) and surface magnetic data (b). The inferred mean depths of the basement are 1.9 km and 1.7 km, respectively.

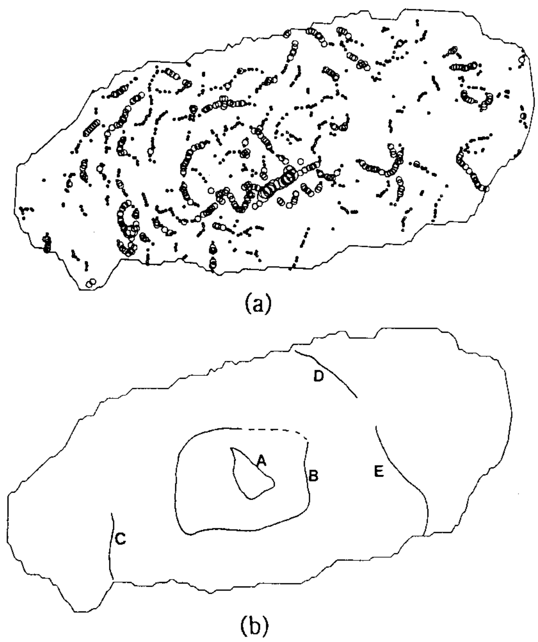

Fig. 10. Apparent magnetic source boundaries delineated from aeromagnetic anomalies. (a) Large, middle and small size circles denote the points where the maximum horizontal gradient of pseudogravity anomaly is over 1.3 mgal/unit distance, between 0.67 and 1.3 mgal/unit distance and between 0.45 and 0.67 mgal/unit distance, respectively. (b) Some boundary lineaments which are well matched with lithologic boundaures appeared on the geologic map. A: boundary of Hallasan trachyte in Halla volcanic edifice; B: between Halla volcanic edifice and surrounding geological units; C: between Pyosunri basalt and Sihungri basalt; D: between Jeju basalt and Sihungri basalt; E: between Seongpanak basalt and Sihungri basalt.

gnetic body is magnetized in the direction of geomagnetic field in middle latitude region. But the details of anomaly patterns of two maps are somewhat different. This may be caused by several reasons: spatial distribution of surface magnetic measurement points are not quite satisfactory in comparison to that of aeromagnetic data, and near surface magnetic effects are more strong in surface data than aero data. Some of cinder cones appear to be the sources of isolated small magnetic anomalies in aeromagnetic data, but they are not quite clear on the surface data because few measurements were made across the cinder cones. The surface magnetic anomaly map, however, provides more detailed informations about surface lithologic boundaries which the aeromagnetic map may fail to notice.

Analysis of Magnetic Anomalies

To analyse the magnetic anomalies quantitatively, several methods, such as reduction to the pole, two-dimensional power spectrum analysis and delineation of apparent magnetic boundaries, were proceeded.

The process of reduction to the pole converts magnetic data which have been recorded in the inclined earth's magnetic field to what the data would have looked like if the magnetic field had been vertical. Fig. 8(a) and (b) are the RTP processed maps of aero and surface magnetic data showing the very typical pattern of the shield volcano of Cheju island with the prominent large magnetic anomalies centered on the Halla volcanic edifice and along the ENE trending long axis where the main magnetic sources of the rift zones are located. Some of the small anomalies sporadically distributed along the major axis are due to parasitic cinder cones. It is also noticeable that N-S directional anomalies in the eastern part of the island where low gravity anomaly are also appeared in the gravity map (see Fig. 3).

To determine the mean depth of the interface between

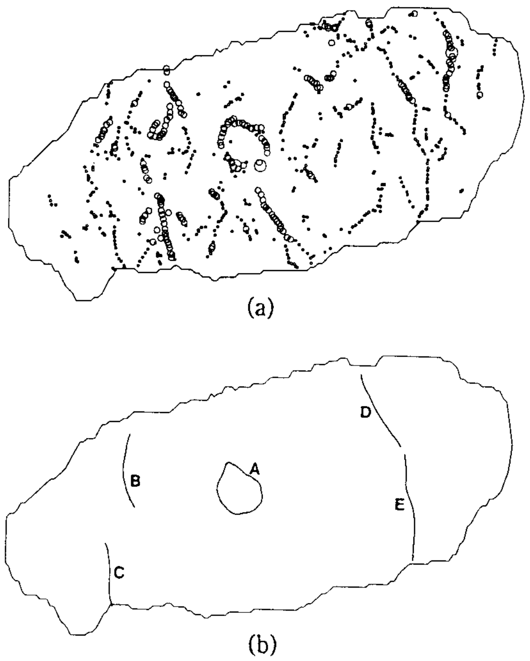

Fig. 11. Apparent magnetic source boundaries delineated from surface magnetic anomalies. (a) Large, middle and small size circles denote the points where the maximum horizontai gradient of pseudogravity anomaly is over 2./25 'mgal'/unit dustance, between 1.12 and 2.25 mgal/unit distance and between 0.67 and 1.12 mgal/unit distance, respectively. (b) Some boundary lineaments which are well matched with lithologic boundaures appeared on the geologic map. A : boundary of Hallasan trachyte in Halla volcanic edifice; B : between Jeju basalt and Pyosunri basalt; C : between Pyosunri basalt and Sihungri basalt; D : between Jeju basalt and Sihungri basalt; E : between Seongpanak basalt and Sihungri basalt.

upper volcanic rocks and basement, two-dimensional power specrtum analysis of magnetic data were performed (Fig. 9). Mean depths to the basement calculated from the aero and surface magnetic data are 1.9 km and 1.7 km, respectively, which are very similar to the mean depth (1.6 km) calculated from gravity data.

Cordell and Grauch (1982, 1985) developed a method which identifies boundaries of magnetic sources by evaluating the difference of the horizontal intensity of magnetization. The apparent magnetic boundaries are obtained by three-step procedures. First, the grid magnetic data are converted into a grid data of pseudo-gravity anomalies by using the Poisson's relation. Second, a new grid data of maximum horizontal gradients are calculated from the pseudo-gravity anomalies. Third, the horizontal coordinate of important maxima are selected. Although the pseudo-gravity anomalies computed in this procedure show some deviation of values in comparison with the observed gravity anomalies, the pseudo-gravity anomaly map gives more detailed configuration of anomaly pattern because the total number of measured points of magnetic survey is much more than that of gravity survey. Therefore, this method provides very useful information on litholgic boundaries of volcanic rocks which are more clearly defined on the magnetic map than the gravity map.

Figs. 10 and 11 show apparent magnetic boundaries. The patterns of the boundaries look somewhat different: the magnetic boundaries delineated from surface data are less complex than those from aero data. This was partly caused from the difference of data distribution and their characteristics. These maps, however, give valuable information about both shallow and deep magnetic sources in the island.

Some of boundaries identified from the surface magnetic map are better matched with geologic boundaries than those of aeromagnetic map. This may be resulted from the fact that surface magnetic data were more influenced by shallow depth rocks than aeromagnetic data. The circular-shaped large magnetic body, which corresponds to the Halla volcanic edifice, are found at the center of the island in both maps. Some of magnetic boundaries can not be matched with the lithologic boundaries appeared on the geologic map of the island. These boundaries are inferred to be related to the magnetic bodies which are coverd by overlying less magnetized materials on the surface.

Modeling of Magnetic Structure

As mentioned previously, the basement rock of the Cheju island is inferred to be granite and tuff and it is considered that the depth inversion offers the tuff undulation of the discontinuity between upper volcanic rocks and basement. Although mean depths of discontinuity are computed as 1.7~1.9 km by power spectrum analysis assuming that the susceptibilities of both basement and volcanic rocks are constant, the results of apparent magnetic boundary analysis and measurements of susceptibilities of rocks reveal that the intensity of magnetization of volcanic rocks has large variations. The RTP processed magnetic maps also show that significant anomalous bodies are distributed along the major axis and at the Halla volcanic edifice. Thus inversion process which takes a single variable of depth may provide unsatisfactory results in describing the precise shape of the interface. To overcome this problem, the susceptibility as well as depth of each prism should be taken as variables in the inversion process.

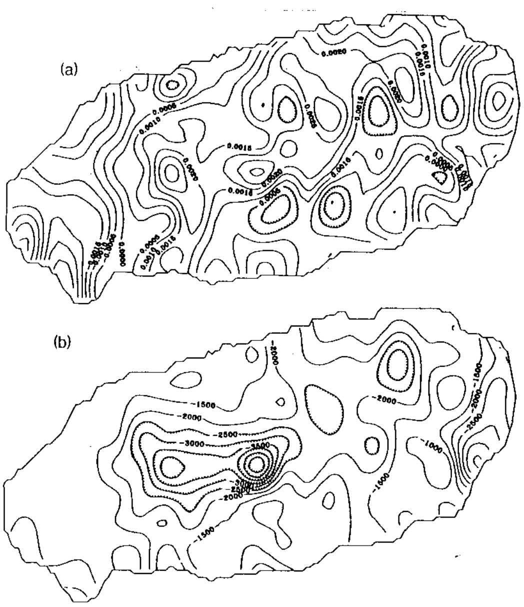

Fig. 12. Distribution of apparent susceptibility of volcanic rocks of Cheju island (a) and depth distribution of basement beneath the volcanic rocks (b) calculated by inversion of aeromagnetic data. Contour intervals are 0.0005×10^6 cgs unit for susceptibility and 500 m for depth.

For the magnetic inversion, the basement assumed to be homogeneous having constant magnetic susceptibility. Then, the volcanic rocks of the island are divided into retangular prisms with a horizontal cross section of 2 km on a side and bounded on top by the average surface topography of the prism and below by the basement. The initial depth of each prism is taken to be 1.8 km which is the mean depth obtained from power spectrum analysis. The height of magnetic stations are taken to be real measurement height so that both topographic effect and height of measurement point effect could be reflected in the process of inversion. The initial value of susceptibility of each prism was assumed to be the average value of susceptibilities of rock samples measured in the laboratory (Kwon *et al.*, 1993). The inversion was attempted with the aeromagnetic data only, because it seemed that the aeromagnetic data better represent the overall characteristics of geology of the island.

Fig. 12(a) and (b) show distribution of susceptibility of the magnetic bodies and depths to the basement obtained by inversion of aeromagnetic data. High susceptibility zones are appeared along the long axis of the island. The depth distribution of magnetic discontinuity also show similar patterns. The maximum depth appeared at Mt. Halla where the volcanic rocks extend

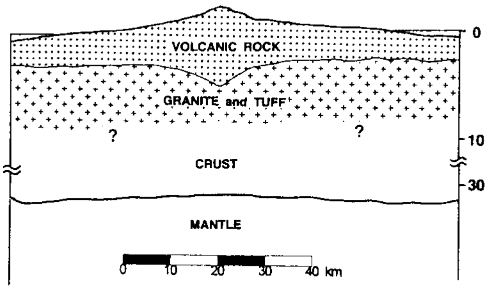

Fig. 13. Simplified schematic of interpreted geologic section along the long axis of the Cheju island composited based on graity and magnetic data.

down to 5 km. The depth to the basement along the major axis ranges 1.5~3 km and is deeper than those of other zones in lava plateau 1~1.5 km. As revealed in reduced-to-pole magnetic anomaly maps, $N-S$ directional anomalous bodies are shown in the eastern part of the island.

Susceptibility range of the Halla volcanic edifice is $1{,}000 \times 10^{-6}$ cgs ~ $3{,}000 \times 10^{-6}$ cgs and that of summits of Mt. Halla is $2{,}000 \times 10^{-6}$ cgs ~ $3{,}000 \times 10^{-6}$ cgs. High susceptibility rock of Mt. Halla is inferred to be Hallasan trachyte. Susceptibility range of volcanic rocks distributed along major axis is $1{,}000 \times 10^{-6}$ cgs ~ $2{,}000 \times 10^{-6}$ cgs, and that of lava plateau is less than 500×10^{-6} cgs.

Total volume of volcanic rocks can be estimated from the inversion result of aeromagnetic data. Total volume of the magnetic model appears to be $4.0 \times 10^{12}\,m^3$ by summing the volumes of rectangular prisms used in the inversion of magnetic data, and total mass of volcanic rocks in Cheju island is estimated to be 9.9×10^{12} ton assuming the density of 2.5 g/cm^3. But, the gross mass of volcanic body of the Cheju island should be greater, because the mass out of shoreline of the island, were not considered in modeling process.

RESULTS AND DISCUSSION

Bouguer anomalies are generally circular low on the central volcanic edifice and the maximum difference of Bouguer anomaly with respect to relative gravity datum is about 30 mgal. Bouguer anomaly pattern in the central volcano is very similar to that of the reduced-to-pole magnetic maps. But any characteristic features related to the rift zones are not well noticed on the Bouguer gravity map contrary to the magnetic anomaly maps.

Anomaly patterns of aero and surface magnetic anomalies resemble the very typical ones appeared when anomalous bodies are magnetized in the direction of geomagnetic field in middle latitude. But the details of anomaly patterns of two maps are somewhat different. Some small independent magnetic anomalies could be related with volcanic cones. RTP processed maps reveal that main magnetic sources in the island are rift zones and the Halla volcanic edifice. Some of apparent magnetic boundaries are well matched with known geologic boundaries. Boundaries of Pyosunri basalt and Sihungri basalt are very apparent, and this reflects the fact that Pyosunri basalt and Sihungri basalt are the ones of latest erupted mass.

Mean depths to the discontinuity calculated from power spectrum analysis of the gravity, aero and surface magnetic data are 1.67 km, 1.9 km and 1.7 km, respectively. This discontinuity seems to be the interface between basement and upper volcanic rocks.

The Marquardt-Levenberg inversion method was adopted in three-dimensional inversion of gravity and aeromagnetic anomaly maps. The result of depth-inversion of gravity data show that the interface between upper volcanic rocks and lower basement bends down in central volcanic edifice with the maximum depth of 5 km. Inversion of aeromagnetic data was conducted with two variables of depth and susceptibility. Inversion results show the maximum depth of the basement is appeared at Mt. Halla reaching 5 km. The basement depths under the major axis vary 1.5~3 km and 1~1.5 km under the lava plateau.

On both the gravity and magnetic maps, prominent $N-S$ trending anomalies appear in the eastern part, of which direction is nearly perpendicular to the long axis of the island. It is speculated that this boundary may be associated with an unidentified concealed fault.

The magnetic data indicate that the regional structure of the volcanic layers in the Cheju island is two-dimensional with the strike to the direction of the long axis. This result supports the idea that the long axis of the Cheju island forms rift zones. Fig. 13, as a summary of the integrated gravity and magnetic studies, is a simplified schematic section of the present geologic structure below the major axis of the Cheju island. The depth of Moho discontinuity is adopted to be 31 km as proposed by Choi *et al.* (1993) in their study on the crustal structure from gravity data in and around the Korean peninsula.

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중력 및 자력 탐사에 의한 제주도 지질구조 연구

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요 약 : 중력 및 자력 탐사자료를 분석하여 제주도의 지질구조를 연구하였다. 부우게 중력이상도에서 섬 중앙의 한라산체에서 뚜렷한 원형의 저이상이 나타나며, 이상값의 차이는 최대 30 mgal 로 나타났다. 지하지질구조 모델링을 위하여 기반암 상부에 위치하는 화산암체를 각주로 나누어 중력자료의 삼차원 심도역산을 실시한 결과, 화산암의 기저면은 한라산 아래로 휘어지며 최대 깊이는 5 km 정도에 이른다. 자력자료로는 항공탐사자료와 육상탐사자료를 함께 이용하였다. 이들로부터 구한 자력이상도는 다소의 차이는 보이나 전체적으로는 중위도 지방에서 지구자기장의 방향으로 자화된 자력이상체로 부터 야기되는 전형적인 이상의 형태를 보인다. 자극화변환을 한 이상도를 보면 섬의 주된 자력원은 장축을 따라 발달하는 열곡대와 한라산체로 나타난다. Cordell과 Grauch (1985)의 방법으로 구한 자력원의 경계는 표선리 현무암과 시흥리 현무암과 같은 비교적 최근에 분출된 화산암의 경계와 잘 일치한다. 자력모델링은 심도와 대자율을 두 변수로 취하여 항공탐사자료의 삼차원 역산을 수행하였다. 역산 결과, 높은 대자율을 가지는 화산암은 열곡대와 중앙화산체에서 나타나며 기반의 심도는 장축을 따라서는 1.5~3 km, 용암대지에서는 1~1.5 km 정도로 나타나며, 한라산 하부에서 최대 5 km 로 나타난다. 중력과 자력이상도 모두에서 나타나는 동부 지역의 남북 방향의 이상은 지질도 상에서는 확인되지 않는 단층 또는 파쇄대에 의한 것일 가능성이 있다.