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Interpretation of Aeromagnetic Anomalies in the Southwestern Part of the Ogcheon Belt, Korea

옥천대 남서지역의 항공자력자료해석

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Abstract : In order to uncover the subsurface geological structure in the southwestern rim of the Ogcheon Fold Belt including the Cretaceous Neungju Sedimentary Basin, we analysed and interpreted the aeromagnetic anomalies over the region. The study area belongs to Muan-gun, Yeongam-gun, Gangjin-gun, Jangheung-gun, and eastern Haenam-gun. From the qualitative analysis and quantitative modeling of the reduced-to-the-pole magnetic anomalies, following things are revealed or suggested; Even though the porphyry of higher susceptibility is not crop out in the Donggang Myeon in the northwestern part of the study area, it is supposed to have intruded the Precambrian gneiss and the Cretaceous Bulgugsa granite of lower susceptibility. Two-dimemsional modeling of profile data across the sedimentary basin of Neungju Group reveals that the northern part of the basin is deeper than the southern part, and that the maximum depth of the basin is supposed to be 3 km below the surface. The western flank of the basin bottom is steeper than the eastern flank. The high susceptibility value of the Neungju Group sedimentary rocks indicates that the rocks comprises large amount of volcanic materials. This fact implies that it is hard to expect hydrocarbon reservoir in the sedimentary rocks of the Neungju Basin.

Key Words: Aeromagnetic Anomaly, Ogcheon Belt, Neungju Basin

요 약

백악기 능주분지를 포함한 옥천대 서부 일부지역의 지하 지질구조를 파악하기 위하여 이 지역의 항공자력 자료를 분석 및 해석하였다. 연구지역은 전라남도 무안군, 영암군, 강진군, 장흥군 및 동부 해남군 등이 포함된다. 극자료화 자력이상을 정성적 분석 및 정량적 모델링에 의해 다음과 같은 사실을 알게 되었다.; 연구지역의 북서부의 나주군 동강면에서는 대자율이 작은 선캠브리아기의 편마암과 백악기의 불국사 화강암이 분포되어 있다. 그러나 자력이상을 설명하기 위해서는 이들 암석이 지하 깊숙히에서 대자율이 큰 반암에 의해 관입되어 있는 상태를 가정해야만 한다. 능주퇴적분지를 동서로 가르는 단면 자력자료를 모델링한 결과에 의하면 분지의 북부는 남부보다 그 깊이가 더 깊고 최고 깊이가 3 km 정도 된다. 분지의 기저부는 서부쪽이 동부쪽보다 경사가 더 급하다. 능주분지의 퇴적암의 대자율이 크게 나타나는 점으로 미루어보아 상당한 양의 화산암류가 포함되어 있을 것으로 유추된다. 이러한 사실은 능주분지에 석유 또는 천연가스의 부존 가능성을 배제한다.

주요어 : 항공자력, 옥천대, 능주분지

INTRODUCTION

Many researchers have been studying on the evolution of the Ogcheon Fold Belt and related tectonic movement. However, nobody still clarify the exact time and process of the evolution. Clazel *et al.* (1990) set up a kind of geological hypothesis by introduction of the continental rifting process in the Camb-ordobician periods and the Ogcheon Orogenic process in the Silurian-Devonian periods. His proposed solution still does not coincide with results of paleomagnetic, paleontologic and radio-chronological studies. The deformed strata of the Ogcheon Fold Belt by the Ogcheon Orogeny suffered again by the plutonic intrusion and volcanic extrusion by a few orogenies in the Mesozoic Era. Thus most of the deformed Ogcheon sedimentary rocks in the southwestern part of the Ogcheon Belt were disappeared by the igneous processes. Furthermore the erosion process for long geologic time let the distribution of the Ogcheon sedimentary rocks be limited to very small areas scattered here and there. Now most of the area in the southwestern part of the Ogcheon Belt are covered by Precambrian gneiss and Cretaceous sedimentary, volcanic and intrusive rocks. Therefore the research interest in this study is concerned with these Precambrian and Cretaceous rocks

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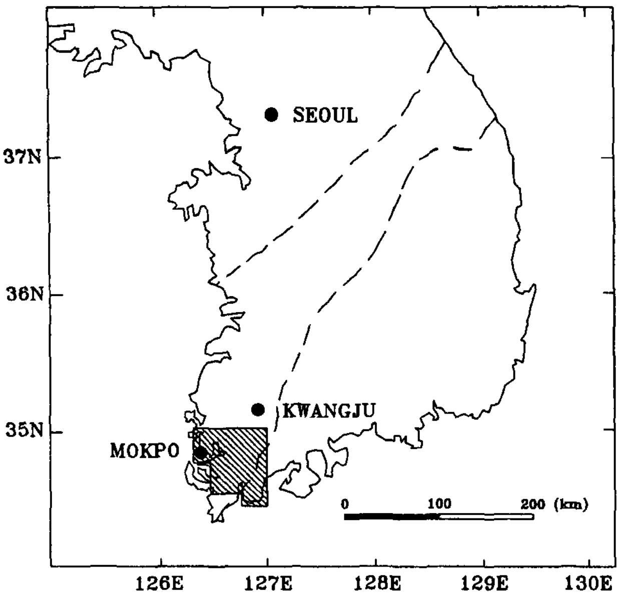

Fig. 1. Location map of the study area. The area is shaded by striped pattern. Dashed line indicates the boundary of Ogcheon Belt.

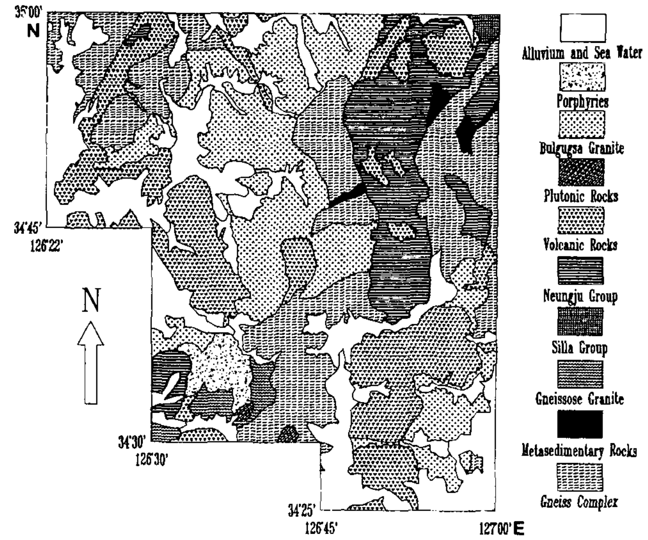

Fig. 2. Geologic map of the study area. Modified from Chang K. H & kim KT (1967), Cheong, C. H. & Kim G. S. (1966), Choi, S. O. & Ko, C. B. (1971), and Choi, Y. K. & Yoon, H. D. (1968). Gneiss complex corresponds to Precambrian, gneissose granite to jurassic, and all other rocks except metasedimentary rock and Alluvium to Cretaceous periods. Age of the metasedimentary rock is unknown.

rather than with the Ogcheon sedimentary rocks. In order to uncover the subsurface geological structure and get information on the geological relations between distributed rocks in the southwestern rim of the Ogcheon Fold Belt including the Neungju Sedimentary Basin (Fig. 1), we analyzed and interpreted the aeromagnetic anomalies over the region. The study area belongs to Muan-gun, Yeongam-gun, Gangjin-gun, Jangheung-gun, and eastern Haenam-gun. Even though there are a few literatures on the geological study in this area including geological maps and their explanatory texts (Cheong and Kim, 1966; Chang and Kim, 1967; Choi and Yoon, 1968; Choi and Ko, 1971), qualitative or quantitative interpretation of aeromagnetic anomaly maps in the study area rarely have done before. The anomalies produced by the subsurface magnetic bodies can reveal information on geological structures in this area. We try to find the source of magnetic anomaly and susceptibility contrast between rock types. We also extract characteristic features of magnetic anomaly shapes and amplitude distributions. Based on these information, the subsurface structures are deduced by qualitative and quantitative analyses.

GEOLOGY OF THE STUDY AREA

Geology of the study area consists mainly of Precambrian metamorphic rocks, Cretaceous sedimentary, volcanic and intrusive rocks (Fig. 2). Small amount of Permian metasedimentary rocks and Jurassic gneissose granite are distributed locally. In order to have clarity in simplified geologic process and to help magnetic interpretations in this study, the rocks are grouped into three categories : Pre-Cretaceous rocks, Cretaceous sedimentary and volcanic rocks, and Cretaceous intrusive rocks.

Pre-Cretaceous rocks are composed of the Precambrian Sobaegsan gneiss complex, the Permian metasedimentary rocks, and the Jurassic gneissose granite. Rocks of Sobaegsan gneiss complex are distributed in the northwestern region, central-to-the-eastern region, centrally southern region. The source rock of the gneiss is conjectured to be sedimentary origin since they include mica schists, quartzite, limestone, etc. (Cheong and Kim, 1966; Chang and Kim, 1967; Choi and Yoon, 1968; Choi and Ko, 1971). The Sobaegsan gneiss complex in the eastern region grades into metasedimentary rocks which overlies the gneiss complex unconformably (Cheong and Kim, 1966). Gneissose granite of Jurassic age distributes in the southwestern region in a small scale.

Cretaceous sedimentary and volcanic rocks are chronologically correlated with the upper part of the Gyeongsang Supergroup (Son, 1969). Sedimentary rocks of Neungju Group are composed of tuffs, tuff breccias, rocks of lava flow, and conglomerates (Cheong and Kim, 1966). These rocks are mainly distributed in the northeastern region of the area, where they form a sedimentary basin on the basement of the gneiss complex. The intrusive rocks of the Cretaceous are related to the Bulgugsa Disturbance of ages ranging from the Late Cretaceous to Early Tertiary. The Bulgugsa Granite is widely distributed in the central and southeastern parts of the study area. Porphyries locally crop out on a small scale in the southeastern part of the area.

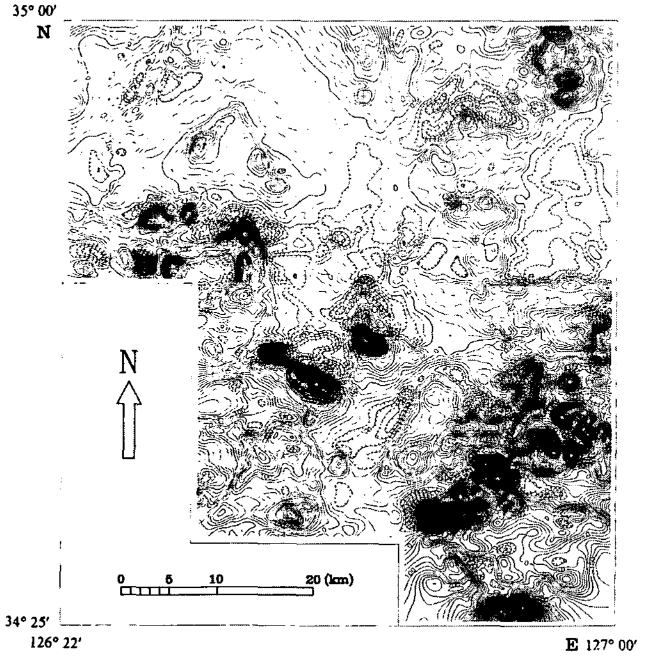

Fig. 3. Aeromagnetic anomaly map of the study area. Terrain clearance and contour interval are 400 feet and 20 gammas, respectively.

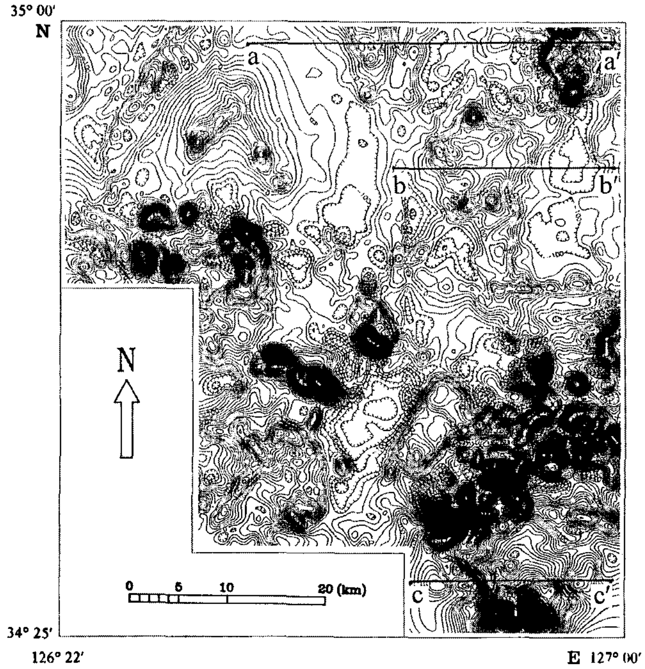

Fig. 4. Reduced-to-pole magnetic anomaly map of the study area. Contour interval is 20 gammas.

MAGNETIC DATA ACQUISITION

Aeromagnetic surveys in the study area were carried out in years 1988-1989 by Korea Institute of Energy and Resources(KIER); Yeongam and Haenam regions in 1988, Cheongpung and Jangheung regions in 1989. The survey instrument was Model G813 of Geometrics with the sensitivity of 0.01 gamma. Data were collected at altitude 400ft (122 m) above the terrain. The distance between the east-west flight lines of survey was 1km. Tie lines were flown in north-south direction at 5 km of line space.

The raw digital magnetic data were corrected for the diurnal variation and the regional field was removed from the data using the IGRF-85 by KIER to produce the residual magnetic anomaly map. For the present study, the magnetic contours of the anomaly map were digitized and processed to get a data set for grid points with the grid interval of 250 m using Laplace interpolation technique. The processed contour plot of the residual magnetic anomaly map is shown in Fig. 3.

DATA PROCESSING

As shown in Fig. 3, almost every positive magnetic anomalies accompanied by negative anomalies to the north or north-east of the positive anomalies. The pair of the positive and negative anomalies comes from the vector dipole field of the magnetic body of finite extent caused by the inclination of the ambient geomagnetic field. These phenomena makes the magnetic anomaly map look complicated.

Furthermore, positions of the positive and negative anomalies do not coincide with the location of the magnetic body. In order to get rid of this problem, the residual magnetic anomaly data should reduced to the pole position using equations (3) and (4) given in Baag and Kang (1994). The computed anomaly map of the reduction to the pole position (RTP) using the anomaly map of (Fig. 4) is given in (Fig. 5). The inclination and declination of 50 and 353, respectively are used in the RTP process. These two angular values were calculated from IGRF for the date of December 1, 1988 which is approximately at the middle point of the total survey period. Most of the negative anomaly troughs on the north-side of the positive anomalies are disappeared after the RTP process. On the other hand, the positions of the positive anomaly peaks are shifted northward compared with those before the RTP process (Fig. 3, 4). Thus, locations of anomalies are supposed to be put directly above the positions of magnetic source bodies.

QUALITATIVE INTERPRETATION

In comparison of the geological map (Fig. 2) and RTP anomaly map (Fig. 5), some basic information on magnetic properties of distributed rock types is deduced. There are four types of anomaly patterns according to the susceptibilities of rocks and characteristic shapes of anomalies. Firstly, the volcanic rocks distributed in the northwest-southeast trend produce very high magnetic anomalies

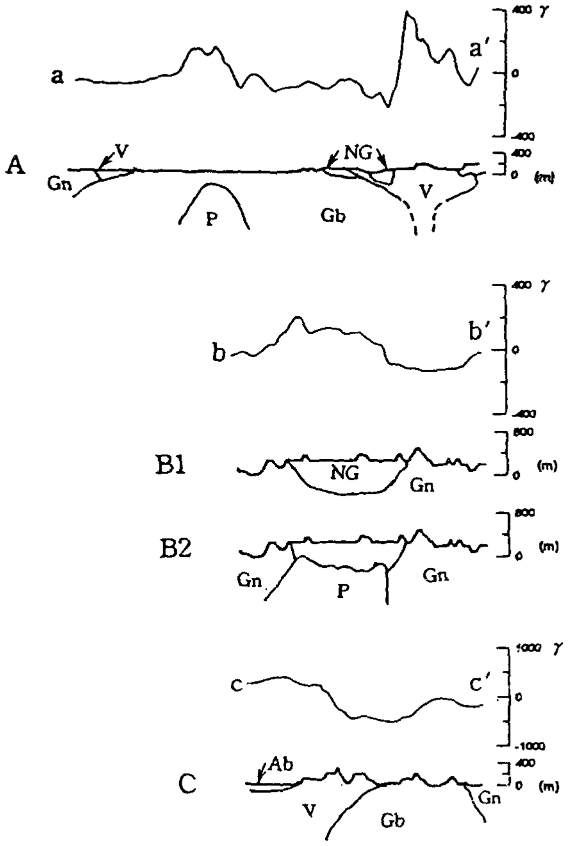

Fig. 5. Qualitative interpretation of reduced-to-the-pole magnetic anomaly profiles. The three profile lines a-a', b-b', c-c' correspond to those in Fig. 4. Symbols Gb and Gn indicates Bulgugsa Granite and gneiss, respectively. NG and SG indicates Neungju Group and Sila Group, respectively. V, P, Ms, and Ab indicate volcanic rock, porphyry, metasedimentary rock, and alluvium, respectively.

which show high spatial frequencies. This fact indicates volcanic rocks have higher susceptibilities compared to other rocks in the study area. The high spatial frequency property of anomalies may reflects the irregular surface distribution of volcanic rocks at shallow depths. Secondly Porphyries at the southwestern part of the area also produces high anomaly like volcanic rocks. However, the anomaly by porphyries does not show as high spatial frequency contents as those of volcanic rocks. Thirdly, sedimentary rocks of the Neungju Group in the northeastern part of the area generate moderate amplitude of magnetic anomaly which is smaller than those of porphyries or volcanic rocks. We guess sediments of the Neungju Group comprise contemporary volcanic materials if the magnetic anomaly comes from the sedimentary rock. Fourthly, the Bulgugsa granite and Gneiss Complex which are distributed at central part of the area in north-south trend and at southeastern part show negative RTP anomalies. This implies these rocks have relatively low susceptibility values. Thus, from the all information of anomaly patterns and amplitudes, we guess the spectrum of relative susceptibility values of rocks distributed in the study area : volcanic rocks, porphyries, Neungju Group, plutonic rocks (Bulgugsa granite and Gneiss Complex) in the order of higher susceptibility values.

The anomaly map of Fig. 4 was obtained by the RTP process of the aeromagnetic data measured at 400 feet above the topography by way of draping survey. Since the measurement surface is not a plane of a constant altitude, the RTP process is not accurate enough to model anomaly profiles quantitatively for subsurface structures using the anomaly map of Fig. 4. However, qualitative analyses can be done along profiles of interesting regions. We choose three anomaly profiles (Fig. 4) laid in east-west direction. The northern profile a-a' of the three passes the regions of Bulgugsa Granite, Neungju Group sedimentary rock and volcanic rock. There are two high anomaly amplitude in the profile (Fig. 5). The western anomaly of them is located in the region of the Bulgugsa Granite with verv low susceptibility. The shape of the anomaly is relatively smooth compared to the anomaly at the eastern part of the profile. Thus we interprete this phenomena by assuming a mass of porphyries with higher susceptibility under the Granite which was intruded by the porphyries. The eastern anomaly of the profile is very large, and has sharp and rugged form due to high susceptibility of intruded volcanic rock. The profile b-b' (Fig. 4) passes across the region of sedimentary rock of Neungju Group. The shape of the positive anomaly of the profile (Fig. 5) is broad and smooth. The cause of the anomaly is interpreted in two ways based on assumptions in the origin of the higher susceptibility. The first case is that the sedimentary rock of Neungju Group with volcanic materials of high susceptibility generates the magnetic anomaly (Fig. 5). The second case is that the sedimentary rock has smaller susceptibility and there is a porphyritic or intruded volcanic body of higher susceptibility beneath the Neungju Group of sedimentary rock. The profile c-c' (Fig. 4) passes through regions of volcanic rock and Bulgugsa Granite (Fig. 2). We expect high anomaly value in the volcanic rock region and low value in the Granite region. However, the location of the volcanic rock in the geologic map is shifted to the east from the location we expect. This might imply the thickness of the volcanic rock should be thin to the earthern margin.

QUANTITATIVE ANALYSIS

The magnetic intensity data was collected at the altitude 400ft above the mean terrain by draping surveying. The measurement surface is not a plane of constant altitude. Therefore, the data set on the curved measurement surface should be upward continued to a plane of a constant altitude in order to use these equations. This process is necessary because quantitative modeling inversion of the data on a curved surface are not easy and could result in spurious results. The procedure for this type of continuation is given in Baag and Kang (1994) following the computational method of Bhattacharyya and Chan (1977). The topographic map of the scale 1:50,000 was digitized and altitude of the topography were added by 400feet to obtain the heights of measurement surface. This data is upward continued to a constant altitude of 1250m above the sea level. The RTP process was applied to the upward-continued anomaly map following the method given in the previous section. The result is given in Fig. 6. The inclination and declination of 50 and 353, respectively are used in the RTP process as were used for the data before the process of upward continuity. Talwani and Heirtzler (1964) presented a method to compute magnetic anomaly caused by a polygon cylinder of finite length. A compact form of the equation for the computation of the anomaly is given by Baag and Kang (1994) using matrix form of parameters. The method is applied to three representative profiles of upward continued RTP data (Fig. 6) to get possible subsurface structure.

The profile line 1 (Fig. 6) lies at the northwestern quadrant of the study area with northwest-southeastern directional trend. The main objective of the line profile 1 is to examine the cause of the large anomaly with a peak value 200 in the southeastern half of the profile. The surface geology of this anomalous region around Donggang Myeon area consists of Precambrian Sobaegsan banded gneiss and Cretaceous Bulgugsa Granite. These rocks are supposed to have overall low magnetic susceptibilities throughout the whole region of the study area, as shown in the previous section. Therefore, the high anomaly of the profile originated due to other source rock at depth rather than the granite or gneiss at surface. The possible candidates of the buried source of the high anomaly are the intrusive volcanic rock and the Cretaceous porphyry. However, the volcanic rock cannot be the candidate, because the intrusion of the granite chronologically follows the extrusion and intrusion of the volcanic rocks. The porphyry rock mass formed later than the intrusion of the granite. An example of the anomaly shape caused by porphyry rock mass can be found in the southwestern part of the study area (Fig. 6). The pattern of the anomaly is similar to that of the profile line 1. Therefore, we suppose that the porphyry lies at depth beneath the granite body in the state of intrusion. The result of two-and-a-half dimensional modeling for the anomaly profile of the upward-continued RTP data (Fig. 6) is shown in Fig. 7. Notations used for each rock type are explained in Table 1. The modeled substructure profile shows the porphyry rock intruded the Sobaegsan Banded Gneiss (Sobgn) and Bulgugsa Granite at about 1km depth. The porphyry has high

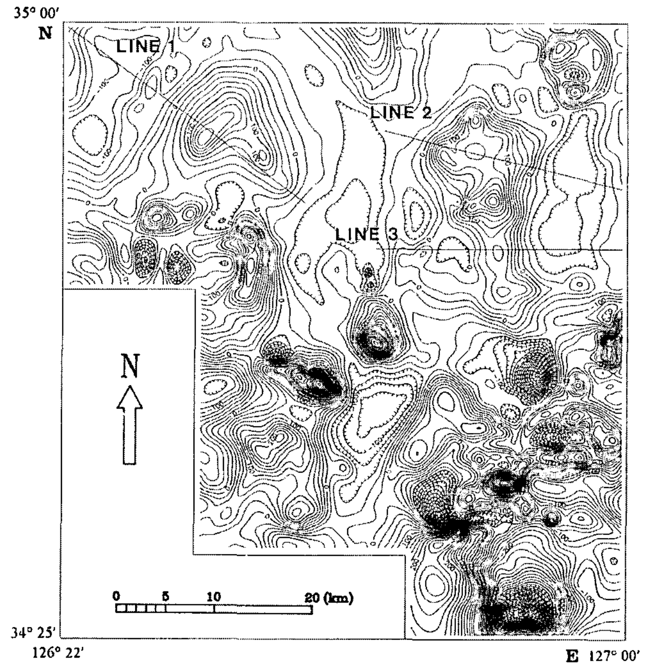

Fig. 6. Reduced-to-the-pole magnetic anomaly map of the upward continued data. The data is corresponds to that of the constant altitude of 1250 m above the sea level.

susceptibility contrast with that of the surrounding rocks.

The profile lines 2 and 3 (Fig. 6) pass across the sedimentary basin of Neungju Group in the northeastern quadrant of the study area. In Fig. 6 rough outline of Neungju basin stands out in the background relief of anomalies, since the sedimentary rocks of the Neungju Group (Kne) are supposed to include volcanic components and have higher susceptibilities compared with the surrounding metamorphic rocks. The result of modeling of the profile line 2 is shown in Fig. 7. This suggests that the bottom of the Neungju Basin is as deep as 3km below the surface. In the eastern flank of the basin, Permian metasedimentary rocks (Ps) are embedded between Neungju Group and Pre-cambrian gneiss. It is suggested that Pre-cambrian granitic gneiss (Pcggn) to the east of the profile time has a very low susceptibility value. In Fig. 6, the size of the anomaly over Neungju Group becomes gradually smaller to south compared to the north part. Configuration of the substructure beneath the anomaly profile line 3 (Fig. 7) obtained by modeling suggests that the width and depth of Neungju sedimentary Basin are narrower and shallower than the northern part of the basin. The susceptibility of Neungju Group along the profile line 3 is smaller than that along the profile line 2. This fact supports the geological interpretation by Choi and Yoon (1968) which insists that the volcanic activity in the southern part of the basin was not as frequent as that in the northern part and most of the sediments are non-volcanic origin.

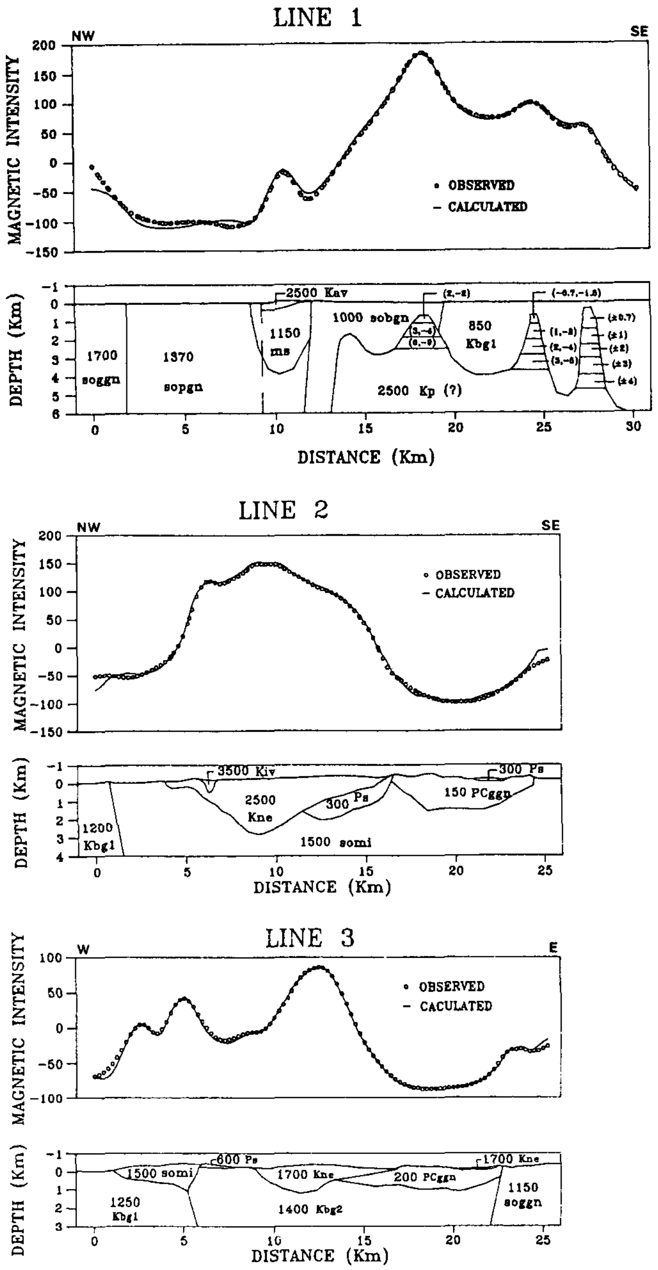

Fig. 7. One-and-half dimensional magnetic models of the profile line 1, line 2 and line 3 (Fig. 6.). Notation of each rock type is explained in Table 1. The value assigned to each rock notation is magnetic susceptibility in cgs unit. Values in parentheses indicate the body length along the axis perpendicular to the page surface.

CONCLUSION

From the qualitative and quantitative analysis of the aeromagnetic anomalies in the area of the southwestern Ogcheon Belt, a few things on geological substructures are suggested. With regard to susceptibility values, there are four types of rocks distributed in the study area. The first one is Cretaceous volcanic rocks, the second one Cretaceous porphyry, the third one Cretaceous sedimentary rocks of Neungju Group, and the fourth one Precambrian Sobaegsan gneiss and Cretaceous Bulgugsa granite in descending order of susceptibility value. The porphyry of higher susceptibility is supposed to have intruded the Precambrian gneiss and the Cretaceous Bulgugsa granite with lower susceptibility around Donggang Myeon area in the northern part of the study area. This conclusion is based on both of the qualitative and quantitative analysis of the magnetic anomalies. Two-dimensional modelings of the profile data across the sedimentary basin of the Neungju Group reveals that the northern part of the basin is deeper than the southern part, and that the maximum depth of the basin is supposed to be 3 km below the surface. The western flank of the basin bottom is steeper than the eastern flank. The high susceptibility value of Neungju Group sedimentary rocks indicates that the rocks comprises large amount of volcanic materials. This fact implies that it is almost impossible to have petroleum reservoir in the sedimentary rocks. The susceptibility of sedimentary rocks in the southern part of the basin is comparatively smaller than that of the northern part. In the southeaster part of the study area, the large negative anomaly over the volcanic rock distribution implies that the volcanic rock is very thin or the boundary with the granite in the published geologic map should be moved to the west considerably.

Table 1. Notations and explanations for rock types used in the magnetic models of profiles in (Fig. 7).

Age	Notation	Rock type
Cretaceous	Kp	Porphyry
	Kbg1, Kbg2	Two types of Bulgugsa granite
	Kav, Kiv	Two types of volcanic rock
	Kne	Neungju Group Sedimentary rock
Permian	Ps	metasedimentary rock
Precambrian	PCggn	granite gneiss
	ms	metasedimentary rock
	Soggn, Sopgn, Sobgn, Somgn	four types of gneiss

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REFERENCES

Baag, C. -E. and Kang, D. J., 1994, Geophysical studies on major faults in the Gyeongsang Basin: Aeromagnetic and radiometric data interpretation on the Ulsan Fault, *Journal of Geological Society of Korea*, 30, 193-205.

Bhattacharyya, B. K. and Chan, K. C., 1977, Reduction of magnetic and gravity data on an arbitrary surface acquired in a region of high topographic relief, *Geophysics*, 42, 1411-1430.

Chang, K. H. and Kim, K. T., 1967, *Geological map of Gangjin sheet*, scale 1:50,000, Geological Survey of Korea.

Cheong, C. H. and Kim, G. S., 1966, *Geological map of Neungju sheet*, scale 1:50,000, Geological Survey of Korea.

Choi, S. O. and Ko, C. B., 1971, *Geological map of Muan sheet*, scale 1:50,000, Geological Survey of Korea.

Choi, Y. K. and Yoon, H. D., 1968, *Geological map of Jangheung sheet*, scale 1:50,000, Geological Survey of Korea.

Cluzel, D., Cadet, J. -P. and Lapierre, H., 1990, Geodynamics of the Ogcheon Belt (South Korea), *Tectonophysics*, 183, 41-56.

Son, C. M. 1969, On the Cretaceous volcanic activity of Korea, *Journal of Geological Society of Korea*, 5, 259-267.

Talwani, M. and Heirtzler, J. R., 1964, Computation of magnetic anomalies caused by two-dimensional bodies of arbitrary shape, in *Computers in the mineral industries, Part 1 : Geological Sciences*, 9, 464-480, Ed. Parks, G. A., Stanford Univ. Publ.

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