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Gravity and Magnetic Model Study of Block VI-2, Offshore Korea

한국근해 제 6광구에 대한 중력 및 자력 모델 연구

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Abstract : Two-dimensional gravity and magnetic models were constructed for seismic profiles in Block VI-2, offshore Korea. For each seismic profile, a longer length model showing geometric configurations of all employed polygonal bodies and an expanded version of the area of interests were made. The results of this modeling study indicate 1) that the depth to the deeper basement surface appear to be shallower than indicated in the seismic sections, 2) that the Middle Miocene section (the bottom formations in the models) appears to contain significant amounts of volcanic materials, 3) that identification and/or determination of depth to the top of basement is difficult in the study area due to thick volcanic materials in the lowermost formation (Middle Miocene), and 4) that the study area is unfavorable for hydrocarbon generation and accumulation due to wide spread volcanic activities during the Middle Miocene Epoch. The maximum calculated depth to the magnetic basement in the study area is approximately 4 Km sub-sea.

Key Words : Two-dimensional gravity and magnetic models, Block VI-2, offshore Korea, magnetic basement.

요 약

한국근해 제 6광구내의 탄성파탐사 단면도에 대한 이차원의 중력 및 자력모델을 연구했다. 각 단층면에 대하여 사용된 모든 지층의 기하학적 형태를 보여주는 긴 모델과 중요한 부분을 확대한 모델을 작성했다. 이 모델연구 결과는 다음과 같은 사항들을 지시한다. (1) 보다 깊은 기반암까지의 심도는 탄성파탐사 단층면에서 보여주는 깊이보다 약간 깊은 것 같고, (2) 중기 마이오세 지층(모델에서 최심부층)은 무시못할 양의 화산물질을 포함하고 있는 것 같고, (3) 최하심층(중기 마이오세)에 포함된 두터운 화산암 물질 때문에 본 연구지역내에서 기반암의 상부면까지의 깊이를 정의하거나 결정하기가 어렵고, (4) 중기 마이오세 동안의 광범위하게 있었을 화산활동 때문에 본 연구지역은 탄화수소(석유 또는 천연가스)가 생성 또는 집적됐을 유망지역이 될 수 없다고 판단된다. 본 연구지역에서 가장 깊은 기반암까지의 깊이는 해수면에서 약 4 km이다.

주요어 : 2차원 중력 및 자력 모델, 한국근해 제 6 광구, 자력 기반암.

INTRODUCTION

The study area, Block VI-2 (Fig. 1) is of geological and geophysical interest in that it lies on a very wide continental shelf. The basin is of particular economic interest because of a reported oil and gas show in one of the wells and because of the presence of significant amount of sand encountered in the two wells drilled in Block VI-2. Since volcanics are known to be distributed in the sediments offshore Korea, gravity and magnetic methods are useful in confirming seismic interpretation or determination of depth to the basement and in investigation of presence of volcanics in the overlying sediments.

In order to generate various interpretive profiles and processed maps, the data supplied by EDCON (See next section) had to be reprocessed (Note: They were the corrected survey data and gridded data was not included in the magnetic tape provided by EDCON). After the seismic (time) profiles were converted to depth profiles, geometric parameters of geologic bodies were then digitized for initial model structure. In our detailed modeling study we used reduced-to-pole data in order to achieve better results.

Objectives of this study were: (a) to confirm or to determine basement depths; (b) to confirm or to delineate magnetic basement surface configuration as well as geometry of the overlying sediments; and (c) to investigate presence of volcanics in the overlying sediments by constructing detailed 2-D models.

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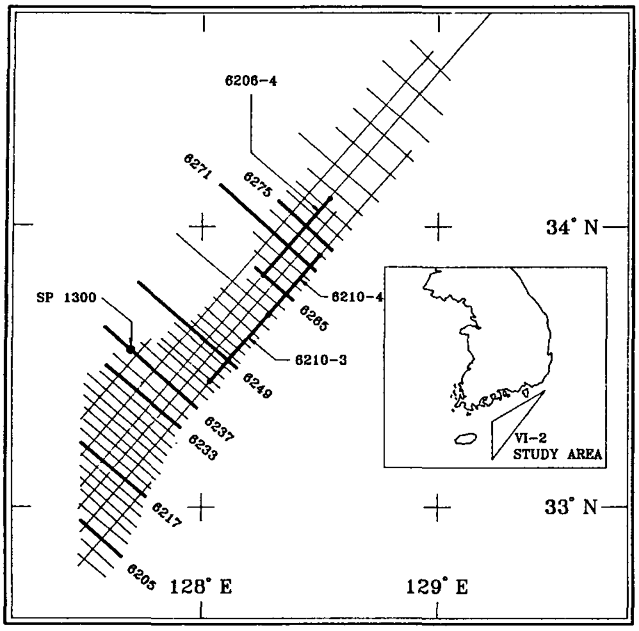

Fig. 1. Location map of the study area, Block VI-2. The thin and thick straight lines are traces of surveys. The numbers assigned to the thick lines are the identifications of the profile lines processed in this study. SP indicates the seismic shot point.

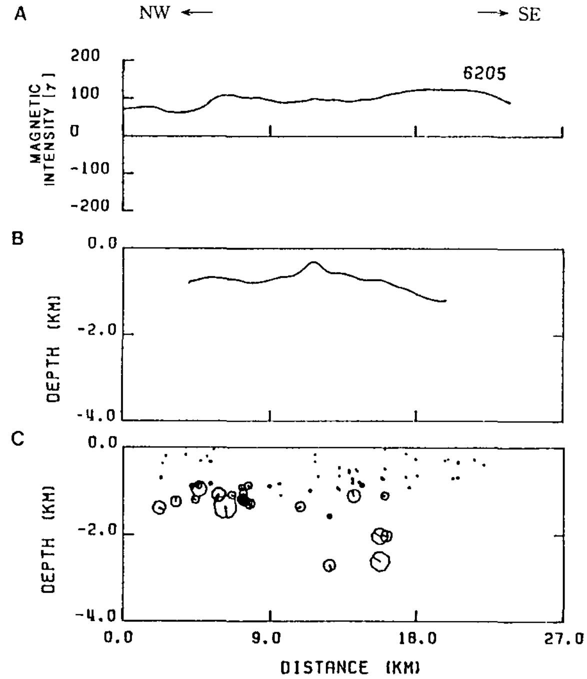

Fig. 2. Calculated depth profiles for line 6205 based on autocorrelation and Werner deconvolution methods. Shown are RTP total intensity magnetic profile (A), depths profile based on autocorrelation (B) and Werner method (C).

GRAVITY AND MAGNETIC DATA QUALITY

The marine gravity and magnetic survey was conducted by EDCON, Inc. in conjunction with seismic survey from July 1990, through August 1990. Primary ship-track line spacing was 4~5 km in a NW-SE direction. Tie line spacing was 6~8 km in a NE-SW direction. EDCON collected, in digital and analog forms, gravity and magnetic data of 2,497.0 km and 2,442.7 km, respectively (EDCON, 1991). The wide line spacing may have caused loss of detail and reduction of data quality. However, in the area outside of the NE-SW oriented narrow basin, gravity and magnetic data were collected on every 5th seismic line, which made the spacing approximately 20 km. In the NE part of the study area gravity and magnetic data were collected along a single line.

According to EDCON's report the average absolute intersection misties are 0.29 milligals and 0.61 gammas for 2-D Bouguer gravity and magnetics, respectively. However, the average absolute intersection misties before systematic adjustment is 2.13 milligals and 22.16 gammas, respectively. We believe that the original misties are too large to be regarded as an accurate survey; systematic adjustments would not remove but would help reduce errors introduced by several causes such as, non-linearities in the gravity meter, errors in determination of the E tv s correction, etc. (Note: EDCON' s use of the word, "correction" in place of "mistie adjustment" is misleading and improper.) For the case of magnetic data it appears that a 600-second filter with a 50 percent cosine taper (Note: this filter would completely remove all wavelengths shorter than 6.67 minutes and those longer than 20 minutes unaffected) that EDCON employed may have made the data too smooth to identify some of the low-amplitude and high-frequency anomalies.

GRAVITY AND MAGNETIC DATA PROCESSING

In order to produce various interpretive processed maps and profiles, it was necessary to grid both the gravity and magnetic data. Two main frame computers (IBM and VAX) at Seoul National University were used for the reprocessing operations. Since the magnetic data were already corrected by EDCON for the towing offset of the magnetometer sensor and the Earth's normal field, no additional removal of IGRF (International Geomagnetic Reference Field) was necessary. The following computer processes and operations were made:

Gridding and Contouring Bouguer Gravity and Magnetic Data

Line data stored in a magnetic tape provided by EDCON were gridded using a grid interval of 1 km.

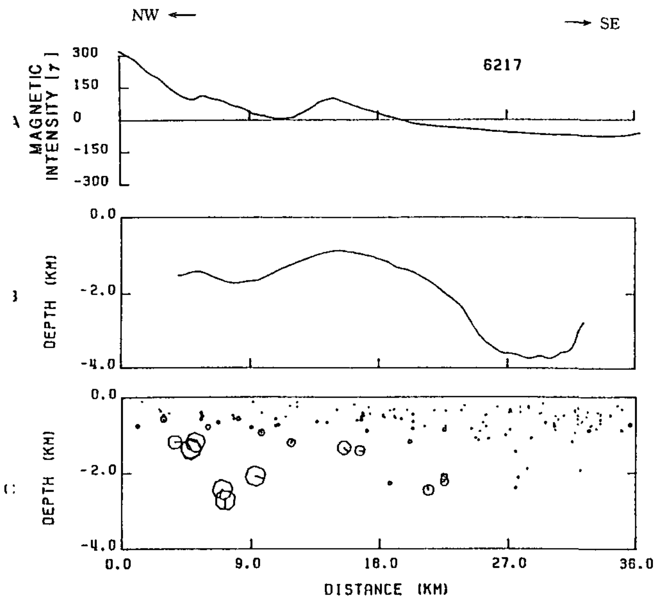

Fig. 3. Calculated depth profiles for line 6217. See Figure 2 for further details.

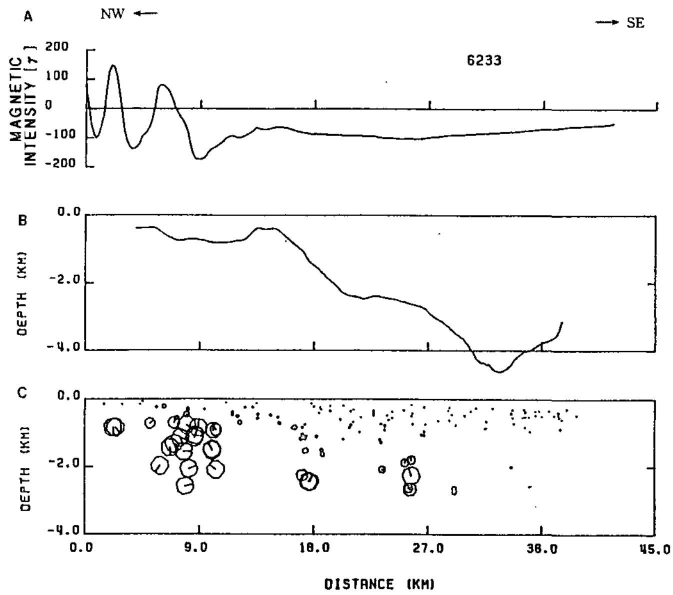

Fig. 4. Calculated depth profiles for line 6233. See Figure 2 for further details.

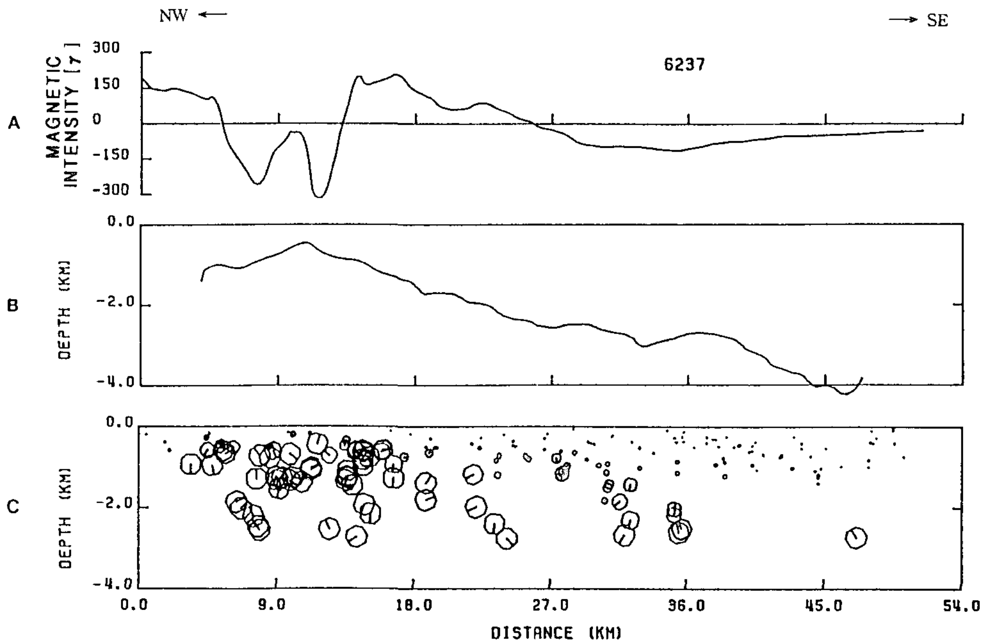

Fig. 5. Calculated depth profiles for line 6237. See Figure 2 for further details.

Reduced-to-Pole(RTP) Magnetic Anomaly

Since the mean geomagnetic inclination in the survey area in 1990 was approximately 49 degrees north, anomaly peaks are significantly shifted toward south. In order to correct this and bring positions of anomalies more or less on top of each corresponding anomaly causing body, RTP operation was applied to the total intensity magnetic anomaly in Fourier-transformed domain. A mean declination and inclination of 353° and 49°, respectively, were used.

Downward Continuation of Bouguer Gravity and RTP Total Intensity Magnetic Anomalies

Since the shallowest magnetic surface appeared to be at 500 m below the sea level, both the Bouguer gravity and RTP magnetic data were continued to 500 m sub-sea in order to enhance the details of the anomalies.

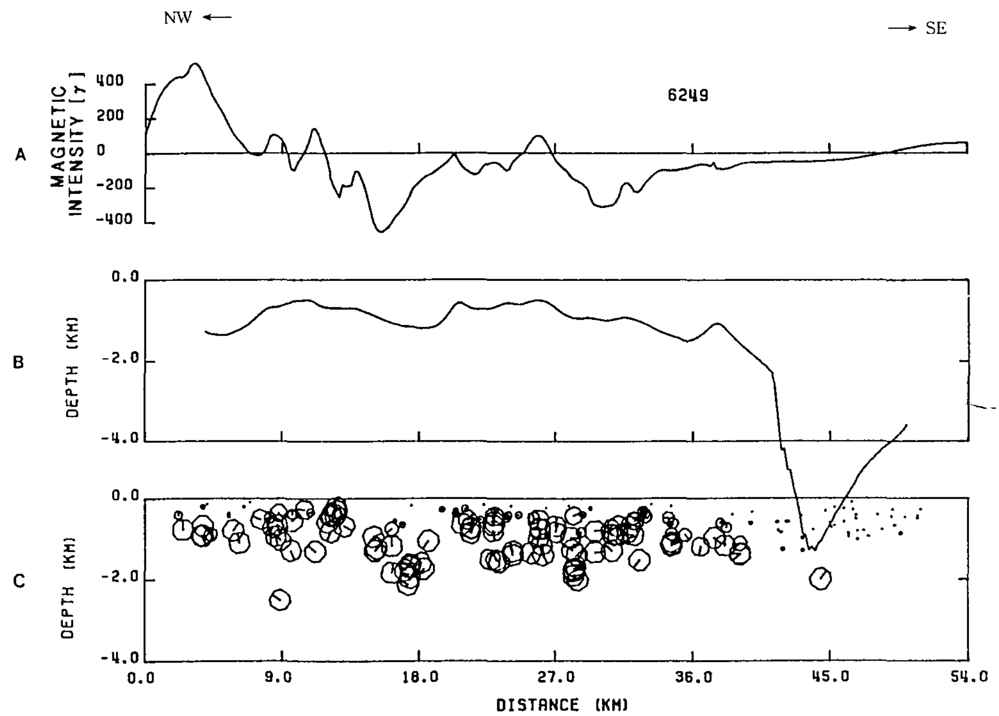

Fig. 6. Calculated depth profiles for line 6249. See Figure 2 for further details.

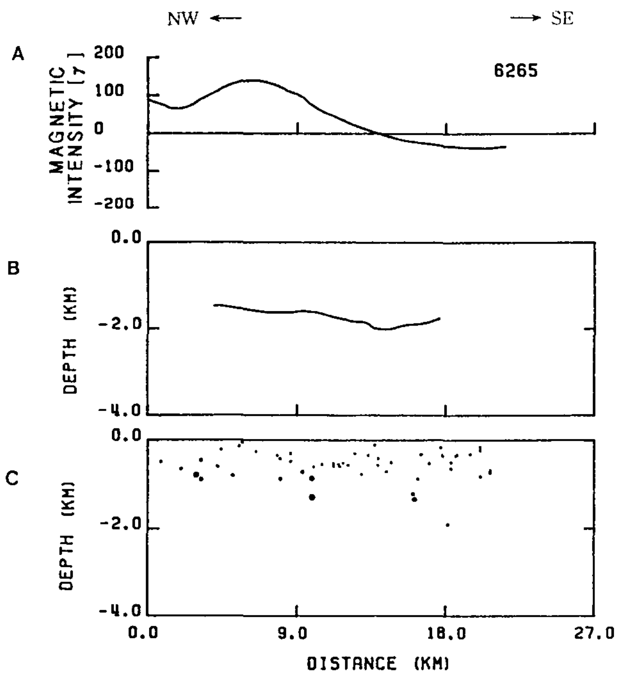

Fig. 7. Calculated depth profiles for line 6265. See Figure 2 for further details.

Upward Continuation of Bouguer Gravity and Reduced-to-Pole Magnetic Anomalies

Upward continued (1000 meter level) Bouguer gravity and RTP anomaly maps were made to remove high-frequency anomalies due to near water bottom sources.

Low-pass filtering of RTP magnetic Data

A 13 km Butterworth low-pass filter was applied to the RTP magnetic data in wavenumber domain to isolate anomalies caused by deeper magnetic bodies.

High-pass filtering of RTP magnetic Data

In order to remove those anomalies from deeper sources and isolate anomalies caused by shallower magnetic bodies, a 13 km Butterworth high-pass filter was applied to the RTP magnetic data in wavenumber domain.

Horizontal Gradient of RTP Magnetic Data

Because horizontal gradient maxima often indicate magnetic contacts and edges of anomaly causing bodies, the gradient operation was applied to several selected lines from NW to SE direction.

Magnetic Depth Calculation Using Autocorrelation Technique

An autocorrelation technique (Philips, 1979) was applied to eight selected RTP magnetic profiles to obtain preliminary information on the depth to the magnetic basement. In the

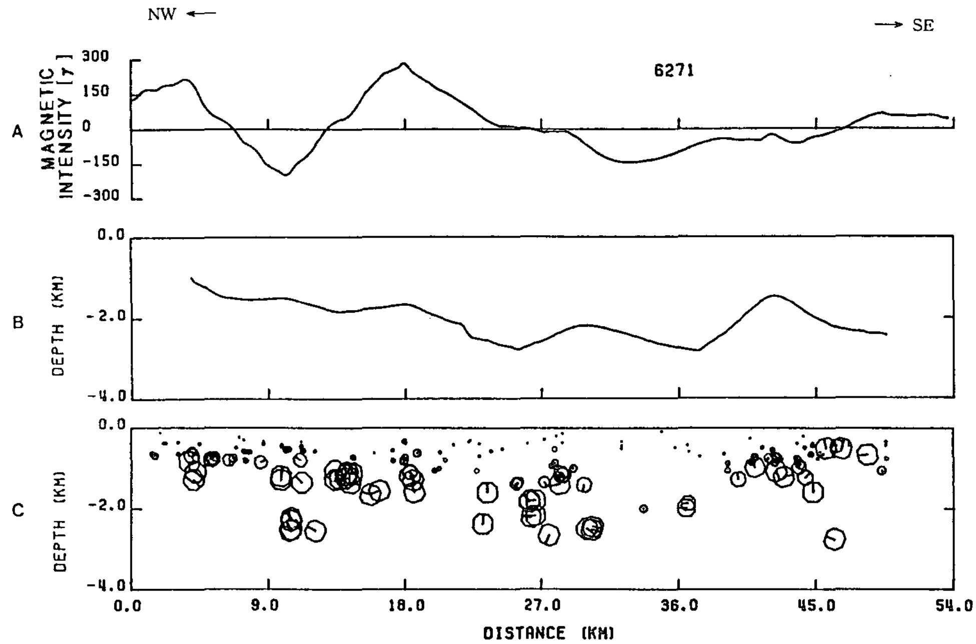

Fig. 8. Calculated depth profiles for line 6271. See Figure 2. for further details

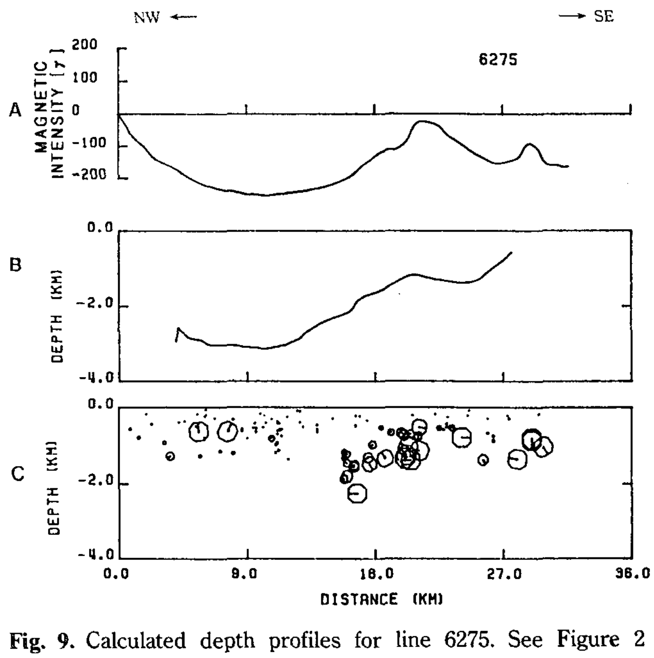

Fig. 9. Calculated depth profiles for line 6275. See Figure 2 for further details.

computational procedure the maximum entropy method (Burg, 1967 and 1968) was employed to get reliable autocorrlation coefficients from relatively short data sets.

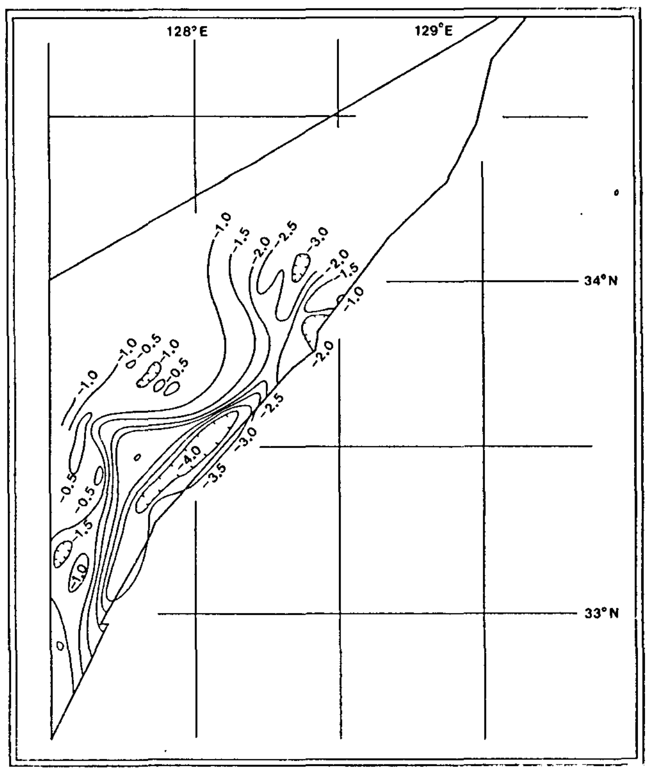

Fig. 10. Simplified depth to the magnetic basement surface based on autocorrelation method. Contours are the result of interpolation of depths from profile lines given in Figures 3~9 Contours are in kilometers below sea level.

Magnetic Depth Calculations Using Werner Deconvolution Method

The calculation of magnetic source depths were made using Werner deconvolution method(Werner, 1953) along eight RTP magnetic profiles for total field.

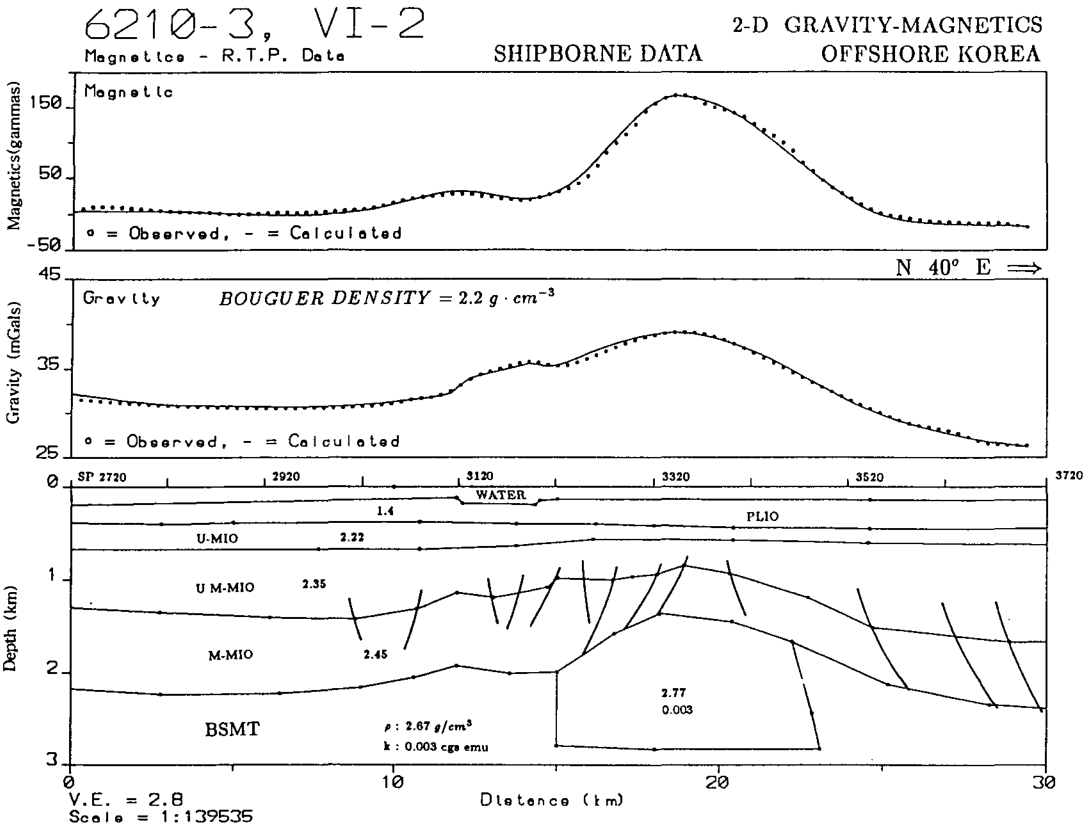

Fig. 11. 2-D gravity and magnetic model of the profile line 6210-3, VI-2. Geological body geometries are modified from the interpreted seismic profile (time-section) provided by PEDCO. SP indicates the seismic shot point. PLIO=Pliocene and Quaternary, U-MIO=Upper Miocene, UM-MIO=Upper Middle-Miocene, M-MIO=Middle Miocene, and BSMT=Magnetic Basement.

QUALITATIVE GRAVITY AND MAGNETIC INTERPRETATION

The following processed maps, which are not shown due to proprietary nature, were used in this work: total magnetic intensity map, Bouguer gravity map, reduction-to-pole total magnetic intensity map, downward continued RTP total magnetic intensity map, downward continued Bouguer gravity map, upward continued RTP total magnetic intensity map, upward continued Bouguer gravity map, low-pass RTP total magnetic anomaly map, high-pass RTP total magnetic anomaly map.

The most outstanding feature of the total intensity magnetic map is the clear separation of two distinctively differing anomaly patterns in the study area. High-amplitude, short wavelength anomalies are clustered in the NW and NE parts of Block VI-2 and they occupy approximately three-fourths of the study area. The remaining one-fourth can be characterized by low-intensity and low-frequency anomaly area, which can best be interpreted by a NE-SW oriented narrow basin.

In the study area some of the gravity and magnetic (RTP) anomalies are anticorrelated to each other (in terms of intensities). This strongly suggests that some of the magnetic basement rocks possess significant amounts of remanent magnetization.

Results of magnetic depth computations using the autocorrelation technique and Werner deconvolution method are shown in Figures 2~9. The southeastern portion of each profile line has deeper depth. The depth from the autocorrelation technique is contoured to be shown in Figure 10. A sedimentary basin in NE-SW trend is located in the southeastern part of the area.

TWO-DIMENSIONAL GRAVITY AND MAGNETIC MODELS

Two-dimensional gravity and magnetic models were made for the six "prospect" areas which were identified and prioritized by Schulenberg (1991). (Note: one area was excluded from this study due to lack of two-dimensionality). In all models the sedimentary rock body geometry and the basement surface configurations were initially digitized from depth profiles which were converted from the interpreted seismic time-sections provided by PEDCO. For each of the six chosen areas, we selected a line which is regarded to suit

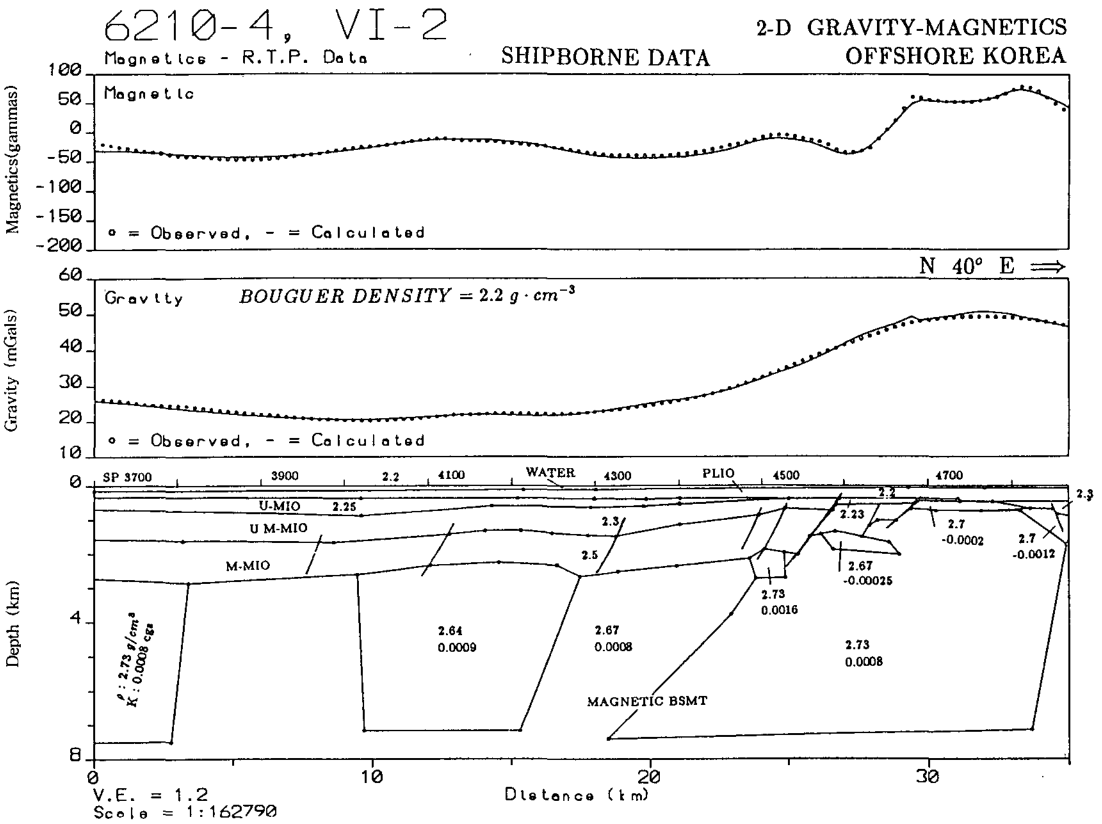

Fig. 12. 2-D gravity and magnetic model of the profile line 6210-4, VI-2 based on the interpreted seismic profile (time-section) provided by PEDCO. See Figure 11 for further details.

itself better with respect to two-dimensionality. The main objectives of detailed 2-D gravity and magnetic model study are 1) to investigate if any significant amount of volcanics are present in the overlying sedimentary section and 2) to confirm or to define basement depths. In the following, the best fitted final models are described in order of decreasing priorities (The priorities were set by Schulenberg, 1991).

Gravity and magnetic modelling software GM-SYS(version 1.89) of Northwest Geophysical Associates, Inc. Corvallis, Oregon, U.S.A. was used in all 2-D gravity and magnetic models.

Model 6210-3, VI-2

A significant amount of modifications with respect to body geometry was made from the initial form (Fig. 11). This model shows that the "anticlinal" structure in the left part (between SP 2900 and SP 3200) is much reduced in size than it appears in the seismic section. This model also shows that the depth to the basement at the NW side of the model may be significantly shallower than the seismically interpreted depth. The plausible causes for the discrepancy between the seismic data and gravity-magnetic interpretation are, 1) velocity anomalies, 2) inaccuracy of gravity and magnetic data, and 3) lack of two-dimensional characteristics for the geological features.

In this model we clearly demonstrate that the Bouguer density of 2.20 g/cm^3 used by EDCON was too high a value for the study area and that a better value may be approximately 1.4~1.5 g/cm^3. From this model it is interpreted that the presence of volcanics in the area is very unlikely.

Model 6210-4, VI-2

This model indicates that the structural bulges associated with the overlying sediments and the basement surface below SP 4100 through SP 4300 are probably much smaller in size than those appear in the seismic section (Fig. 12). It appears that no significant amount of volcanics are present in the sediments in and around the "prospect" (SP 4100-4300). A shallower depth to the basement is also shown in the model than what appears in the seismic section.

Model 6206-4, VI-2

In this model a poor correlation between the highs and lows of gravity and those of magnetic data are observed (Fig. 13). The most plausible explanation for the poor correlation turned out to be that the lowest sedimentary layer (Middle Miocene) may contain significant amounts of volcanic mate-

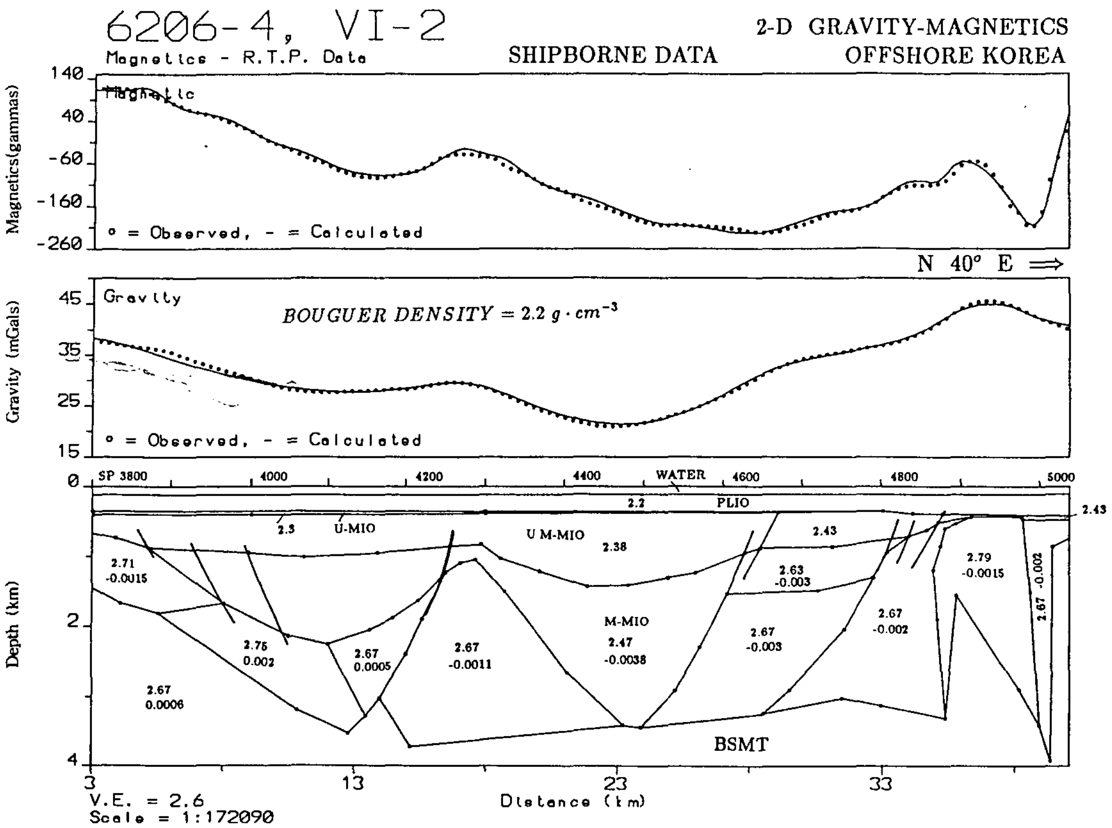

Fig. 13. 2-D gravity and magnetic model of the profile line 6206-4, VI-2. See Figure 11 for further details.

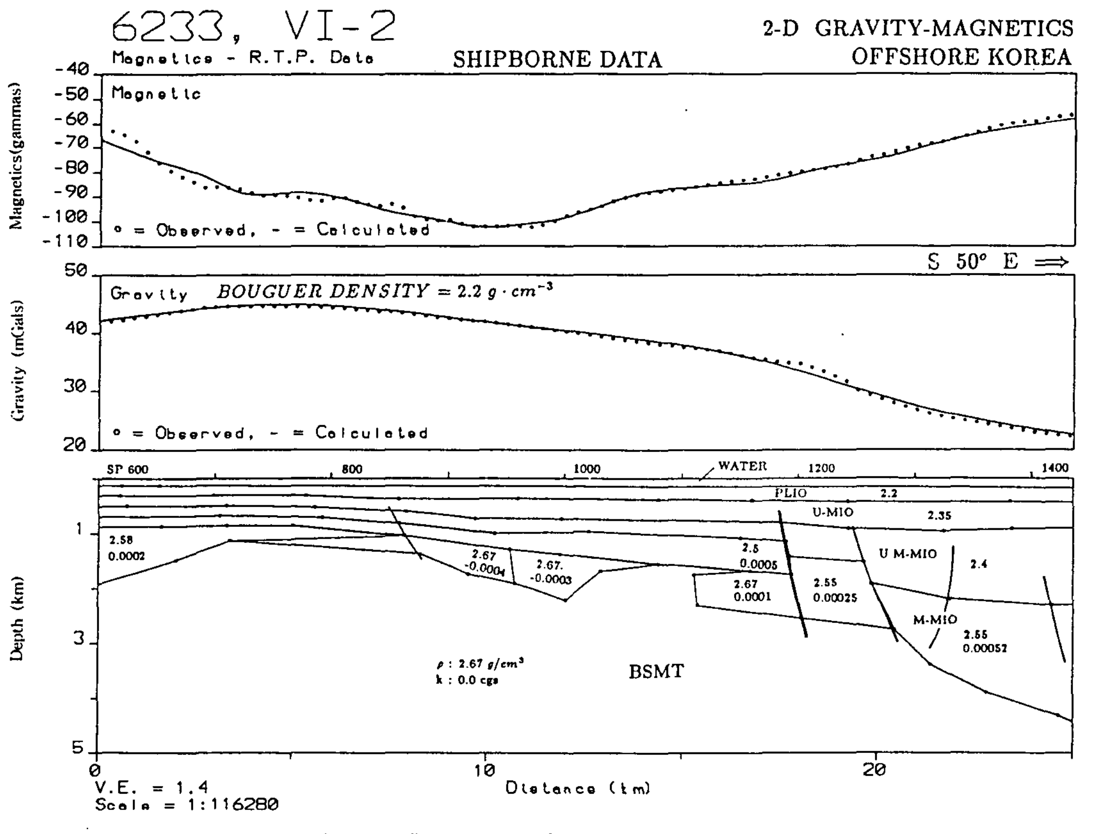

Fig. 14. 2-D gravity and magnetic model of the profile line 6233, VI-2 based on the interpreted seismic profile (time-section) provided by PEDCO. See Figure 11 for further details.

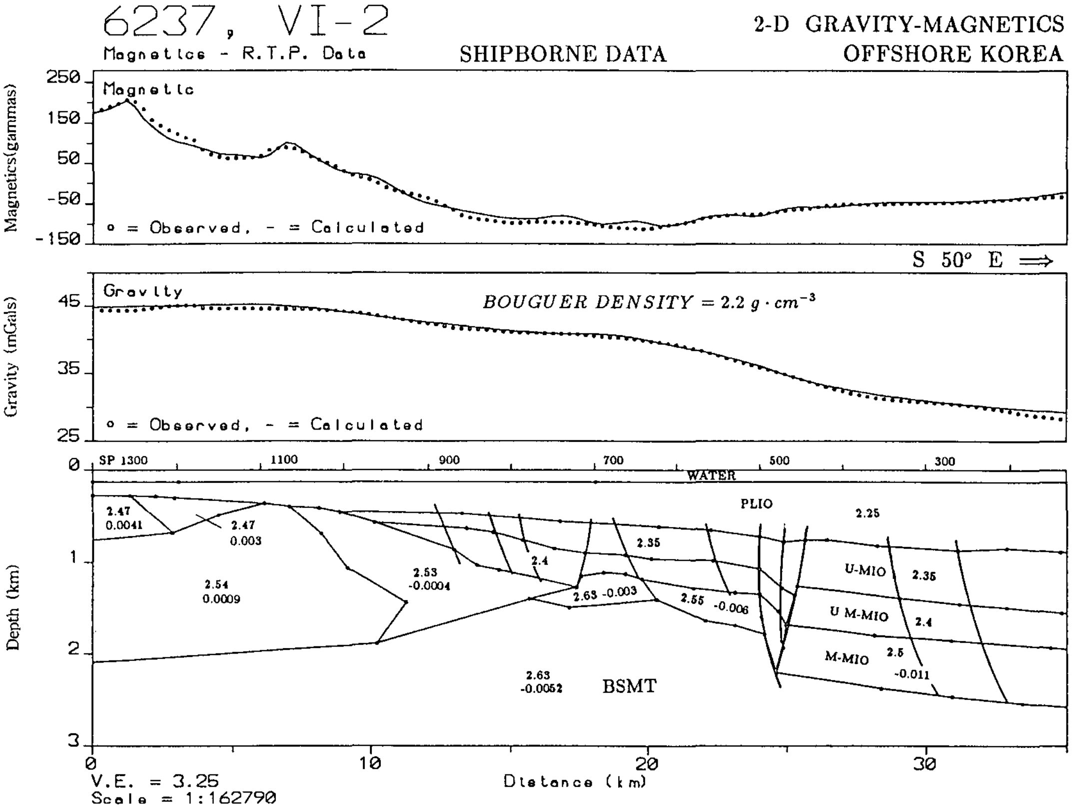

Fig. 15. 2-D gravity and magnetic model of the profile line 6237, VI-2. See Figure 11 for further details.

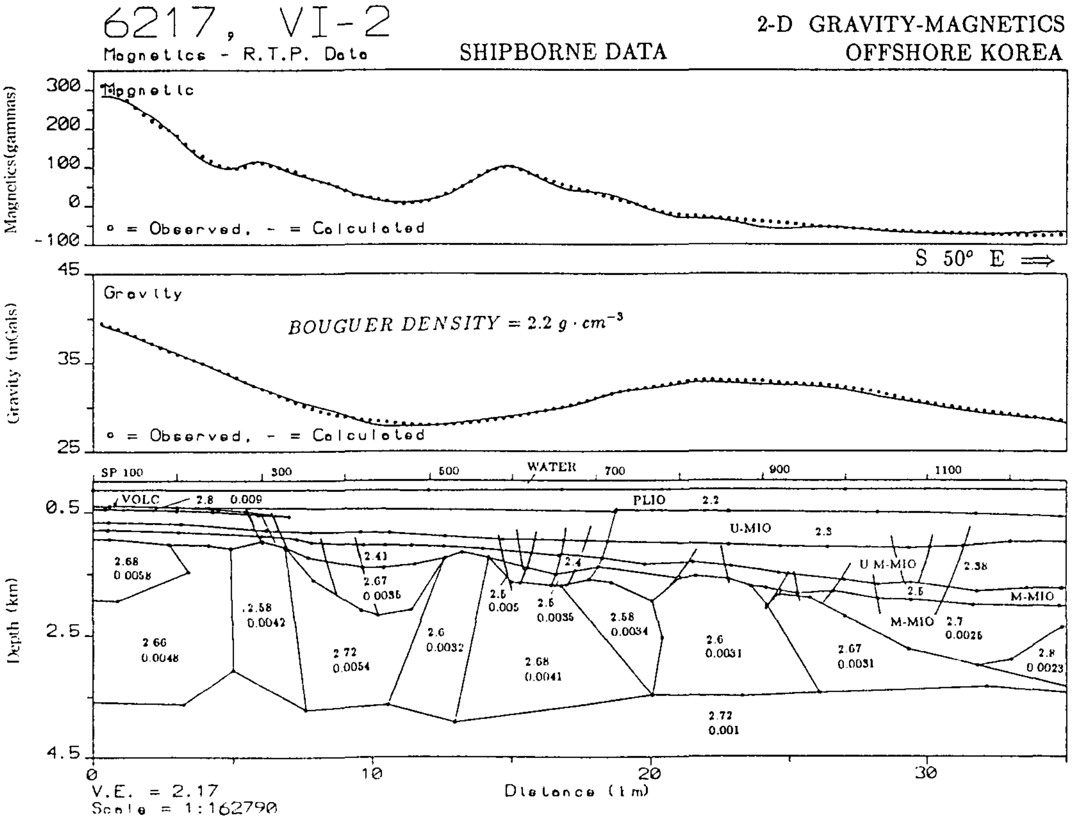

Fig. 16. 2-D gravity and magnetic model of the profile line 6217, VI-2. See Figure 11 for further details.

rials. Some of the intra-basement intrusives also appear to have significant amounts of reversely magnetized remanent magnetizations.

Model 6233, VI-2

The most striking feature from this model is that the magnetic and the Bouguer gravity values are inversely correlated (Fig. 14). This anticorrelation strongly indicates that the bottom sediments (Middle Miocene) contain significant amounts of volcanic materials whose remanent magnetization intensities are probably strong and in reverse polarity. It should be noted that the gravity and magnetic data cannot confirm or deny a minor basement high that shown at the SE part of seismic section, 6233 (SP 1300-SP 1500). (Note: Schulenberg (1991) states that this basement high is not evident on line 6210-2, which lies on the NW flank rather than the crest.) This model also indicates that some of the basement rock bodies may have their remanent magnetizations in reverse polarity.

Model 6237, VI-2

Magnetic and gravity data are anticorrelated especially at the SE part of this model (Fig. 15). This can best be interpreted as the lowermost sedimentary layer may contain volcanics and they are reversely magnetized. At the right side of the model significantly shallower depths to the basement than shown on the seismic line are interpreted.

Model 6217, VI-2

Except at the far left portion of the line, the gravity and magnetic data are anticorrelated (Fig. 16). This indicates that the lower-most layer of sediments (Middle Miocene) contain significant amounts of volcanic materials in the formation. The possible presence of volcanics was also seismically predicted.

CONCLUSIONS

The interpretation of the gravity and magnetic profile data in the study area indicate that volcanics are present in the Middle Miocene sedimentary formation in the study area. The results of this study suggest that lava flows covered extensively throughout the entire Block prior to the completion of normal faults which separate the NE-SW oriented narrow basin from the rest of basement highs. It appears that volcanic activity started in the study area contemporaneously with the development of rift tectonics. Because it appears that the activity gradually lost its intensity during the Middle Miocene, the basement surface may not be clearly defined in the study area by any geophysical means and methods. In terms of formation geometry, with the exception of the geometry of the lowermost layer (Middle Miocene) and the basement surface, the results of this gravity and magnetic study support the seismic (time) interpretation made by Schulenberg (1991). It appears that during the Middle Miocene Epoch, volcanic activities were widespread and most of the study area was covered with volcanic materials. Weaker volcanic activities renewed in the Late Miocene were mostly in the NW portion of the area. Due to the interpreted widespread volcanics, the study area appears to be unfavorable for hydrocarbon generation and accumulation.

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