The Depth and Configuration of The Basement at Sokotra Basin, Offshore Korea Using Marine Magnetics

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Abstract

Marine magnetic survey were carried out at SoKotra Basin offshore Korea between latitudes 31° 42′ 32″ N and 32° 46′ 29″ N, and longitudes 123° 56′ 26″ E and 125° 49′ 16″ E in order to estimate the depth of basement complex and as well as to configure its surface and produce the thickness of sedimentary sequence at the study area. Two methods have been used for depth estimation and basement configuration: the power spectrum and the 3-D analytical signal. The estimated depths resulted from the power spectrum method range from 1.4 km to 6.0 km for deep sources (basement troughs), and from 0.3 km to 1.75 km for shallow source (basement peaks). An isopach map was prepared for estimating the thickness of the sedimentary sequence at the study area; it ranges from 1.2 to 4.66 km. The estimated depths resulted from the analytic signal method range from 1.0 to 6 km. A basement configuration map was constructed for the study area in the basin. They show a well agreement with the geology of the study area.

1. Introduction

The study area is situated at the East China Sea, and occupied a surface area of about 22081 km^2 (198.7 km^2 x 116.4 km^2). It is involved in the block IV that covers the area of SoKotra basin. The Sokotra Basin is located in the northern part of the East China Sea. It is surrounded by Precambrian rocks of the Korean Platform including the Hupijiao Rise. In the southeast, however, the basin is interconnected with the Xihu Depression. The basin experienced downfaulting in the Paleogene, and downwraping in the Neogene. The basin is filled with tertiary clastic sediments and volcanic rocks, in which the sequence is more than 5 km thick (**KIGAM, 1993**). The major structural characteristics of the East China Sea Shelf Basin are E-W zonation and N-S differentiation. The Sokotra Basin forms a part of these structural grains, and belongs to a rift basin in which the subsidence initiated in the Late Cretaceous.

The SoKotra basin characterized by a thick sedimentary sequences and trending NE-SW, parallel to the Taiwan-Sinzi Fold Zone and Okinawa Trough (**Chough et al., 2000**).

According to previous gravity and aeromagnetic survey results, the SoKotra Basin comprises Jurassic-Cretaceous volcanics, forming graben and horst, overlain by non-marine clastics Paleogene (**Hyun et al., 1980; W.Y. Lee et al., 1985; Zhou et al., 1989**).

In the Western part of the basin, three gravity and aeromagnetic anomalies having negative values are recognized, which can be interpreted as subbasins (or sags) filled with sediments (density: 2.1-2.6 g/cc). These data suggest that depth of the acoustic basement is approximately 5 km (**KIGAM, 1993**).

Seismic data revealed five regional unconformities, including Pliocene-Pleistocene/Late Miocene, intra Miocene, Miocene/Oligocene, Oligocene/Eocene and top basement. Below the Oligocene unconformity, three subbasins (subdepressions) are present, named Sag A, B and C. At the end of the Paleogene, the three sags were connected probably due to the regional subsidence and resultant expansion of the basin. In the Miocene time, the whole East China Sea Shelf Basin (including Sokotra Basin) experienced regional subsidence, which resulted in the regional marine transgression. This movement may be responsible for the interconnection of the Sokotra Basin and Cheju Basin (**KIGAM, 1993**).

Since the origin of marine magnetic anomalies was explained by the **Vine-Matthews-Morley hypothesis in 1963**, which is the basaltic Layer 2A of the oceanic crust, it can be identified easily by marine magnetic survey (**Lawrie, 1997**). The conventional method of interpreting surveyed magnetic anomalies assumed that the anomaly was due to the susceptibility contrast between adjacent crustal blocks (**Lowrie, 1997**).

Accordingly, the present study tends to use the marine magnetic data to estimate the depth and configuration of the basement rocks as well as determining the thickness of the sedimentary sequence. The power spectrum and analytic signal methods have been used for verifying those objectives.

2. Results

2.1. Magnetic

The obtained magnetic data were corrected for diurnal variation and removal of the regional magnetic field using IGRF model 2000, and then reduced to the magnetic pole (RTP) to reveal the results as they were measured at the magnetic pole (**MacLeod et al., 1993**) assuming that there was no remanent magnetization. In other meaning, the dipolar magnetic anomalies are transformed to monopolar anomalies centered over their causative bodies and the actual inclination is changed to the vertical.

The magnetic anomalies of the RTP map show the variations in the geomagnetic field as a result of differences in the magnetic susceptibility of the subsurface rocks distributed throughout the sea floor of the survey area.

Overwhelmingly, these variations may due to the lithologic or the structural elements related to the high magnetized igneous rocks. The sedimentary rocks have a silent effect due to less content of magnetic minerals.

The RTP map of the study area shows the range of the magnetic intensity from 290 nT to -280 nT. The middle and eastern side of the study area are in general represented by negative anomalies (low-amplitudes), while the western part is mixed of positive and negative anomalies. The study area was divided into six magnetic zones (Z1, Z2, Z3, Z4, Z5 and Z6) based on the general dominant polarities and the geological background. The most expressive anomalies have been denoted by capital letters.

The sharp gradient noticed at the border of the positive anomalies located at the study area (e.g. A, B, I, J, K and O) reflects shallow depths of the sources that may be basement uplifts, while that noticed at the border of the negative anomalies (e.g. D, E, F, M, N and Q) reflects deep depths of the sources that may be basement troughs.

There is no doubt that the noticeable high gradient at the borders between negative and positive anomalies are reflecting the variations in the basement topography and meanwhile probable to be interfaces (or planes) of structurally affected elements.

2.2. Depth estimation

The depth to the various points of the subsurface magnetic basement allows mapping the surface and topography of basement rocks as well as the thickness of sedimentary cover (**Breiner, 1973**).

In the present study we used two methods for estimating source depths: the power spectrum and the analytic signal methods. The depth estimates resulting from each method are compared. Moreover, basement configuration and isopach maps have been prepared for interpretation with respect to the geology of the study area. Both of the applied methods were succeed to estimate the depth of the basement peaks and troughs in Sokotra basin.

(1) *a- Power spectrum method*

The algorithm given by **Spector and Grant (1970)** was used to estimate the depth of the causative body from the relationship between the logarithmic powers and frequencies. The depth is to be estimated from the slope taken at the best linear fit. The maximum depth was estimated from the slope of the best linear fit of the low frequency portion, while the minimum depth was estimated from the slope of the linear best fit of the high frequency portion.

The basement configuration map concluded from the low frequency sources shows estimated depth ranges from 1.5 km to 6 km. Similarly, the basement configuration map concluded from the high frequencies sources shows estimated depth ranges from 0.3 km to 1.75 km.

The previous estimated depth values were helped to construct the thickness map of the sedimentary sequence of the study area. The sedimentary sequence is somewhat thick at t1, t2, t3, t4, t5, and t6 with values of 4.2, 4.5, 2.7, 3.7, 2.9, and 3.1 km respectively. It is also thin at t7, t8, t9, t10 and t11 with values of 1.34, 1.64, 1.61, 1.48 and 1.24 respectively.

The depth values of the shallow and deep sources are well agreed with geological information of the study area, particularly at the parts of the Sokotra basin and the Hupijiao Rise.

(2) *b- Analytic signal method*

The concept of analytic signal in 2-D case **Nabighian (1972)** was first extended by **Nabighian (1984)** to 3-D case as a first step toward the development of an automatic interpretation technique for potential field data.

Nabighian (1972) calculated the shape of the analytic signal over several simple bodies. In the present study we used the analytic signal over a vertical magnetic contrast at depth d, given by:

$$|A(x)| \;\alpha\; \frac{1}{x^2 + d^2} \qquad (1)$$

Equation (1) shows that the amplitude of the analytic signal has a bell shape, with a half width that equals the depth to the magnetic source. The resultant depths from the method have represented by plotting different symbols at the interpreted source locations of the analytic signal map.

The basement configuration map concluded from the analytic signal amplitude shows that the estimated depth ranges from 1.5 km to 6 km. The depth results concluded from the analytic signal amplitudes are matching with those concluded from the power spectrum method.

An interpretive map was prepared from the results of depth estimation of both of the applied methods to show the most prospective areas for any future exploration work (e.g. Hydrocarbon exploration). It has been shown from depths and thicknesses results that the areas of shallow depth (basement uplifts) and less thickness of sediments represent the best locations for drilling and exploration works.

3. Discussion and Conclusions

The application of magnetic data for depth estimation and basement configuration is a complicated process due to the inherent ambiguity of the subsurface layers and also the different geometrical shapes of the hidden sources. . In our case, we didn't specify a certain kind of model shape to avoid the uncertainty of the expected source bodies, and also it is preferable for regional data (**MacLeod et al., 1993**). For that reason, the interpretation method selected must related to the geology (**Vallee et al., 2004**).

The concepts of the geologic evolution of the East China Sea have heavily depended on single-channel seismic and aeromagnetic data, whereas the abundant multi-channel seismic and other geophysical data by both domestic and foreign exploration activities have not been integrated (**KIGAM, 1994**).

The marine magnetic survey carried out in Sokotra basin have used the results of the previous geophysical and geological information surrounding the study area to get a fulfill interpretation about the depth estimation and basement configuration.

The low magnetic amplitude of the RTP map are generally concentrated in the middle part and extended to some parts in the eastern side of the study area. However, those concentrated at the middle part reflecting deep sources, which agree with the Changjiang Depression (**Chough et al., 2000**). The high magnetic amplitude are concentrated at the northwestern part reflecting shallow sources which supposed to be basement uplifts, particularly in the absence of geological tectonic information at this part. Further studies can be done to estimate the structural system at this part of the basin.

The drilling information of five wells surrounding the study area have given depths ranges from 1.186 km at well KV-1 to 2.903 km at well Okdom-1, however, the nearest well to the study area (PZ-1) shows a total depth of 1.205 km, which gives relative similar results to the depths of the shallow sources (basement uplifts) concluded from the power spectrum and analytic signal methods at the nearest location to the well.

The geological information mention that the basin experienced downfualting in the Palaeogene, and downwraping in the Neogene, which led to the deposition of the Paleogene and Miocene sequences with thickness supposed to be equal to/or more than 5 km (**KIGAM, 1994**). This is somewhat agree with the thickness results estimated from the power spectrum, particularly at t1 and t2 of values equal to 4.2 and 4.5 km respectively.

In addition, the gravity and aeromagnetic results at the western part of the basin suggest that the depth of the acoustic basement is approximately 5 km (**KIGAM, 1994**). However, and with respect to the study area, the depths estimated from the power spectrum and analytic signal methods indicate relative results to those concluded from the western part, particular at d1, d2 and d4 (power spectrum) of values equal to 5.7, 5.6, and 5.1 km respectively. Also, at a1, a2, and a4 (analytic signal) of values equal to 6.1, 4.8, and 4.7 km respectively. These results expect to reflect the basement troughs exist in the basement surface.

The obtained results have been helped to locate the boundaries between the basement uplifts and troughs as it agree with the geologic information at the southeastern part of the study area (**Chough et al., 2000**). They also detected the most prospective areas for any future exploration work.

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