Aeromagnetic Interpretation Data to Locate Buried Faults a case study of Tabas Region, Eastern Iran

Dr Mohammad Aryamanesh[1] and Dr Mehdi Zare[1]

Abstract

The aeromagnetic data is used in the reduction of poll, the first order derivation in vertical direction and Euler deconvolution, to elucidate the subsurface structures and redefine the structural zoning of Tabas region – eastern Iran. The main objective of this study is to delineate the buried faults and structural setting of the area, and define the main tectonic trends, responsible for the structural features. The present study deals essentially with the application and correlation between geology and aeromagnetometry to establish the structural framework of the area. Two interpreted magnetic basement structural (IMBS) maps are constructed along the two computed interfaces to show the structural setting of study area, including the display of uplifted and subsided blocks in it. Filtering combined with analytical upward continuation on the two assigned interfaces is then conducted. The shallow and deep anomalies can be determined and the structural setting indicated through four model profiles across the area under investigation. The structural elements affecting the basement complex at the two assigned interfaces are delineated and the fault system is statistically analyzed to determine the main structural trends affecting the area. The trend analysis of these structural elements shows that the most abundant trends affecting the area are the NW-SE followed by the NE-SW and then the E-W, considered as the most ancient trend affecting the area under investigation.

Keywords: Aeromagnetic, Buried Faults, Tabas, Eastern Iran.

Archive of SID

Introduction

The study area is located in the central part of the eastern desert of Iran (Fig.1) and covered by good outcrops of Precambrian basement complex, igneous and metamorphic rocks, Cretaceous sandstones and Quaternary sediments. The present study deals with the application and correlation between geology and aeromagnetometry to establish the structural setting of the area under investigation. The area is very important from the viewpoint of sesimotectonical problems..Tabas depression is located in this area and contains extensive salt flats, sand dune and other Quaternary alluvium which have been surrounded by series heights such as Shotori in the east, Kalmard in the west, Kalshaneh and Shirgesht in the north, and Cheshme Rostam and Se-changi in the south. Neogene red beds and various Mesozoic sediments are also exposed in the Tabas Depression. Shotori, Kalmard and Cheshme Rostam, and Tabas faults, seen across the area, are active. However, the knowledge about the buried faults in the area is rudimentary due to the paucity of geologic data. Therefore, the existing model on seismotectonic zoning of the area is revisable which can affect the seismic hazard analyses and produce new

[1] International Inistitude of Earthquake Eangineering and Seismology

www.SID.ir

results. To construct coherent and realistic models, the data from large areas should be synthesized and the aeromagnetic and gravity data can be used. Airborne magnetic survey is an indirect exploration tool for refining structural zoning and recognizing magnetic lineaments.

Aeromagnetic applications are well known in a wide variety of geological studies, playing an important role in tracing lithological contacts and recognizing the structures such as: faults and shears, dykes and layered complexes. Aeromagnetic data along with conventional geological maps can be used in the evaluation of various earth resources. (Reeves, 1999). The regional aeromagnetic study of anomaly map brings out the regional geological pattern and structural features, and provides an exceptional background for interpretation of specific purposes (Sharma. 1986). The aeromagnetic data, available in the Geological Survey of Iran (GSI), is the only fairly uniform database and complete data coverage that can provide a coherent view in reconstructing the tectonic evolution of the region. Analysis of aeromagnetic data over this large region (>250,000 km2) has not been attempted before. In this study, it is demonstrated that the quantitative analysis of magnetic data is used to delineate the geotectonic blocks of the region.

Objectives

The principal objectives of this research are to demarcate the buried faults, define the depths of magnetic sources and identify the important trends and structures in the magnetic anomaly field. Monopolar forms of the magnetic field anomaly are required for both depth estimation and trend analysis.

Aeromagnetic data

The survey area is flown in blocks of constant barometric altitudes of 3500, 5500 and 6000 feet. The traverses are flown with headings of 180^o and 360^o degrese for the 3500 and 5500 feet blocks, respectively, and 90^o and 270^o degrees for 6000 feet block, respectively, with 7.5 km spacing. The tie lines were flown perpendicular to the traverse with a 40 km spacing. The exact flight path location is given in the map (Map No). The numbers on the flight lines are referred to either the line or fiducially (data point) numbers. The contour travel intervals for the total magnetic intensity are in 2 (fine line) and 10 (course line) gammas.

Methodology

Several techniques have been developed for the analysis of aeromagnetic data, which are used in quantitative interpretation, reduction to poll, first order derivation in vertical direction and Euler deconvolution methods, to elucidate the subsurface structures and redefine structural zoning of Tabas region. OASIS montaj software package is used for data possessing. OASIS montaj software, applied in earth sciences, is used for processing and interpretation of exploring data such as geophysical and geochemical ones. This software is used especially to create maps and various filtering functions in order to process and interpret geophysical data. Other software packages like ARC View, Surfer, GM_SYS, etc. are also used as the supplementary tools for main software, if necessary. However, the following are some of the quantitative techniques, applied to delineate the geologic structure of the study area to get a better accuracy**.**

I. Reduction To The Pole (RTP)

The reduction to the pole operation is a data processing technique that recalculates the total magnetic intensity data and the inducing magnetic field of a 90^o inclination. This transforms dipolar magnetic anomalies to monopolar ones centred over their causative bodies which can simplify the interpretation of the data. Reduction to the pole simplifies the assumption that the rocks in the survey area are all magnetized

Archive of SID

www.SID.ir

parallel to the earth's magnetic field. This is true in the case of rocks with an induced magnetisation only; however, remanent magnetisation will not correctly deals with the direction of remanence different from that of the earth's magnetic field. In sedimentary basins, remanence is usually not considered as a problem. In the majority of cases the RTP transform is stable. RTP does not work as well close to the magnetic equator (<10^o declination) as there is a large correction to be made for the amplitude of the anomalies. This is usually addressed using specially designed variations of the RTP transform. Errors in the RTP transform usually appear as narrow anomalies elongated parallel to the declination of the earth's magnetic field. While the RTP transform is usually applied to grids, it can be used in the profile data as well.

II. Euler Deconvolution

The Euler deconvolution is used as an interpretation tool to determine the source location of potential fields and the well established anomalies. Thompson (1982) developed the technique and applied to profile data; Reid et al. (1990) developed the more widely used version for grid-based data. Euler's homogeneity relation has attracted sporadic interest from geophysicists over the years. It may be stated succinctly in the form of:

$$(x-x_0)\frac{\partial T}{\partial x}+(y-y_0)\frac{\partial T}{\partial y}+(z-z_0)\frac{\partial T}{\partial z} = N(B-T) \quad (1)$$

where, (*x0*, *y0*, *z0*) is the position of a source whose total field *T* is detected at (*x*, *y*, *z*). The total field has a regional or background value of *B*. *N* is the degree of homogeneity, interpreted physically as the fall-off rate with distance and geophysically as the structural index (Thompson, 1982).

Euler deconvolution assists the interpreter, indicating portions of the data which can then be modelled in detail. No particular geological model is assumed; a range of elementary magnetic distributions such as point poles and dipoles are used as the source of the anomalies. The input is a magnetic, gravity or analytical signal profile, and the output is a location plot of the different types of present sources. The method is used for rapid interpretation of magnetic and gravity data. It is particularly good for delineating contacts and rapid depth estimation. The quality of the depth estimation mostly depends on the choice of the proper structural index. The structural index is a function of geometry of the causative bodies.

Geology and tectonic setting of the area

Geologically, Tabas area is part of central Iran (Stocklin, J., 1968), a triangular region comprised of complicated geologic units. This complex was deformed by orogenic movements from the Precambrian to Triassic. Much of the area is covered by younger continental deposits of the Iranian platform. The rock types are divided into three main lithounits: 1- Shotori heights, consists of limestone and dolomite in the east of Tabas city, 2- the Kalmard mountains with almost similar units, towards the west of the study area, 3- The middle part, covered by quaternary deposits. Right-lateral shear is taken up on several north-south right-lateral fault systems that surround the Lut desert. In the north, the right-lateral shear is seen as clockwise rotation about vertical axes of east-west left-lateral shear. Shortening components are associated with the strike-slip faults, resulted in widespread thrust faulting (Nowroozi, A., 1976). These thrust faults often fail to reach the surface ('blind' faults).

Shotori mountain range, at the northern end of Nayband active fault, is one of the east central Iranian ranges towards the east of Tabas city, but the low rates of seismicity lead to the central parts of Iran, west of Tabas area, considered as relatively strong and non-deforming crustal

Archive of SID

www.SID.ir

blocks in which relatively few active faults have been mapped and relatively few historical earthquakes recorded (Ambraseys and Melville, 1982). However, there are clear evidences of Quaternary fault movement in these areas. Many of these fault systems have been responsible for destructive earthquakes and pose a serious seismic hazard to local populations. However, little is known of their evolution, development and rate of slip. The seismic activities in Eastern Iran are characterized by the occurrence of large magnitude shallow earthquakes, concentrated in limited regions on active fault zones around Lut Block. Considering the pattern of seismicity around Lut Block, the characteristic of earthquake occurrences as well as north to south migration on their bounding fault zones in the west and east shows an alternative occurrence of large destructive earthquakes on the northeast and southwest borders,. The borders between the blocks absorb some kinetic energy between the plates and create complex structures. Considering these facts we believe that the existing structures can not be justified by a simple tectonic regime. Numerous studies indicate that there are various models for the tectonic setting of the study area. Some suggest that central Iran has been formed as a result of suturing of sub-continents, transformed to a sub plate and faced transformations and rotations. Some others suggest that central Iran consists of the plates and right lateral movements dissected into inter-continental basins, dependent structures to which the changes are related. What is important is that these borders blocks consist of the main faults of the region that are deep and more or less indicators of infrastructure changes. Their kinetic inversion during compression- tensional phases indicates that the deep expression and witnessing long geological history of the main faults. Some of them have been controlling the sedimentation regime and geometry of the old basins. Thus, the above mentioned zones can be considered as a collection of rigid blocks, moving and displacing beside each other; those which have controlled the old basins have been surrounded by a large thickness of different sediments. The Shotori mountain range is one of the east central Iranian ranges in the east of Tabas city.

Folds and faults are the most important structures in the area (especially in the eastern parts). They show 3 main trends: N-S, NW-SE and W-E .The recent brittle deformations along with sudden movements have induced an incompatibility. Generally, main faults structures in the Shotori system emerge only in the right-lateral forms, while the younger structures in the Tabas plain, most often, exhibit left –lateral shapes. All these evidences point to a complicated tectonic regime, caused by the interaction of the regional and local stress fields.

Aeromagnetic interpretations and discussion

Here, as the first step, in order to get the total – field magnetic map Oasis montaj software package is applied. Finally the processed total-field magnetic flight line data are girded using a minimum curvature routine, about one-fourth of the line spacing of the survey. The data are displayed as a color shaded-relief image (fig. 2). This is the basic map for magnetic interpretations which shows total magnetic field, fig. 2, due to the existence of various geological units in the area. Different magnetic anomalies have been exposed in depth, from low to high intensity ranges. As stated above, the total magnetic field in each point is influenced by the existing materials and magnetic structures.

The IGRF (International Geomagnetic Reference Field) value is eliminated from recorded data and the remained value is assigned to the existing anomalies in the region. Due to the earth inclination angle and magnetic deviations, the source of these abnormalities evidently seems not to be seated exactly under measurement points as their shapes may also be changed

Archive of SID

www.SID.ir

slightly. On the other hand, the existence of magnetic dipole masses and the way they are positioned against the earth magnetic field direction and data line extensions may change the field magnitude or resulted abnormal shapes. This problem can be resolved by eliminating these effects through applying digital filters. Therefore, magnitude and shape of observed anomalies can be attributed to their origins after eliminating the effects. In this study the total magnetic field of each lithological unit shows an especial magnetic response which is discussed briefly.

The main objective of this study is to delineate buried faults, so special filters should be used to get a clear view of the aeromagnetic condition of the area. For this purpose, several interpretation methods are applied with the final goal of enhancing the signature of shallow faults and aeromagnetic lineaments. The methods include reduction-to-pole, gradient window, anomaly separation, and depth estimation using horizontal gradients. The interpretation is accomplished using reduction-to-pole in conjunction with the total magnetic intensity maps. The interpretation of faulting and folding is based on the existence of continuity or discontinuity of both magnetic anomalies and calculation of depth to the magnetic sources, plotted on the map. The basic information, including both magnetic data and calculated depth values, should be accurate, although the depth values are from shallow volcanic and intrusive rocks in some areas and may be misinterpreted as basement and vice-versa. The exact location and direction of the faults and mapped structures are available and may be changed as new geological and geophysical data. Generally, structural and tectonic processes may influence the magnetic response of geological units; e.g. fault zones or fractured zones normally show low intensity..It can be due to the water flow or some weathered minerals. The shapes of these abnormalities are generally shown in the form of linear structures. In contrast, some of these regions also may be influenced by the mineral formation processes of mineral solution and form the secondary magnetic minerals. In this case, such structures show linear magnetic anomalies with high density.

The enhancement provides more comprehensive view of fault patterns than other available methods. Therefore, the first order derivation map is applied in the vertical direction. The derivation method is used in the investigation of magnetic field density changes (gradient) in various directions. A digital filter, the first order derivation in the vertical direction is used to enhance surface abnormalities compared to deeper ones. Applying this filter on reduction of pole map, the surface abnormalities will become more outstanding, thereby the behavior of these magnetic masses in surface can be studied better. One of the important applications of first order vertical derivation is finding magnetic lineaments and determining the border between lithological units more exactly. The mentioned map is used in the final interpretation of determining these lineaments and the magnetic field density changes in vertical direction is shown in fig.5. These effects are manifested as a shift of the main anomaly from the center of the magnetic source and are due to the vector nature of the measured magnetic field. Gradient window method is applied to enhance the lineaments signature. The horizontal-gradient method (Cordell and Grauch, 1985; Blakely and Simpson, 1986) is based on the gravity and magnetic methods principle, from which steep gradients occur over near-vertical contacts between units of different physical properties. For magnetic data, the same principle can be applied after transforming the data into a form, mathematically similar to the called pseudogravity data (Baranov, 1957). Local peaks (or ridges) in the magnitude of the horizontal gradient of pseudogravity give the locations of

Archive of SID

www.SID.ir

steepest gradients, intuitively similar to taking the first derivative of a curve. A method modification, isolating the horizontal-gradient magnitudes, is associated with short-wavelength anomalies (Grauch and Johnston, 2002). In this step, the linear anomalies relevant to the faults are clearly evident after application of the gradient window method (fig. 3), and the aeromagnetic lineaments map are prepared (Fig.4). These aeromagnetic linear structures might be considered as buried faults in the area.

The depth of the recognized anomalies are estimated, as the next step, using Euler deconvolution standard method. Euler method is based on the concept that the magnetic fields of localized structures are homogeneous functions of the source coordinates and therefore satisfy Euler's equation. Euler deconvolution method is used to estimate the approximate depth of obtained lineaments. This method works on gridded magnetic data in order to determine the depth of magnetic source. This method is the first step toward interpreting the depth which can specify a general and useful estimation of magnetic source distribution. Other methods like modeling and analysis, based on profiles, are needed in estimating the depth of high quality. For determining magnetic lineaments, using Euler methods, the structural index of (SI=0), windows size of 20X20 and flight altitude as barometric and 2500 are used. So the obtained depth is measured against the sea level. Fig. 5 shows that the correspondence of anomalies depth with obtained depth is possible from Euler method (Fig.5).

Conclusion

High-resolution aeromagnetic data over the region of Tabas show many subtle, generally east-western aeromagnetic anomalies - striking, linear to sinuous features superposed on large-amplitude anomalies produced by magnetic bedrock. The linear anomalies are akin to those demonstrated and similarly corresponded well to geologically mapped faults. But in this some new lineaments are found with an E-W trend not exposed to the geological map and on the surface. Thus, these anomalies can be used to extend faults beyond their mapped surface exposure or infer previously unknown faults where they are covered by thin superfacial deposits. Further, it is interpreted that the gradients and anomaly separation are required to protect them against the influence of the large-amplitude anomalies. In particular, the gradient window method worked well to reveal a comprehensive pattern of faulting within the basin fill. Anomaly separation prior to depth estimation increases the determining resolution of the depth range of shallow sources where there is the interference of deeper sources. The methods, altogether, provide the patterns and general depth ranges of intrabasin faults within the geothermal field that will aid in the researching the relation between faults and the geothermal reservoir. Generally, according to the existed magnetic information in the region, collected by relatively high flight altitude, lineament of deep and regional and big terrains are recognized. According to aerial geophysical data, lineaments with northeast-southwest extension have the most correspondence with the faults, recognized on earth surface. In this study, the faults with east-west trend, having no geological reports, are recognized. However, the shadows of linear east-west structures of the region can be found on the earth surface. Tabas faults are generally planar and haven't much depth and are often deep faults of Shotori and Kalmard faulting zone.

It is concluded that the obtained lineaments have a good correspondence with the regional faults. In case of insufficient available information about the existing faults in the region, it is recommended to use aeromagnetic data for seismic potential studies.

Archive of SID

www.SID.ir

Acknowledgment

The auther is thankful to all colleagues in the department of aeromagnetic, geological survey of Iran for their cooperation in providing the aeromagnetic data.

References

- Sharma, K.K.(1998) Geologicalevolutionand crustal growth of the Bundelkhand craton and its relict in the surrounding regions,North Indian Shield .In: Ed. Paliwal, B.S. The Indian Precambrian, Scientific Publshers, Jodhpur, India. pp 33 –43.
- Thompson, D.T. (1982) EULDPH: A new technique for making computer-assisted depth estimates from magnetic data: Geophysics, v. 47, p. 31-37.
- Reid, A. B., J. M. Allsop, H. Granser, A. J. Millett, and W. I. (1990) Somerton, Magnetic interpretation in three dimensions using Euler deconvolution, Geophysics, v.55, p.80–91.
- Stocklin, J., 1968- Structural History and Tectonics of Iran; A Review Bull Am. Assoc Petrol. Geol., v. 52, pp.1229-1258.
- Takin, M., 1972- Iranian Geological Survey.
- Nowroozi, A., (1976) Seismotectonic Provinces of Iran, Bull. Seism. Soc. Am.66, pp1249-1276.
- Ambraseys, N. N. and C.P. Melville. (1982.) History of Persian earthquakes. Cambridge earth science series. Cambridge (U.K.); New York : Cambridge University Press,.
- Blakely, and Simpson, R.W.,(1986) Locating edges of source bodies from magnetic and gravity anomalies: Geophysics, v. 51, p. 1494-1496.
- Cordell L., and Grauch, V.J.S., (1985) Mapping basement magnetization zones from aeromagnetic data in the San Juan Basin, New Mexico, in Hinze, William J. (ed.), The Utility of Regional Gravity and Magnetic Anomaly Maps: Society of Exploration Geophysicists, Tulsa, Oklahoma, p. 181-197.
- Baranov V., (1957) A new method for interpretation of aeromagnetic maps: pseudo- gravimetric anomalies, Geophysics, v. 2, no. 2, pp. 59-383.
- Grauch V.J.S., and Johnston, C.S., (2002) Gradient window method: A simple way to isolate regional from local horizontal gradients in potential-field gridded data: 72nd Annual International Meeting, Society of Exploration Geophysicists.
- Reeves (1990) Olympic Dam copper-uranium-gold-silver deposit; In Geol-ogy of the mineral deposits of Australia and Papua New Guinea, The Australasian Institute of Mining and Metal- lurgy, Hughes, F.E., Editor, p. 1009-1035.

Archive of SID

www.SID.ir