Horizontal gradient and band-pass filter of aeromagnetic data image the subsurface structure; Example from Esh El Mellaha Area, Gulf of Suez, Egypt.

Essam Aboud[1], Serguei Goussev[2], Hassan Hassan[2], Suparno Supriyanto [1], and Keisuke Ushijima[1]

[1] *Graduate School of Engineering, Kyushu university, Japan*
[2] *Geophysical Exploration & Development Corporation (GEDCO), Canada*
e.aboud@mine.kyushu-u.ac.jp

Summary

The Esh El Mellaha area is located on the western coast of the Gulf of Suez that is considered the main hydrocarbon resource in Egypt. The main exploration problems in and around the Gulf of Suez are the complexity of the basement structure and the Pre-Miocene salt formation that masks the seismic energy. Herein, we attempt to image the subsurface fault-system structure of the study area using interpretation of magnetic data based on band-pass filter and horizontal gradient technique. The results are compared with the available information; such as geologic map, drill-hole data, topographic data, and 2D seismic data in the northern part of the area. In general, the area is dissected by a system of faults most of them trending in the NW-SE (Red Sea trend) and NEE-SWW (Tethyan trend). Also, the band-pass filter and horizontal gradient technique could be used in imaging the subsurface structure of the area.

Introduction:

Aeromagnetic data have been widely used by petroleum industry since the aeromagnetic method was first developed after the World War II (McIntyre, 1980). In oil exploration, structure in oil-bearing sedimentary layers is controlled by topographic features (such as ridges or faults) on the basement surface which can be mapped using aeromagnetic data. Recent improvements in acquisition and processing technology enables better understanding of the subsurface structure and define the basin architecture.

In this paper, we attempt to image the subsurface structure of Esh El Mellaha area using aeromagnetic data survey over that area. The aeromagnetic data is filtered as a qualitative aspect of interpretation. Two filters were successfully used, horizontal gradient and bandpass filter. The objective of filtering is to condition a data set and to render the resulting presentation in such a way as to make it easier for the geoscientist to understand and interpret the significance of anomalies in terms of their geologic cause and setting. This operation can be performed several ways through manual /or automatic techniques. The most effective way to filter is with an understanding of the geologic control and an idea of the desired filtered results. In general, filtering data is powerful tool and often leads to important conclusions, but its use should be related to the nature of the geologic problem to be solved.

The filtered maps, bandpass and horizontal gradient, were used to trace easily the faults that characterized the area. The results were compared with the available geologic information, such as surface geology, drilling holes, gravity map, 2-D seismic lines that were available in the north eastern corner of the study area. In general, the area is characterized by NW-SE trending faults, parallel to the Gulf of Suez and NEE faults perpendicular to the Gulf of Suez.

Data processing

In order to locate the observed magnetic anomalies directly over the magnetic source bodies that caused these anomalies, the Total Magnetic Intensity (TMI) data have been transformed into Reduced-To-Pole (RTP) map as shown in figure (1), assuming a total magnetic field strength of 42,000 nT, inclination of 40^0, and declination of 02^0.

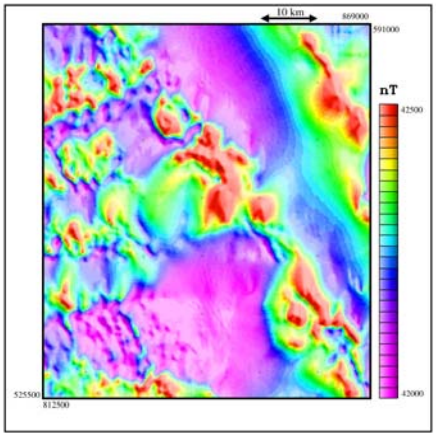

Fig. 1: Reduced-to-Pole Total Magnetic Field (TMF RTP)

The enhancement of magnetic anomalies associated with faults and other structural discontinuities was achieved by the application of bandpass filter and calculation the horizontal derivatives of the TMI-RTP data. Bandpass filter was selected (5-15 Km) after extensive testing of several bandpass ranges to find one which provides the best continuity and resolution. Figure (2) and (3) show the bandpass filtered and the horizontal gradient maps, of TMF-RTP overlain with interpreted faults and intrusions. "Bricks" on faults are placed on the estimated downthrown sides, brown shapes are interpreted as intrusions.

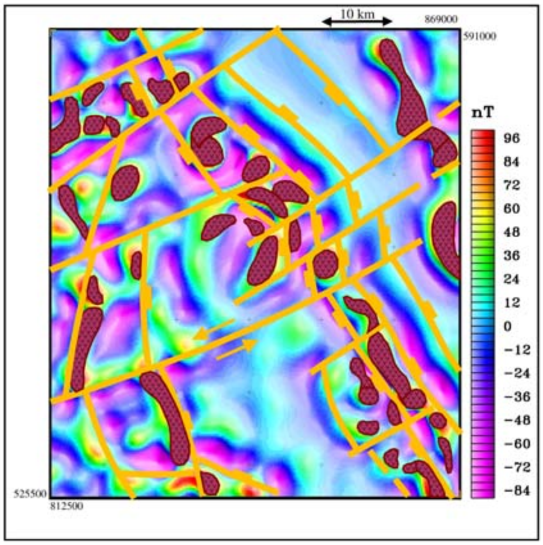

Fig. 2: 5-15 km band-pass filter of TMF RTP overlain with interpreted faults and intrusions

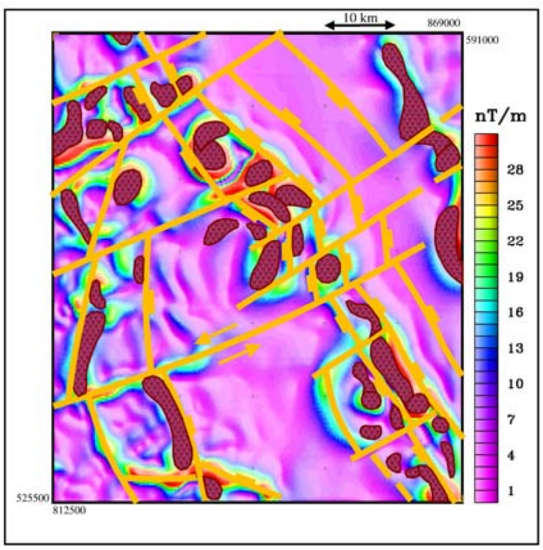

Fig. 3: Horizontal gradient of TMF RTP overlain with interpreted faults and intrusions

The horizontal gradient (HG) method is considered as the simplest approach to estimate the contact locations (e.g. faults). It requires a number of assumptions about the sources, (1) the regional magnetic field is vertical, (2) the source magnetization is vertical, (3) the contacts are vertical, (4) the contacts are isolated, and (5) the sources are thick (Phillips, 1998). In contrast, the method is the lease susceptible to noise in the data, because it only requires the two first-order horizontal derivatives of the magnetic field. If *T* (*x*, *y*) is the magnetic field and the horizontal derivatives of the field are ($\partial T / \partial x$ *and* $\partial T / \partial y$), then the horizontal gradient *HG* (*x*, *y*) is given by:

$$HG(x, y) = \sqrt{\frac{\partial T}{\partial x} + \frac{\partial T}{\partial y}}\,, \qquad (1)$$

Once the field is reduced to pole, the regional magnetic field will be vertical and most of the source magnetizations will be vertical, except for sources with strong remanent magnetization such as basic volcanic rocks (example of which may be existed over Esh El Mellaha). Once, the *HG* data is obtained, the data were upward continued analytically a small interval (2 unit??). Then the difference between upward continued data and the original *HG* is obtained (separation filter) and the output result is considered as Enhancement Horizontal Gradient (EHG) in which the anomalies could be observed clearly and the faults also could be traced along the edges of the anomalies. The EHG map is shown in figure (3).

Data analysis

The TMI-RTP map (Figure 1) displays several dominant trends that do not occur at random but rather are generally aligned along definite and preferred axes that can be used to define magnetic provinces (Affleck 1963; Hall, 1979). The most dominant trend is in the NW-SE direction that is parallel to the Gulf of Suez and associated with the high topographic features of Gabel EL Zeit range, Esh El Mellaha range, and some parts of Red Sea hills. The rock types of these localities could be responsible for these linear anomalies.

The horizontal gradient and bandpass filtered maps (Figure 2 and 3) aided in defining the location of linear features which in turn are related to the trend of the faults in the area. Faults can be traced easily along these linear features which prove the effectiveness of these filters in the interpretation. The faults were traced along both map and compared with the surface faults from the geology and 2-D seismic lines that were covered the north eastern corner of the area (red line square on the figures). In addition, gravity data (re line square) were available and used as a guide in the interpretation for whole the map area. The resulting set of lineaments was compared with available Precambrian wells to determine relative highs and lows in the deep structure. Topography and surface geology map were used to evaluate the correlation between the deep-rooted faults and faults identified on the surface. The Red Sea Hills structural complex is in the WSW part of the area. Based on the consistent magnetic anomaly pattern, the WSW-ENE trending fault in the middle was tentatively identified as a left-lateral strike-slip fault. Interpreted structural elements were shown on figure (4).

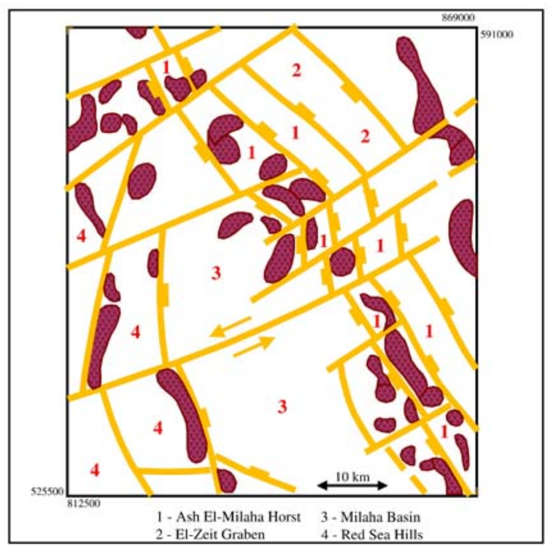

Fig. 4: Interpreted Structural Elements

Conclusion

Using filters in magnetic data is always enhance the data and help define features that were difficult to detect before filters. Integrated interpretation of the geologic-geophysical and topographic data reveals the elements of subsurface structure in the study area. Close correlation between the deep faults and faults mapped on the surface indicates their recent reactivation and control over sedimentation.

References

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