Gravity and magnetic anomalies field characteristics in the South China Sea and its application for interpretation of igneous rocks

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Abstract: Igneous rocks in the South China Sea have broad prospects for oil and gas exploration. Integrated geophysical methods are important approaches to study the distribution of igneous rocks and to determine and identify igneous rock bodies. Aimed at the characteristics of gravity and magnetic fields in the South China Sea, several potential field processing methods are preferentially selected. Reduction to the pole by variable inclinations in the area of low magnetic latitudes is used to perform reduction processing on magnetic anomalies. The preferential continuation method is used to separate gravity and magnetic anomalies and extract the gravity and magnetic anomaly information of igneous rocks in the shallow part of the South China Sea. The 3D spatial equivalent distribution of igneous rocks in South China Sea is illustrated by the 3D correlation imaging of magnetic anomalies. Since the local anomaly boundaries are highlighted gravity and magnetic gradients, the distribution characters of different igneous rocks are roughly outlined by gravity and magnetic correlation analysis weighted by gradient. The results show the distribution of igneous rocks is controlled and influenced by deep crustal structure and faulting.

Keywords: South China Sea, gravity and magnetic fields; reduction to the pole at low latitudes, preferential continuation; igneous rock distribution

Introduction

The South China Sea is surrounded by the Eurasia, Pacific and India-Australia plates. It is one of the largest marginal seas in the Western Pacific. Previous research and exploration have demonstrated that there are abundant oil and gas resources in the South China Sea area. In particular, reservoirs in igneous rocks are good prospects. South China Sea began to experience northwest extrusion from Pacific plate during the rift extension and seafloor spreading in early and post Cenozoic respectively. The multi-stage volcanic activities and magma intrusion resulted in widespread igneous rocks in the South China Sea and continental margin. Late Mesozoic igneous rocks are mainly Yanshan
Interpretation of igneous rocks

Granite rocks concentrating in the northern margin of the South China Sea and the Indochina continental shelf and the western Nansha Islands area. The Cenozoic igneous rocks are mainly basalts, widespread in the continental margin and ocean, especially in the basin rift zone and Taiwan-Luzon arc (Yan and Liu, 2005). The distribution and rock characteristics of igneous rocks have a close relationship with the tectonic properties and structural changes in the South China Sea. The faults are well developed in the South China Sea. The control and impact of fault activity on volcanic activity determine the close relationship between the spatial distribution of igneous rocks and faults (Zhou, 2005).

The stop of igneous rock distribution is the basis of exploration to oil and gas reservoirs in these media. Based on density and magnetic differences between igneous and sedimentary rocks, integrated geophysical studies using gravity and magnetic methods are carried out to determine and identify igneous rocks. However, because of the complicated tectonic evolution, large differences of crustal structure, and diversity of rock types and occurrences in the South China Sea exists at low latitudes, application of the usual or single geophysical techniques to this region cannot yield good results. It is necessary to adopt special and effective methods of processing and inversion for gravity and magnetic data, such as reduction to the pole at low latitudes with variable dips, preferential continuation, and correlative imaging. The usual reduction to the pole factor is a magnification type, which can produce strong amplifications at latitudes near the magnetic equator leading to instability of the reduction calculation. To solve this problem, Yao et al. (2003) suggested a suppression factor method to adjust the reduction factor. Meanwhile, the reduction to the pole method with varying dips in the even layer of the frequency domain can resolve the issue of large latitude changes. Preferential continuation based on Wiener filtering and Green’s equivalence principle (Pawlowski, 1995) is one of the improved methods for analytic continuation. Compared to traditional continuation, preferential continuation minimizes attenuation of the low frequency components and allows extracting regional anomalies precisely and separating local anomalies better. This method is effective separating gravity and magnetic anomalies (Meng et al., 2009) and can be utilized to extract the igneous rock anomalies in the South China Sea. Patella (1997) proposed applying correlative imaging to the interpretation of spontaneous potential anomalies. This method was extended to the fields of gravity and magnetism later (Mauriello and Patella, 2001; Iuliano et al., 2002; Alaia et al., 2008) and does not rely on geophysical data constraints and can be applied to the fast inversion of large-scale data.

In this work, we apply these techniques to the magnetic and gravity anomaly data of the South China Sea and separate and extract the gravity and magnetic anomalies of igneous rocks from the original data. Then we perform 3D correlative imaging on magnetic anomalies and correlative analysis on gravity and magnetic and determine the 3D spatial distribution of igneous rocks, combining with faults at depth derived from the regional gravity and magnetic anomaly fields.

Geological and geophysical setting of the South China Sea

Geological setting

In topography, the South China Sea becomes deeper from rim to center, where are successively distributed the continental shelf, island shelf, continental slope, island slope, and deep ocean basin (Figure 1). In the South China Sea and adjacent lands, there are various sediments and magma rocks of Pre-Cambrian to Cenozoic ages. Because of the long-term evolution, especially reformation in the Mesozoic and sea floor spreading in the Cenozoic, the crust of this region is characterized by vertical layering and horizontal blocks, including continental, oceanic, and transitional crustal types. In the center of the South China Sea, the NE-SW trending basin is oceanic crust. The rim of the sea is transitional crust which links to the continent farther outside. In the central oceanic basin, the magnetic anomaly stripes suggest that this region has experienced two periods of sea floor spreading (Yao et al., 2006, Briais et al., 1993).

The South China Sea has a mosaic-like metamorphic folded basement which is superimposed by sedimentary basins of Mesozoic and Cenozoic ages, which become younger from the center to the rim. Beneath the sea near the Xisha and Nansha Islands is a Pre-Cambrian metamorphic basement, near which are the metamorphic basements of Caledonian, Hercyian, and Indo-China periods. Besides, there are numerous faults in the South China Sea, which can be classified into four groups.