The Depth of Magnetic Basement and Averaged Crustal Magnetic Susceptibility of Afghanistan

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ABSTRACT

In hydrocarbon explorations, knowledge of the depth and shape of sedimentary basins is of crucial importance. Calculating the depth of magnetic basement is capable of estimating the depth of sedimentary basins and their shapes provided that magnetic layers are not intercalated within the sedimentary cover. Calculating the averaged crustal magnetic susceptibility can detect presence of sedimentary basins with intercalated magnetic layers. Applying the fractal spectral method on the aeromagnetic data of Afghanistan, the depth of the magnetic basement and averaged crustal magnetic susceptibility are estimated. The choice of a suitable fractal parameter and an adequate window size is crucial for a reliable approximation of the depth of the magnetic basement and averaged crustal magnetic susceptibility. The calculated depth of the magnetic basement map of Afghanistan highlights the areal extent of the sedimentary basin belt of northern Afghanistan namely the Afghan Tajik, Amu Darya, Kushka and Tripul basins. The large susceptibility of the basins implies that the basins were formed by a volcanic rifting margin. In eastern Afghanistan, Katawaz basin is well detected with a large depth of magnetic basement of ~ 16 km and a low averaged crustal magnetic susceptibility value very similar to Zagros (Iran) suggesting the igneous basement is related to an avolcanic passive margin. Helmand basin has a large depth range suggesting the presence of several sub-basins. The Farah and Rosgan basins show an overall shallow depth of magnetic basement but mean the basins show low averaged crustal magnetic susceptibility. This observation suggests the basin is covered by a thick sedimentary cover despite the presence of surface and interlayered igneous rocks.

Keywords: Afghanistan; Hydrocarbon explorations; Sedimentary basins; Magnetic basement; Fractal parameter; Magnetic susceptibility.

INTRODUCTION

Afghanistan is belted by a set of sedimentary basins including five major basins, namely Helmand, Amu Darya, Afghan Tajik, Katawaz Basin, Kushka Basin and one minor basin, the Tripul basin. The majority of Afghanistan's sedimentary basins are located in the North Afghan platform. A Jurassic to Paleogene sedimentary rock cover in combination with Neogene syn- and post-orogenic continental clastic rocks unconformably overlies the pre-Jurassic rocks in the North Afghan Platform (Brookfield & Hashmat., 2001). Despite the abundance of these sedimentary basins, oil and gas potential has only been recognized in the Amu Darya and Afghan-Tajik basins. Knowledge of the shape of sedimentary basins is an essential parameter in hydrocarbon exploration. The magnetic basement corresponds to the depth to the top of fresh (i.e., unaltered) igneous rocks. The magnetic basement is a close proxy for shape of sedimentary basins if all sedimentary rocks are non-magnetic. For the depth of the magnetic basement to correlate with the thickness of the sedimentary basins, the igneous basement must be strongly magnetized with respect to the overlying sediments and there must be no intercalary magnetic layer in the sediments. The average crustal magnetic susceptibility map has the advantage of highlighting the intercalated magnetic layers in the sedimentary cover of a sedimentary basin. Sedimentary basins with sedimentary cover thicker than 5 km could have potential for hydrocarbon resources. Sedimentary rocks have low magnetic susceptibility thus ensuring a high depth of magnetic basement. A sedimentary basin with large depth of magnetic basement but with high average crustal magnetic susceptibility implies that the basin was formed by a volcanic rifting process.

In the presence of an intercalated magnetized layer of significant thickness, the depth of the magnetic basement would approach the thickness of the sedimentary column above the magnetized layer and this will not give the exact shape of the sedimentary basin. The only remedy to detect such basins is to use average crustal susceptibility which is low over such basins.

DATA & METHODOLOGY

The RAPS method (Pilkington 1993; Maus & Dimri 1995; Maus et al. 1997; Lovejoy et al. 2007; Bouligand et al. 2009; Teknik and Ghods 2017; Kelemework et al. 2021) is used to calculate the depth of the magnetic basement of Afghanistan, and the averaged crustal magnetic susceptibility by using the available aeromagnetic data of Afghanistan produced by United States Geological Survey (2006-2008). The power spectrum of magnetic anomalies is sensitive to the depth to the top and bottom of the magnetic basement, the fractal dimension of magnetization and the size of the window used to calculate the power spectrum.

The calculated susceptibility represents the vertical average susceptibility of the magnetized part of the crust (Teknik et al 2020). The large magnetic susceptibility values are generally observed in igneous rocks and ophiolites, in contrast to the low values in most sedimentary rocks or igneous rocks that have undergone pronounced alteration (Clark and Emerson, 1991; Hunt et al., 1995; Teknik et al., 2017). Since sedimentary rocks are generally weakly magnetized, an area with low magnetic susceptibilities can be interpreted as a sedimentary basin occurrence. Even for sedimentary basin with interbedding magnetic layer, the average crustal susceptibility could be low. In this case, we can still detect presence of as sedimentary basin despite its low depth to magnetic basement.

RESULTS

The map of the depth of the magnetic basement of Afghanistan (Figure)and the averaged crustal magnetic susceptibility map (Figure) are computed using 85 percent overlapping windows of 120 × 120 km, a constant thickness of the magnetic slab (ΔZ) of 30 km and a constant fractal parameter (β) of 3.

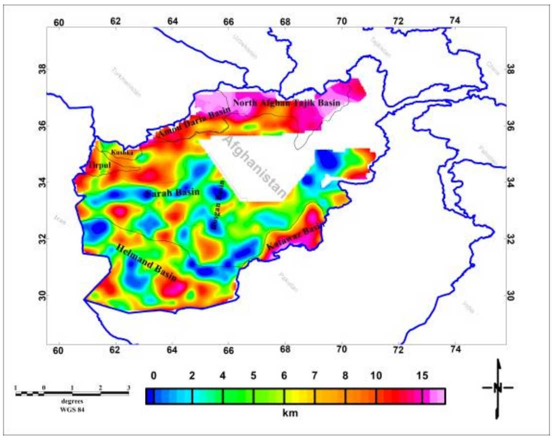

Figure1. Afghanistan's sedimentary basins (momp.gov.af., 2020) overlaid on the depth of the magnetic basement map.

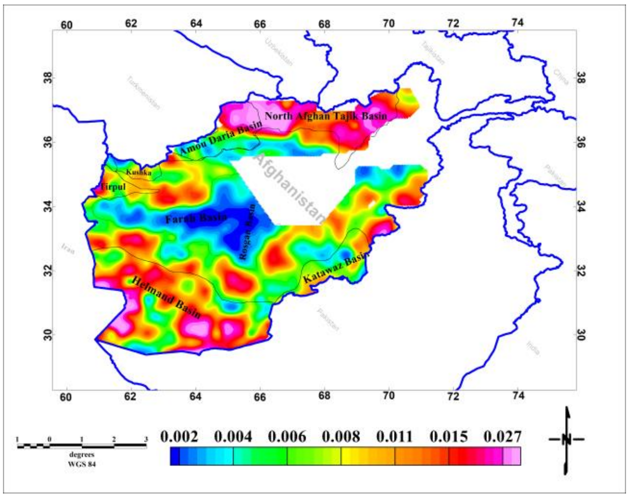

Figure 2: Afghanistan's sedimentary basins (momp.gov.af., 2020) overlaid on averaged crustal magnetic susceptibility map.

CONCLUSIONS

The depth of the magnetic basement map of Afghanistan has highlighted the areal extent of the sedimentary basin belt of northern Afghanistan namely the Afghan Tajik, Amu Darya and Tripul basins. In eastern Afghanistan, Katawaz basin is well detected with a large depth of magnetic basement of ~ 16 km, and Helmand basin has a large depth range suggesting the presence of several sub-basins.

The averaged crustal magnetic susceptibility map shows strong susceptibility in northern Afghanistan suggesting the igneous basement is related to a volcanic passive margin and covered with significant volcanic layers. The Helmand area with the accreted terranes is represented by a broad swath of averaged crustal magnetic susceptibility. Likewise northern Afghan platform sedimentary basin, the subbasin with large depth of magnetic basement are associated with large magnetic susceptibility. Katawaz basin has a low susceptibility value very similar to Zagros suggesting the igneous basement is related to an avolcanic passive margin. The depth of the magnetic basement map of Afghanistan shows a central area of Afghanistan corresponding to Farah and Rosgan basins with a wide range of depths from zero to more than 10 km. The map of the depth of the magnetic basement does not emphasize these two sedimentary basins, but the map of the average crustal magnetic susceptibility does highlight this area of Farah and Rosgan basins. The Farah and Rosgan basins show a low averaged crustal magnetic susceptibility suggesting the basin is covered by a thick sedimentary cover despite presence of surface and interlayered igneous rocks.

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