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The relation between heat flow obtained by curie depth point (CDP) and the faults and gas leaks in the black sea

Abstract

CDP values were measured. They range from 22km to 38km. The deepest CDP values are observed in the Black Sea basins where the sediment thickness is high, while the shallowest values are observed in the middle Black Sea ridge, and in the thin sedimentary regions of the coast. The Central Black Sea ridge generally ranges from 22 to 28 km. From the CDP values, the heat gradient and corresponding heat flow values were also obtained. Heat flow values of the Black Sea basin range from 22 to 41mW/m^2. When the relationship between the deep faults and gas leaks with the heat flow is examined, it is observed that the possible deep fault zones and gas migration places correspond to a higher heat flow value than the average heat flow.

Keywords: black sea; sedimentary regions; black sea ridge; curie depth point; temperatures; basin fault

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Tutunsatar HE,[1] Dolmaz MN,[1] Oksum E,[1] Okyar M,[1] Kalyoncuoglu UY,[1] Starostenko VI,[2] Kutas RI,[2] Rusakov OM,[2] Legostaeva OV,[2] Hisarli ZM[3]

[1]Department of Geophysical Engineering, Suleyman Demirel University, Turkey
[2]Institute of Geophysics, National Academy of Sciences of Ukraine (NASU), Ukraine
[3]Department of Geophysical Engineering, Istanbul University, Turkey

Correspondence: Evrim Tutunsatar, Department of Geophysical Engineering, Engineering Faculty, Suleyman Demirel University, Isparta, Turkey, Tel 00905444161751, Email evrimtutunsatar@gmail.com

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Introduction

The study area includes the marine area of the Black Sea, except for the Azak Sea. The Black Sea has a maximum water depth of 2400m in the 432 000km^2 marine area located on the Alpine - Himalaya belt between the Caucasus in the east, the Pontides in the south, the Balkans in the west and the Crimean Mountains in the north. The Black Sea Basin consists of two deep sub-basins (the West Black Sea Basin- WBS and the East Black Sea Basin - EBS) that are separated by the mid–Black Sea Ridge—an NW trending basement uplift.[1] The origin of the Black Sea and its evolution are still a matter of debates though the area is widely recognized as a back-arc basin due to the northward subduction of the Neo-Tethys Ocean.[1]

According,[2] the average crustal thickness of the Black Sea is 22-28km. WBS has a crustal thickness of 19km and EBS has a crustal thickness of 22km[3] discovered that the crustal thickness is up to 30km on the Middle Black Sea ridge (MBS). The reason of this is explained by the presence of a 5-10km granite layer below the Middle Black Sea ridge. In the central part of the Black Sea, on the basaltic layer, the sedimentation thickness is about 5-10km. The sediments of the basins around the basins are parallel, while the margins contain asymmetrical folds and bindings. Sediments were unevenly stacked over time. It is believed that the sediment accumulation is mostly at Pliocene-Quaternary time.[3] In later studies, it was observed that the sediment thickness of the Western Black Sea basin reached to 19km and it reduced to 12km in the Eastern Black Sea basin.[4] This is because WBS has an oceanic or semi-oceanic crust and EBS has a thinned continental crust. The sediment thickness is about 5-6km on MBS.[5] According to Starostenko V et al.,[6] the crustal thickness is 19km on the basins and 29-33km on the ridge. It is stated that the western basins of the West and East Black Sea basins consist of oceanic crust of 19km and 22km of shallow continental crust, and the continental margin of Central Black Sea consist continental crust.[6] Moho depths in the West and East basins are 20km and 22km respectively. The deepest Moho border has been identified as 40 km under the Shatsky Ridge. In the Black Sea basin basaltic layers, which generally have a speed of 6.6-6.8km/s, dominate. Maden N & Dondurur D[7] detected that sediment accumulation is about 1km thickness of Arkhangelsky ridge.

Fault tectonics seems to play an active role when examining the evolution of the Black Sea. The western Black Sea basin and the eastern Black Sea basin differing physically and evolutionarily are separated from each other by the Odessa-Sinop fault zone (OS) and the continental crust is turning counter clockwise.[8] OS; It is a deep fault zone formed during the expansion of the Black Sea and it moves in a NW-SE direction. The OS fault, which is 100km long, is the continuation of the southern coast of Ukraine Talne fault, which is the pre-Cambrian initial fault zone. Sludge volcanoes, gas outflows and rising heat flow values along OS fault zone are presented in.[9] The eastern part of the OS fault zone is divided into arms with a sloping SW by the rotational movement in a counter clockwise direction. Thus, the Odessa Sinop Ordu (OSO) fault zone formed.[10] The West Black Sea basin fault, which lies to the west of the OS and forms the boundary of the Istanbul block by dividing the western Black Sea basin into two, is a right-strike thrust fault. The West Black Sea basin fault, which is depicted on the sedimentary cover along the western coast of West Crimea at the north of the OS fault zone, is a left-handed thrust fault.[2] However, the existence of The West Black Sea basin fault and West Crimea Fault is controversial.[11,12] These faults are not parallel to each other, and they cannot be classified as transform faults in terms of layer tectonics.[13–15] These faults have upper mantle origin.[14,16] The Alushta-Batumi faults (AB), which is located at the east of the Black Sea, has a diagonal system.[17]

Curie Depth Point (CDP) calculations for the Black Sea are the first aim of this study. The structures that cause magnetic anomalies lose their magnetic properties above the Curie temperatures because of the minerals they contain. CDP is known as the depth at which active magnetic minerals in the crust migrate from the ferromagnetic state to the paramagnetic state under increasing temperature effects. Therefore, the depths of the non-magnetic property were determined by CDP of the study area. One of the procedures to get information about the heat regime in the earth is to calculate the heat flow. For this reason, the study attempted to obtain information about the inner temperature of the study area and other physical properties of the rocks forming the earth's crust, by obtaining heat flow determinations from CDP of the Black Sea and to the CDP's relationship with deep faults and gas leaks.

Method and application

CDP calculations have a serial processing as the reduction to pole of magnetic data, filtering the magnetic data by determining the filter parameters from the spectrum of the whole region, separating the entire study area into the appropriate sub-regions with appropriate dimensions, taking the spectra of each sub-region according to the algorithm of,[18] and their radial averages. Then finding out the center (zo) and the upper depths (zt) of each subregion from the lowest and the second lowest frequency segments.[19] According to this, the equation of CDP is given below

$$q = k\left(dT/dz\right). \quad (1)$$

In general, shallow CDP corresponds to areas with high temperature, whereas deep CDP corresponds to colder areas.

The temperature difference between the ground and the earth causes heat flow. Heat flow is the energy flowing from one substance to another; quantitatively, the amount of heat transferred in a unit time. The multiplications of the heat gradient of the medium (dT/dZ) and the thermal conductivity (k) give the heat flow (Equation 2)

$$q = k\left(dT/dz\right). \quad (2)$$

Here (dT/dz) refers to heat gradient (Grad T). The heat gradient to be used for the heat flow determinations from the CDP is calculated by the following Equation;

$$Grad\ T = 580^{o}\,C/CDP. \quad (3)$$

For CDP determination of the Black Sea, first, low pass filtering was applied to magnetic data which means frequencies smaller than 10km of wavelength were removed. Thus the effects close to the earth surface were removed. Then, the data with low pass filtering were divided into square blocks of 160*160km. The radial averages of the power spectrum of each sub-block are plotted with the number of waves, with 50% interferences. 41 CDP values were calculated for the Black Sea by the Equation 1 and assigned to the centre coordinates of each sub-block.

Conclusion

The CDP map of the Black Sea consists of 41 values ranging from 22 to 38km. The deepest CDP was observed in the Black Sea basins where the sediment thickness was high, while the shallowest values were observed in the Central Black Sea ridge and in the thin sedimentary regions of the coast (Figure 1). The Central Black Sea ridge generally ranges from 22 to 28km.[20] According to Tutunsatar HE[20] Andrusov rift has a CDP of 24 to 26km. Arkhangelsky ridge and around with Dvurechenskogo mud volcanoes have low CDP values (21-23 km). The CDP in the Eastern Black Sea basin ranges from 26 to 33km. It reaches 38km in the deepest points of the Western Black Sea basin. It is thought that the CDP values around 26km in the southwest part of the Western Black Sea basin are derived from the presence of continental slope consisting of Cretaceous volcanic springs and the 24km CDPs in the north are surrendering continental crust of the Moesia plate. The CDP values of 30-32km in the southeastern parts of the Eastern Black Sea are thought to be due to the high Eocene sediments and the high ridge beneath the Trabzon and Gurian depressions. It should be noted that the CDP results are consistent with the.[1]

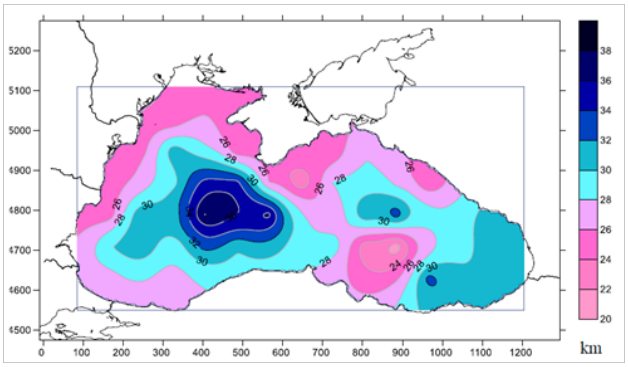

Figure 1 Curie Depth Point (CDP) map of the Black Sea.

Figure 2 shows the heat flow map obtained by the CDP and Curie temperature of 580°C and the heat flow values calculated by taking the average thermal conductivity 1.5 w/m°K for the study area. Where the CDP values are high, it is seen that the heat flow is low and the heat flow is high where the CDP is low (Figure 2). Heat flow values obtained from CDP are independent of sedimentary structure, age and sediment thickness etc.

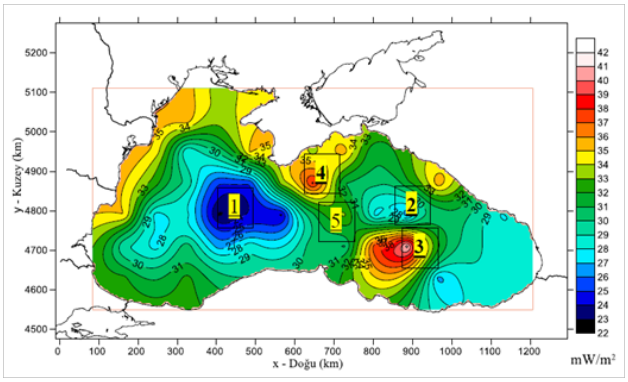

Figure 2 Heat Flow map of the Black Sea.

The heat flow values in the Black Sea basin vary between 22-41 mW/m² (Figure 2). The lowest values of heat flow were observed in the middle parts of the West Black Sea and East Black Sea basins where the sediment thickness is high (1,2). The western and eastern basins have different thermal field morphology. It is thought that the heat flow values of these basins, which are opened at different times, vary depending on the initial temperature distribution during the opening. The opening started in the western Black Sea basin early in the Cretaceous period and started in the Eastern Black Sea basin in the late Cretaceous period. There are remarkable heat flow anomalies

in the eastern Black Sea. Arkhangelsky ridge (3), where the Late Cretaceous volcanic springs are intense, and the Crimean Peninsula and its surroundings (4) have areas with Dvurechenskogo mud volcanoes with relatively high heat flow values. On the west side of the Eastern Black Sea basin, the heat flow in the parts corresponding to the Andrusov ridges (5) is on average 30-32 mW/m^2.

The relationship between heat flow and deep faults and gas leaks is given in Figure 3. The values of the heat flow are above the average in the areas where possible deep fault zones and gas flames or gas migrations similar to.[9] The heat flow values vary from 27 to 34mW/m^2 in gas leaking areas. As seen in Figure 3, the areas where fault zones exist are active in terms of gas density and in these places the heat flow is around 33-34mW/m^2.

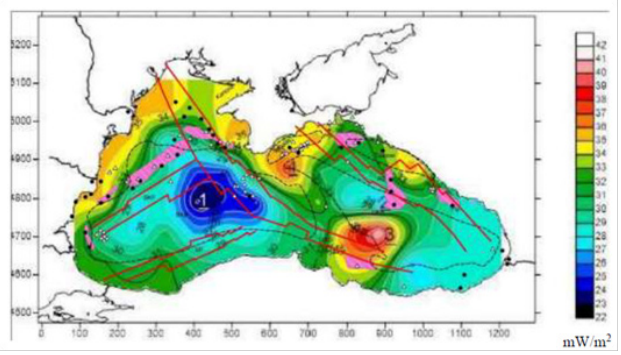

Figure 3 Display of the heat flow map obtained from the CDP of the Black Sea with fault and gas fields. Triangles; Submerged mud volcanoes and dense fluid liquids. The pink areas represent gas leaks and pockmarks.

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Conflicts of interest

Authors declare there is no conflict of interest.

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