

ТЕПЛОВОЙ ПОТОК УЗБЕКИСТАНА:
ГЕОЛОГИЯ И ИНТЕРПРЕТАЦИЯД. Н. АНДРЕЕВ¹⁾, Х. Х. РАХМАТУЛЛАЕВ¹⁾, В. И. ЗУЙ²⁾¹⁾Институт геологии и инженерной геологии Государственного комитета по геологии
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Показана значительная неоднородность теплового поля как в Узбекистане, так и на территории всей Средней Азии. Изучены редкие скважины в пустынях Кызылкум и Каракумы. Определено, что тепловой поток в Узбекистане изменяется в широком диапазоне – от 20–30 до приблизительно 100 мВт/м². Высокие значения наблюдаются в межгорных впадинах и блоках земной коры с плотной сетью глубоких разломов. Тепловой поток значительно увеличивается в южной и восточной частях Узбекистана, как и на соседних территориях, прилегающих к горным сооружениям Тянь-Шаня и Памира, характеризующихся высокой сейсмичностью и активной тектонотермальной активизацией. Составлены карты плотности теплового потока Узбекистана и Ферганской впадины, на которых отражена региональная изменчивость геотермического поля. Отмечено значительное возрастание степени дифференциации по тепловому потоку по мере перехода от сравнительно равнинной территории Туранской плиты к горным сооружениям, что типично в целом для всего орогенного Альпийско-Гималайского пояса.

Ключевые слова: геотермические исследования; геотермическое поле; тепловой поток; карта теплового потока; Узбекистан.

HEAT FLOW OF UZBEKISTAN:
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The first determinations of the heat flow density in Uzbekistan, as well as in Central Asia as a whole, were carried out in the middle 1960s. In subsequent years, many researchers, primarily in connection with the search and exploration of oil and natural gas deposits, studied the geothermal field of the region. The data accumulated to date show a significant heterogeneity of the thermal field in both Uzbekistan and the adjacent territory of Central Asia. Rare wells were studied in the desert areas of Kyzyl Kum and Kara Kum. The heat flow in Uzbekistan varies over a wide range from 20–30 to approximately 100 mW/m². Its high values are characteristic of intermountain depressions and blocks of the earth's crust

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with a dense network of deep faults. The heat flow increases significantly in the southern and eastern parts of Uzbekistan, as well as in the neighbouring territories adjacent to the mountain structures of the Tien Shan and Pamir, characterized by high seismicity, tectonic and thermal activation. An updated map of the heat flow density of Uzbekistan was compiled and, separately for the Fergana Depression. They reflect a significant regional variability of the geothermal field. With the transition from the relatively flat territory of the Turanian Plate to mountain structures, the degree of differentiation by the heat flow increases significantly. This is typical of the entire orogenic Alpine-Himalayan Belt.

Keywords: geothermal investigations; geothermal field; heat flow; heat flow map; Uzbekistan.

Introduction

The main part of Uzbekistan is relatively plain area with orogenic structures of Tien Shan in southern and eastern parts of the country (fig. 1). Many researchers studied geothermal field including the territory of Uzbekistan since 1960–70s. Works on the geological study of this region using drilling were carried out both with the aim of mapping the geological structure of the region, as well as searching for minerals. Largely, they were stimulated by exploration activities for oil and gas related to drilling deep wells and consolidating the network of production wells within areas prospective for identifying new oil and natural gas fields and their subsequent exploitation. As a result, hundreds of thermograms were recorded in deep wells throughout the entire Central Asian region, including the territory of Uzbekistan. As is known, the availability of thermograms is the main requirement for conducting research on the heat flow density, an important parameter, that characterizes in an integral form the degree of heating of the upper part of the earth's crust and its geodynamics. The tectono-thermal activity of the crust is reflected both in seismicity and manifestations of hot springs. Around 80 thermal and subthermal springs were observed within the territory of Pamir and adjoining areas belonging to the Alpine-Himalaya folded belt [1].

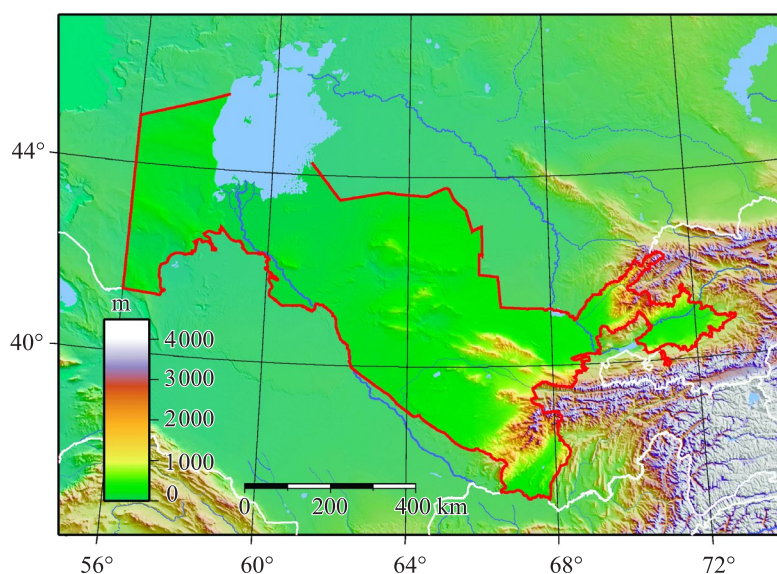


Fig. 1. Relief of Uzbekistan.
Source: [2], modified

Geology

The territory of Uzbekistan with a variety of crustal blocks can be subdivided in geological terms into two large tectonic regions: the orogenic region of the Tien Shan and the Turanian Plate. Both extend to neighbouring regions far beyond the borders of the country.

The Tien Shan region includes large and small tectonic units. The largest of them are folded structures (Chatkal, Kuraminsky, Turkestan, Zarafshan ranges). Folded complexes of geosynclinals of the South Tien Shan include the Zarafshan, Turkestan, Nuratau, Kuldzhuktau ranges, as well as the mountains: South Tamytau, Auminzatau, Sultanuizdag. During Hercynian mountain formation, volcanic processes took place along with tectonic movements.

The following geological structures are distinguished in Uzbekistan: the Amu Darya and North Kyzyl Kum synclises, the Central Kyzyl Kum Uplift Zone, the Nuratino-Zarafshan Uplift and a group of the same name intermountain depressions, the Ustyurt group and the Chatkalo-Kuramin system of structures, the near-Tashkent

Piedmont Trough and the Ferghana Depression. They are broken by a system of active deep faults. Their dense network exists in the South Tien Shan. These structural forms are characteristic of the Palaeozoic geosynclinal structures included in the Ural-Mongolian Mobile Belt [3]. Deep faults delimit the blocks of the earth's crust.

The Turanian Plate in Uzbekistan includes the Ustyurt Plateau, the Bukhara-Khiva and Surkhandarya depressions and the Central Kyzyl Kum Uplift. The basement of the plate is composed of Lower Palaeozoic crystalline schists, and the sedimentary cover is the thickness of terrigenous, carbonate and salt-bearing sediments of the Carboniferous-Quaternary age. In the Central Kyzyl Kum Uplift, the basement is represented by Hercynides of the Southern Tien Shan, overlain by a thin sedimentary cover – terrigenous-carbonate deposits of Cretaceous and Paleogene time [4; 5].

The tectonic activity of mountainous Uzbekistan is gradually shifting from the Caledonian Northern Tien Shan to the Pamir with its Alpine folding. In the south and east of the mountainous part of Uzbekistan are adjacent territories of the Turkestan, Alai, Zarafshan, Kuramin and Gissar mountain ranges. In the west, these ridges are declining and in the south central part of Uzbekistan, they are gradually turning into plains of the Turanian Plate. Intermountain troughs include Ferghana and Tajik-Afghan ones.

The near-Tashkent Trough has Oligocene-Anthropogenic age. The lower-Hercynian and Upper-Alpine structural floors are distinguished. The structure of the rocks of the lower one is not clear enough due to their exposure mainly on the outskirts of the depression.

The Ferghana Depression is entirely located in eastern Uzbekistan. It is about 300 km long and 170 km wide and represents the largest intermountain trench of the Tien Shan with elevations from 350 m in the west to 1 km in the east. It is bounded in the north by the Kuraminsky and Chatkalsky, and in the south by the Turkestan and Alai ranges. Its interior is an accumulative plain. The Syr Darya River runs its water in the northern part of the basin.

The Tajik-Afghan Depression is morphologically associated with the southwestern spurs of the Gissar Range, and in the east – with the spurs of the Darvaz Range, which belongs to the Pamir system outside the region under consideration.

Plains to the west of the southwestern spurs of the Gissar Range represent an extensive semi-desert or desert monotonous plain, bounded in the south of the river Amu Darya and in the west – the Bukhara Oasis. A significant territory in Uzbekistan is occupied by the Kyzyl Kum Desert.

Active tectonic movements almost everywhere continue on the territory of Uzbekistan. Strong earthquakes occur here. Historical data also indicate devastating earthquakes of past centuries [5].

There are five oil-bearing provinces within the territory of Uzbekistan, they are Ustyurt in northern part, Bukhara-Khiva in central part, Southwestern Gissar, Surkhan Darya in south, and Ferghana one in the east.

Geothermal investigations within the region

The first data on the thermal regime within Central Asia were published in the second half of the 1960s [6]. At that time, more than 60 values of heat flow were determined in the whole Central Asian region, including the territory of Uzbekistan, as well as the neighbouring regions of Kazakhstan, a part of Kyrgyzstan west of Issyk Kul Lake and north-west of Tajikistan. The available data were shown on the first heat flow map [6]. In subsequent years, they were supplemented with new data [1; 7–20 and other researchers]. Most of the data in the Central Asian region was obtained before the collapse of the Soviet Union with the separation of Uzbekistan, Kyrgyzstan, Tajikistan and Turkmenistan, as well as Kazakhstan. Heat flow data for Central Asia, including the territory of Uzbekistan, were included in the catalogue of heat flow of the USSR compiled in the first half of the 1970s [21] with subsequent additions. The first schematic heat flow map of Central Asia showed only heat flow points, without isolines of its distribution, performed in the wells of the Ferghana and the Bukhara depressions (fig. 2).

More than 30 values, available at that time, were shown in the Ferghana Depression of Uzbekistan and about 10 points on the Samarkand – Termez profile, as well as adjacent territories of Central Asia [22], were put on the heat flow map. They showed a significant contrast of the heat flow data obtained for these crustal blocks with a complex geology.

The relevance of the problem of studying the thermal state of the earth's interior in those years was evidenced by the fact, that a scientific conference “Geothermal Research in Central Asia and Kazakhstan” was held on 3–4 October, 1985. It was organized by the Institute of Seismology, Ashgabat of the Turkmen SSR under the auspices at that time of the Council for Geothermal Research at the USSR Academy of Sciences¹.

By that time, geothermal measurements in the territory of Central Asia and Kazakhstan were carried out in more than 600 deep wells and the first corrected heat flow map of the region was drawn up at a scale of 1:2 500 000. It was recognized, that the geothermal field has transient features within the study area, which was associated with neotectonic activation processes within this territory; the first thermal models of the lithosphere were constructed along several profiles of deep seismic sounding.

¹Геотермические исследования в Средней Азии и Казахстане / под ред. А. В. Щербакова, В. И. Дворова. М.: Наука, 1985. 271 с.

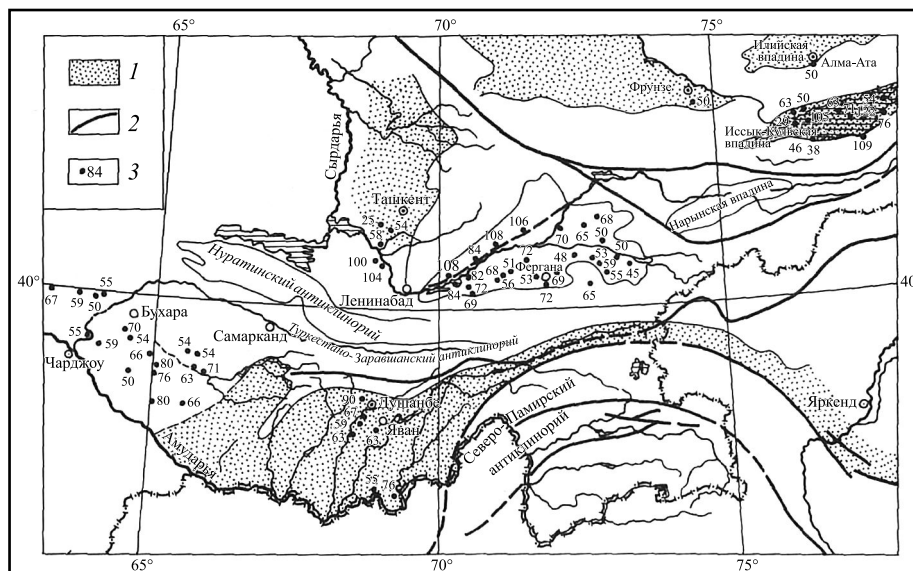


Fig. 2. The first schematic map of the heat flow of Central Asia:
1 – depressive structures; 2 – faults; 3 – heat flow values, mW/m^2 .
Source: [23]

The geothermal exploration within the territory of Uzbekistan, as well as throughout Central Asia, is uneven. The largest number of heat flow determinations was performed within depressions. The heat flow density varies here over a wide range from low values of $20\text{--}40 \text{ mW/m}^2$ in the Ferghana and Issyk Kul intermontane depressions to high values exceeding 100 mW/m^2 in the vicinity of the North Ferghana Fault and the Kuramin Ridge, where its crustal component is estimated to be 63 mW/m^2 [23]. Similar values were reported also in the direction of the Barskaun Transorogenic Zone of the Northern Tien Shan [24], as well as in the Issyk-Kul Depression outside of Uzbekistan.

Up to 7 km of sediments were accumulated in the Ferghana Depression, during the Neogene-Quaternary time at an average sedimentation rate of about $3 \cdot 10^{-2} \text{ cm}$ per year, due to the rapid neotectonic subsidence. This thickness decreases in the direction of the peripheral parts of the basin to 3.0–3.5 km. Moreover, the correction to the observed values of the heat flow for the sedimentation rate reaches an increase from about 10 % in the periphery to 20 % in the centre of the basin [23]. Eastern and southern regions of Uzbekistan are located within mountain structures. It was considered that the effects of erosion and accumulation of sediments influence the observed heat flow density.

The heat flow of $73\text{--}80 \text{ mW/m}^2$ was reported in the Ferghana Depression with the Hercynian age of tectogenesis (and the latest activation), while the crustal component of heat flow was estimated at $63\text{--}66 \text{ mW/m}^2$. Its value within the Bukhara-Khiva Zone of the Epigercinian age within the Turanian Plate decreases to 63 mW/m^2 , and its crustal component was estimated at 55 mW/m^2 . Here only $7\text{--}8 \text{ mW/m}^2$ remained for the mantle component, which seems unrealistically low.

The mean heat flow value of 71 mW/m^2 was reported for the near-Tashkent Trough, with its crustal component of about 54 mW/m^2 [22]. Its highest value 100 mW/m^2 corresponds to the Kuraminsky Ridge.

A number of heat flow investigations were made within the Issyk-Kul Basin in the neighbouring Kyrgyzstan, where also a high heat flow up to $105\text{--}134 \text{ mW/m}^2$ was reported [13; 22]. At this background, a number of low values of $30\text{--}50 \text{ mW/m}^2$ were observed also.

Refreshed map of the heat flow distribution in Uzbekistan

Available data on the territory of Uzbekistan were collected to refresh the heat flow map. The information on the geothermal field of the country would be incomplete without considering adjacent regions, since geothermal anomalies extend beyond its territory. In this regard, we also used the geothermal exploration data from territories of neighbouring countries bordering Uzbekistan, in particular, Turkmenistan, Kyrgyzstan and Tajikistan.

A high variability of the heat flow density and geothermal gradient within the region as a whole was explained by fault tectonics and a high seismicity of the southern part of Central Asia, primarily within the mountainous territories of the region in question [13; 23].

Published data from monographs, articles or abstracts were used to compile the refreshed heat flow map of Uzbekistan and adjacent territories. They were in some cases supplemented by data used from heat flow catalogues compiled in the Soviet Union as well as data available in international geophysical data centres. During many years, the International Heat Flow Commission of the International Union of Geophysics and

Geodesy has compiled heat flow catalogues. A number of data on heat flow is also available on the site [25] with locations of the wells studied for the territory of Uzbekistan.

Thermograms of deep wells, drilled during oil and gas exploration, as well as wells drilled for other minerals, were used to determine available heat flow values. The vast space occupied by the Kyzyl Kum Desert remains poorly studied in heat flow until now. The heat flow data for adjacent territories of Turkmenistan, Tajikistan, Kyrgyzstan and Kazakhstan in frames of the map were also taken from the above sources. The latest world heat flow data, including the territory of the Central Asian republics, is available also at <http://www.heatflow.org/data>.

The histogram of heat flow density distribution within the borders of Uzbekistan is shown in fig. 3. Heat flow values in the range of 45–80 mW/m² prevail within the country, of which the maximum amount of the data refers to the interval of 60–70 mW/m².

The heat flow density map for the considered region is shown in fig. 4. Geothermal anomalies and their configuration, shown only on the basis of the heat flow density database of Uzbekistan, as it was mentioned,

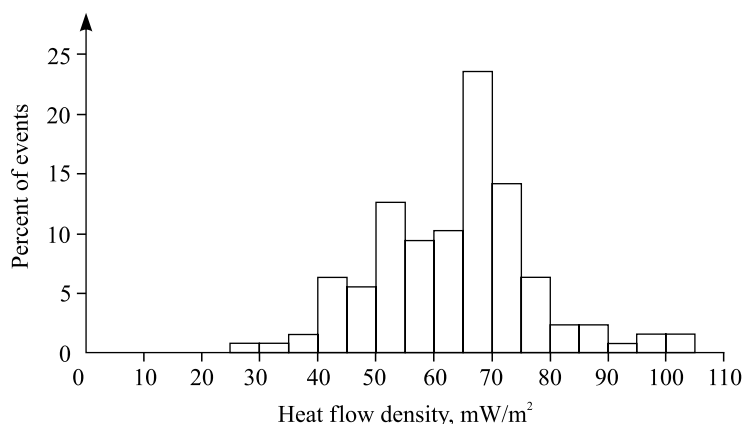


Fig. 3. Histogram of heat flow density distribution within borders of Uzbekistan

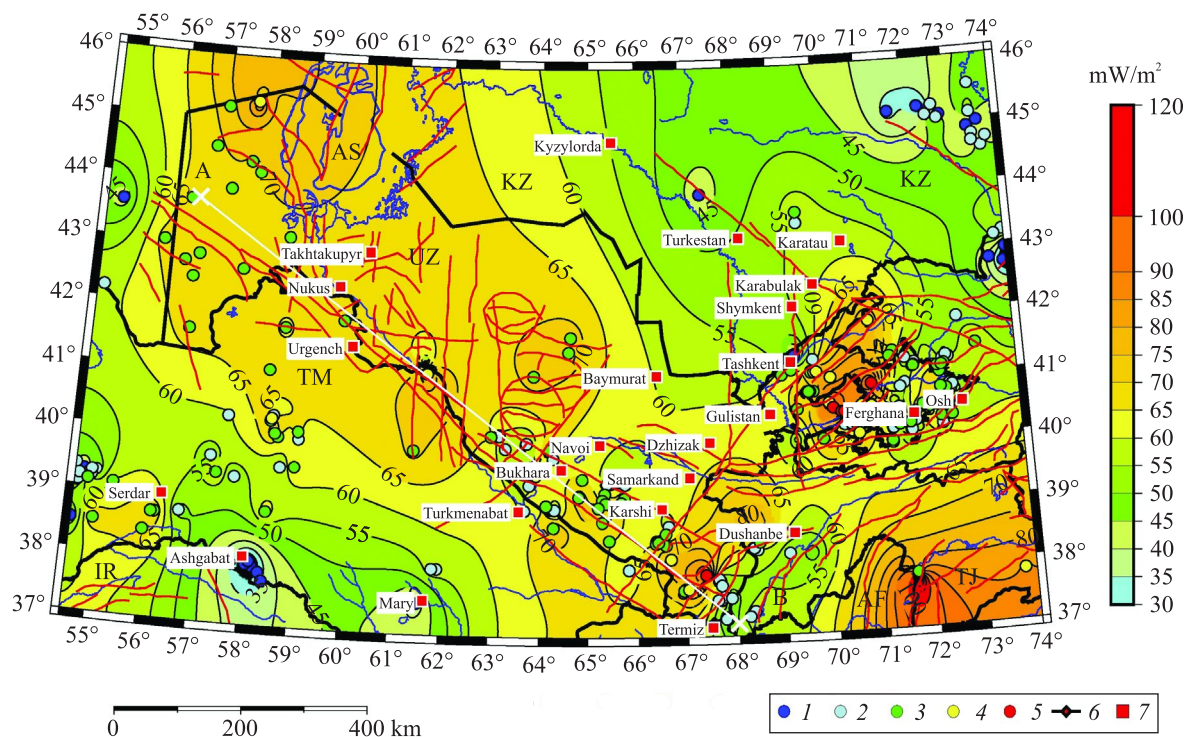


Fig. 4. Heat flow density map for Uzbekistan and adjacent areas. Range of heat flow values, mW/m²:

1 – 20–40, 2 – 41–60, 3 – 61–80, 4 – 81–100, 5 – 100–120; 6 – active faults; 7 – main cities.

Abbreviations for countries of the region: AF – Afghanistan; IR – Iran; KG – Kyrgyzstan; KZ – Kazakhstan; TJ – Tajikistan; TM – Turkmenistan; UZ – Uzbekistan; AS – Aral Sea.

A–B – heat flow profile

would be incomplete without taking into account of their continuation into adjacent territories of neighbouring countries. Therefore, when constructing the heat flow map, heat flow values were also taken into account from adjacent territories of Central Asia countries. The map of the heat flow was compiled using the software package Generic Mapping Tools (GMT) release 5.4.2 [26]. The network of deep faults were used from [27; 28].

The range of changes in individual heat flow density values for the wells is shown in the map in different colours of circles: 20–40 (dark blue), 41–60 (blue), 61–80 (green), 81–100 (yellow), 100 mW/m² or more (in red). Values above 100 mW/m² exist in the southern part of the country near the city of Termiz and in the Ferghana Depression.

Discussion

The territory of Uzbekistan is situated in the area of transition from the Turanian Plate in the north to Tien Shan mountain structures in the south. This transition region is characterized by manifestations of seismicity due to the complex geodynamic interaction of lithospheric blocks. The structure of seismicity clearly correlates with the deep penetrating faults, crustal tectonics and geological structure of the region as a whole [5]. The most clearly identified foci of earthquakes of different rank (different magnitudes) are the Pamir-Hindu Kush and South Tien Shan zones [27].

The heat flow density in Uzbekistan varies from 25–30 to values slightly exceeding 100 mW/m² in individual wells of the Ferghana Depression and the mountainous part of the country. Its distribution along the A–B profile (fig. 5) shows relatively uniform values of about 60–70 mW/m² in the flat part of the Turanian Plate, and when approaching the orogenic part in the south, the heat flow has a significant variation with maximum values up to 80–90 mW/m². This is associated with increased fragmentation of the earth's crust and an abundance of active faults there [28]. This zone is also characterized by increased seismicity. Higher seismicity is also noted in the central western part of the country near the settlement Gazli, there is a dense network of active faults, and the heat flow increases to 70–80 mW/m². In the southern part of this profile within Tajikistan, it drops again to 40–60 mW/m².

A large number of deep wells were studied by heat flow in the oil-bearing Ferghana Depression. Its distribution is given in a more detailed scale in the separate map (fig. 6).

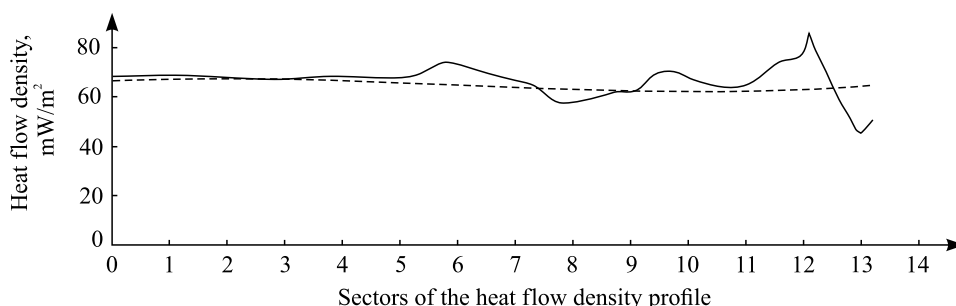


Fig. 5. Heat flow pattern along the A–B profile (solid line) and the trend of its variation (broken line)

The distribution of heat flow within the Ferghana Depression and neighbouring regions has a contrasting pattern. The histogram of its distribution gives fig. 7.

Very high value of 207 mW/m² within the map was observed in a single well near the border of Tajikistan. It is marked in the legend to the fig. 6 under number 6. When drawing contours on the map, this single value was excluded from consideration. The heat flow variability is shown in two profiles drawn through the Ferghana Depression: submeridional one (fig. 8) and sub-latitudinal one (fig. 9).

The largest heat flow variation and its pronounced contrast are characteristic for the C–D profile, where it ranges from 40 until 100 mW/m², while along the E–F submeridional profile its significant variability is also observed with fluctuations from 45 to 70 mW/m². The E–F profile was drawn through a series of oil-bearing structures of the Ferghana Depression.

Dashed lines in both figures, show the smoothed trend of the heat flow along the profiles. In the latter case, it reflects the heat flow, significantly decreasing from the western to eastern parts of the basin. In general, within Uzbekistan and adjacent territories of neighbouring countries it is significantly differentiated by area. It rises to values of about 100 mW/m² in the vicinity of the North Ferghana Fault and the Barnskaun Trans-Orogenic Zone. According to available data [23], there is a relatively high mantle component of the flow up to 34 mW/m², which is typical for activated blocks of the earth's crust; it is also observed here near the North Ferghana deep fault.

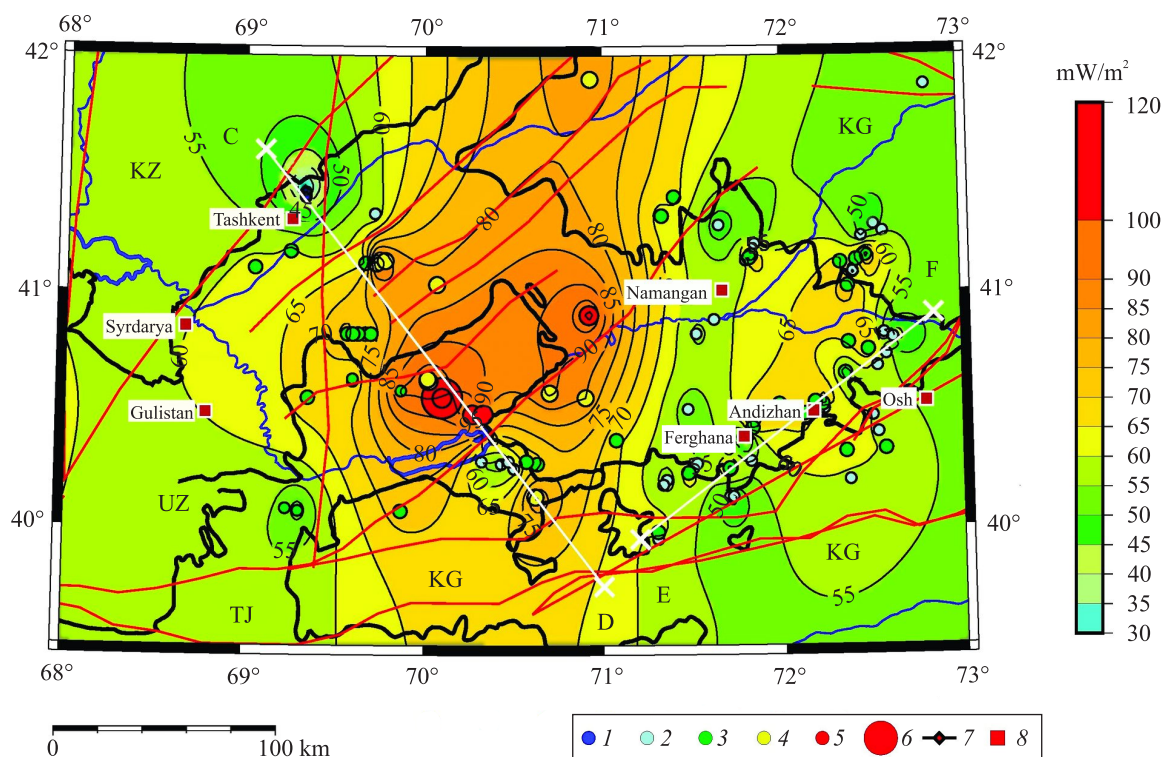


Fig. 6. Heat flow density map for the Ferghana Depression and adjacent areas.
Range of heat flow values, mW/m^2 : 1 – 20–40, 2 – 41–60, 3 – 61–80, 4 – 81–100, 5 – 100–120;
6 – highest heat flow in the region (217 mW/m^2); 7 – active faults; 8 – main cities. Abbreviations for countries of the region:
KG – Kyrgyzstan; KZ – Kazakhstan; TJ – Tajikistan; UZ – Uzbekistan. C–D and E–F are heat flow profiles

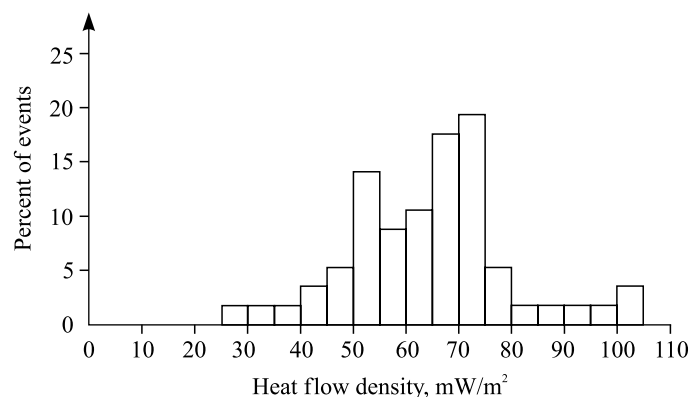


Fig. 7. Histogram of the distribution of heat flow density in the Ferghana Depression

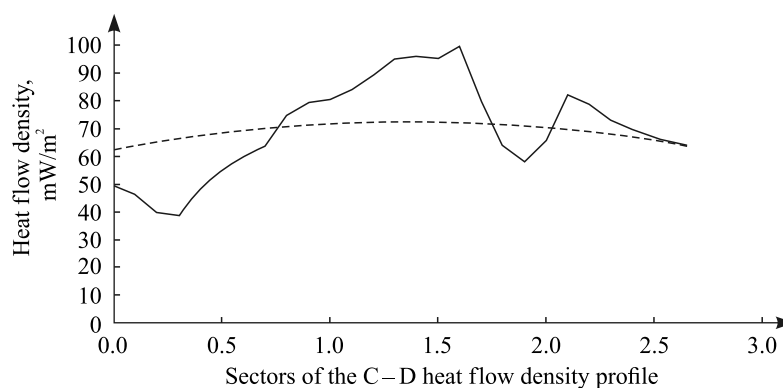


Fig. 8. Heat flow density pattern along the C–D profile (solid line)
and the trend of its variation (broken line)

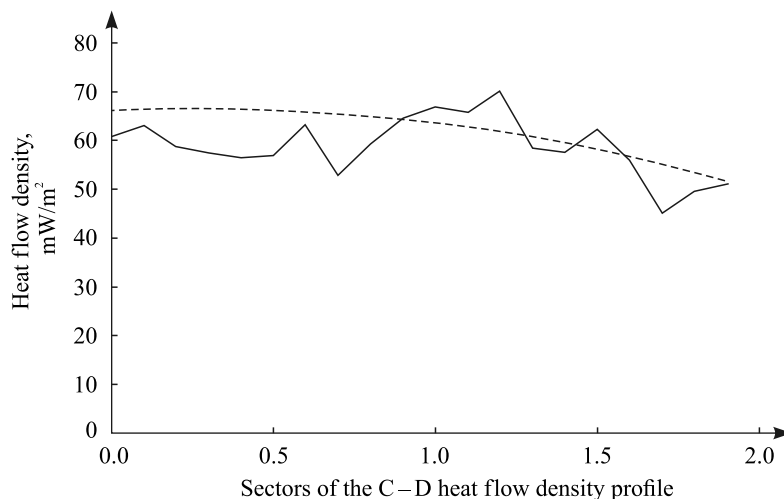


Fig. 9. Heat flow density pattern along the E–F profile (solid line) and the trend of its variation (broken line)

On the whole, heat flow values are more homogeneous in flat Uzbekistan within the Turanian Plate, while approaching the mountainous part of the country, the degree of its differentiation becomes higher and its average value increase too. This in general, is typical of the central part of the folded Alpine-Himalayan Belt.

Two largest oil and gas provinces within Uzbekistan are located in the Ferghana and the Bukhara depressions. Most of developed oil fields are within the Ferghana Depression, and gas deposits prevail in the latter one.

In the E–F profile of heat flow, its generally increased values (55 to 70 mW/m²) are shown, which is typical for a number of oil-bearing regions in other areas. For example, the location of exploited oil deposits in the Pripyat Trough, Belarus belongs to the zone of increased heat flow above 55 mW/m². Their main number here corresponds to the territory contoured by isolines of 60–75 mW/m², and in the strip between isolines of 55–60 mW/m² only less than 10 small deposits have been identified. Two gas condensate fields: Krasnoselskoye and Zapadno-Aleksandrovskoye (marked with a blue fill) belong to the zone with a higher heat flow of 65–75 mW/m² (fig. 10).

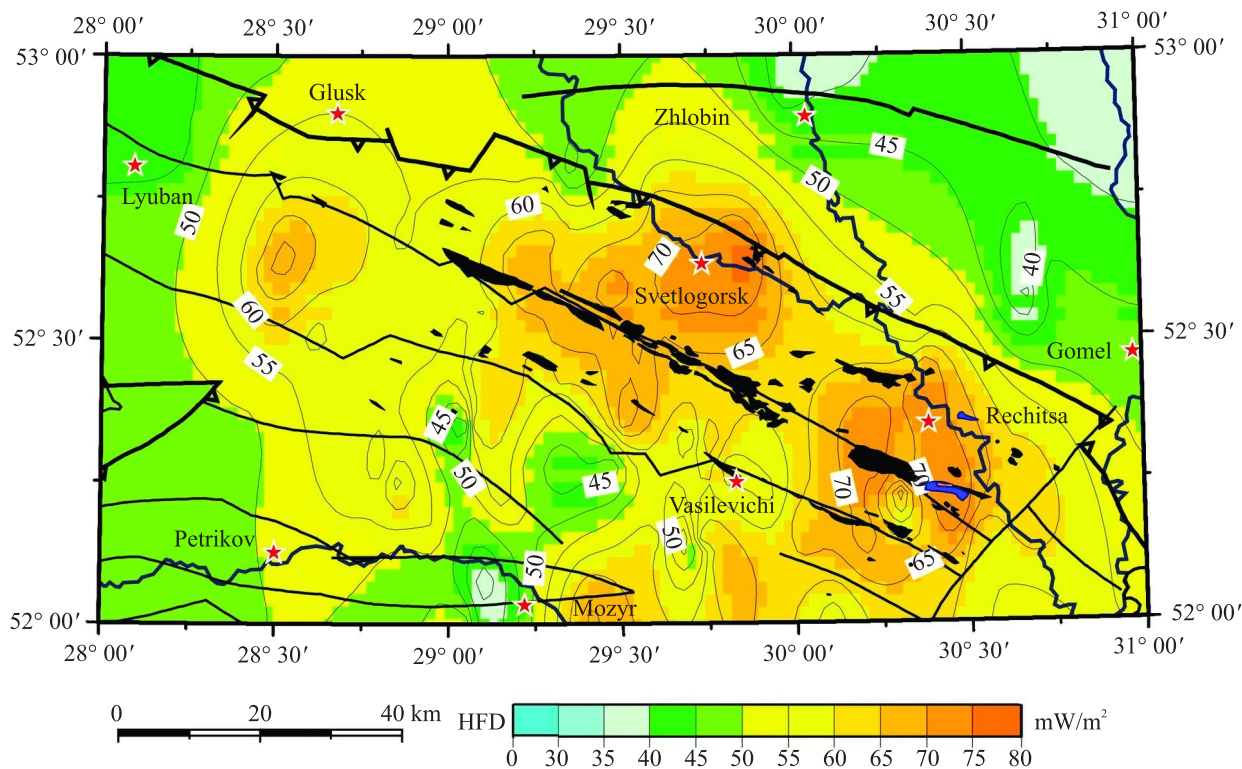


Fig. 10. Correlation of the areal distribution of heat flow density (mW/m²) and oil fields in the Pripyat Trough, Belarus. Contours of oil fields are shown by black fill. A blue fill indicates two gas condensate fields (Krasnoselskoe and Zapadno-Aleksandrovskoe) in the eastern part of the trough.

Source: [29]

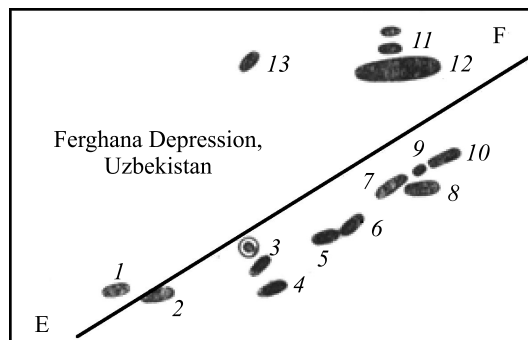


Fig. 11. Position of the heat flow profile E–F crossing the oil-bearing region of the Ferghana Depression.
Main oil fields: 1 – Northern Sokh; 2 – North Rishtan; 3 – Khankyz; 4 – Auval; 5 – West Palvantash;
6 – Palvantash; 7 – Andijan; 8 – Khojiabad; 9 – Boston; 10 – South Alamyshik; 11 – Miley-Su; 12 – Izbaskent; 13 – Kushan.
Source: [30]

A position of the heat flow profile crossing the oil-bearing region of the Ferghana Depression is shown in fig. 11. As it was described above, this area is also characterized by an increased heat flow of 55 to 70 mW/m² (see. fig. 6).

Conclusion

The heat flow knowledge of the territory of Uzbekistan is very uneven, dozens of wells have been studied in areas with the presence of hydrocarbons and the data are practically absent or characterized by rare determinations within the Kyzyl Kum Desert.

Heat flow in Uzbekistan has significant differentiation throughout the region. Its highest variability is observed within intermountain depressions of the mountain-folding structures of Tien Shan and range from 20–30 to approximately 100 mW/m². It is even higher outside the country in adjacent areas of Tajikistan and Kyrgyzstan. A network of active faults, that penetrate deep into the earth's crust, exists throughout the region. Near such faults, as a rule, an increase in the heat flow density is observed. The maximum heat flow value in the considered region of 207 mW/m² was observed in one of the wells in adjacent Tajikistan.

Seismic activity is noticeable in the region under consideration. The densest network of earthquake epicentres was found in the Tien Shan mountain-folding structures, where, as indicated above, an increased heat flow is observed both in Southern Uzbekistan and in territories of neighbour countries: Tajikistan, Kyrgyzstan, and Kazakhstan.

The compiled heat flow density maps for the entire territory of Uzbekistan and separately for the territory of the Ferghana Depression reflect a significant contrast of the region's geothermal field. In general, when proceeding from the relatively flat territories of the Turanian Plate to mountain structures, the degree of the heat flow differentiation increases and its average value increases too. This is generally typical of the central part of the folded Alpine-Himalayan Belt.

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