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STUDY OF THE NEOTECTONICS AND GEODYNAMICS OF THE REPUBLIC OF BULGARIA

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Abstract

In the paper, the modern tectonics and geodynamics of Bulgaria are studied. The specification of general tectonic units, its varied inner morphologic. tectonic structure, the borders between them and the recent geodynamics have been investigated by combination of two approaches: use and application of remote sensing information and general interpretation of data obtained by geodetic, geophysics, geologo-geomorphologic observations, measurements and different in scale maps, photographs and other materials.

Using the two approaches ring and linear structures on the territory of Bulgaria are established. The following important ring structures have been observed: Beloslatinska, Plevenska, Lukovitska, Popovska, Nikopolsko-Pavlikenska, Montanska, Velikotarnovska, Botevgradska, Central Srednogorska, Sakarska, Central Rhodopean. Some more important lineaments are: South-Moesian, Maritza, Olt–Ossamska and others.

On the territory of Bulgaria there are recent vertical movements. At present, the Danube plane (Moesian platform) generally sinks by 1-2 mm/year along the Danube river. All ring structures have risen by about 0,1-0,2 mm/year whereas some of them like the Pirin and the Rhodopes mountains have risen by up to 3-3,5 mm/year.

Key words: remote sensing, vertical movements, tectonics, geodynamics, geology, geomorphology.

1. Introduction.

In this publication, the modern tectonics and geodynamics of Bulgaria are studied. For the purpose, both remote sensing (aerospace) and ground-based data from the whole complex of Earth sciences are used.

The task was implemented on a polygon of Bulgarian territory comprising the central regions of the country from the Danube river as far as the Greek border. The polygon's width is 200 m. In the north, it stretches from the town of Lom on the west to the town of Russe reaching the White Sea coast to the south. The polygon was chosen in such a way as to cross transversely the major neotectonic units of Bulgaria: the Moesian platform or the Danube plane, the Predbalkan, the Stara Planina mountain, the Srednogorie region, and the Rhodopes massif. This polygon is known as the Balkanprob Project; it constitutes the southern deviation of the Europrob European geodynamic model.

The set task was theoretically based on the principles of new global tectonics (platetectonics). In view of the latest achievements in the field, Bulgaria and the Balkan peninsula are considered as an active outskirts (segment) of the European plate. In it first-class tectonic units are outlined: the Moesian platform, and the platform's deformed outskirts (Balkanides, Stednogorie and the autohtonous parts of the Kraishte, the Rhodopes, Sakar, and Strandzha). On the latter two areas, post-collage paleogen-neogen sediment basins are identified. Nowadays, space onlook onto Bulgarian territory becomes essential, since it provides both global and regional overview of the individual accretion blocks with various paleographic behaviour, which underwent and are still undergoing varied paleogeodynamic development.

In the methodological aspect, the task was accomplished using both aerospace (remote sensing) data as well as data from the classical Earth sciences..

2. Analysis of remote sensing, geologo-geomorphologic, and geodetic data.

2.1. Analysis of remote sensing (aerospace) data.

The studied territory comprises the central band of Bulgaria, from the Danube river to the Bulgarian-Greek frontier; it is 200 km wide and crosses well-known tectonic zones: the Danube platform, the Predbalkan, Stara Planina mountain, the Srednogorie, and the Rhodopes mountain.

As a result of the deciphering of space images of various scale and spectral ranges, linear and concentric structures were identified, and with respect to North Bulgaria, space images of scale M 1:100000 were also used. The latter allowed to outline some new structures, which will be considered, too.

In the course of work, a hypsometric map of Bulgaria was used, with height belts drawn at every 100 m (in scale M 1:1000000). The topographic background greatly assists the process of deciphering. Geologic and tectonic maps were used (M 1:500000; M 1:200000) and besides, some geophysical materials were interpreted, concerning the depth structure of Bulgaria.

In the process of structural-geomorphologic deciphering of space and photograph images of Bulgaria, most often, linear and ring structures are identified structures (Fig. 1, Fig. 2).

2.2. Analysis of linear structures.

On the neotectonic scheme (Fig. 1, Fig. 2), the linear structures are divided into two groups:

a) geologic faults known from other studies and confirmed by this interpretation;

b) space-tectonic lineaments, some of which have been identified with great certainty by a number of direct or indirect deciphering indexes.

An important and notable boundary of the Moesian platform is the North-Predbalkan or South-Moesian fault [3, 8]. The different sections of the South-Moesian lineament bear different names. Among them, the Vodoley-Draganovski segment is distinguished for its seismogeneity [7]. Recently, some authors assume that the South-Moesian fault is not a deep-penetrating in-depth fault reaching the mantle, but it is sooner an epidermal trass or a monoclinal slope with various manifrstations in the structural floors [7].

Another well-known fault structure is the Brestnishko-Preslavska flexure. In the southern direction, between Stara Planina mountain and the Srednogorie, the Zadbalkan fault is located, as well as the series of chariage along the southern slope of Stara Planina (Staroplaninski, Kashanski, Shipchenski etc.).

The next big fault structure is the Maritsa fault which serves as a boundary between the Kraishtensko-Rhodopes arc and the Srednogorie.

One of the lineaments identified by interpretation of space images and outlined by other authors as well is the Olt-Ossam lineament, which is delimited by the straight-line course of the rivers Olt in Romania and Ossam in Bulgaria. Actually, it series as a tectono-geomorphologiic boundary between the Lom depression and the North-Bulgarian (Ludogorsko) rise. The valley of the Ossam river ranks among the most ancient river valleys created yet during the upper Eocene, the Oligocene, and the lower Miocene, continuing its development but for short interruption periods until nowadays.

The other lineaments identified on space photos have no essential importance for the development of tectonic areas in Bulgaria.

2.3. Analysis of ring structures.

As a result of deciphering and interpretation of space images, combined with topographic maps of various scale, on the territory of the studied area, ring (concentric) structures of various form, size, depth, and orientation have been outlined. Among these are the structures in the Moesian platform, the Predbalkan, Stara Planina mountain, the Srednogorie, and the Rila-Rhodopes massif.

2.3.1. Ring structures in the Moesian platform.

Within the platform, the following structures can be identified: Beloslatinska, Lukovitska, Plevenska, Nikopol-Pavlikenska, Streletska, and Popovska.

The Beloslatinska structure is mentioned by many authors [5, 9]. It has a size of 45/25 km and represents an elongated oval pointing in the east-west direction. Most often, its formation is referred to the Troas period, in which a similar depression was formed. Within this structure, an industrial oil deposit was revealed (at the town of Knezha).

The Pleven oval structure is about 70 km long and up to 35 km. In depth of the structure, magma rocks with gabro-diorite compositions are revealed; whereas the positive structure was formed as a result of the slow squeezing of the magma body. Actually, the latter creates the biggest positive magnetic anomaly in Central North Bulgaria.

Another important structure is the Nikopol-Pavlikenska, sized 80/50 km. It is delimited by the rivers Ossam and Yantra, the northern half of being strongly eroded by the short tributaries of the Danube river. Among the most important structures to the east of the Yantra river are the Streletska and the Popovska structures, which are outlineded by the tributaries of the river of Rusenski Lom. The Popovska structure may be referred in depth to a magnetic body with gabro-diorite composition [11].

2.3.2. Ring structures in the Predbalkan and Stara Planina.

Within the Predbalkan and Stara Planina, the strongest deciphering indexes were the configuration of the hydrograph network as well as some tectono-geomorphologic indexes, the orientation of the tectonic structures (synclinal and anticlinal) against the linear chain outlook of the Predbalkan and Stara Planina. The major structural units here are: the Botevgradska, Montanska (Belogradchishka) and Tarnovska (Fig. 2) structures.

The Tarnovska regional morphostructure is emphasized mainly by a number of mountain-like elevations, risings, and hills. These orographic forms are part of Stara Planina and the lower mountains and elevations of the Predbalkan and the periplatform South-Moesian depression.

The morphostructure is about 200 km long from west to east, with an average width of 50-60 km and an area of about 12,000 km^2. In it, a central nucleus can be outlined, surrounded by a higher-terrain belt, followed by another, not well manifested and lower belt. The latter belt is closed to the south by the high terrains of Stara Planina (Fig. 2).

Another structure of this kind is observed in the Botevgrad region. It spreads to the west as far the Vrachanski Balkan, to the east – the Vassilyova Planina, and to the south – the Murgashko-Tetevenska Stara Planina. In its center, a depression is formed, which is occupied by the Botevgradska valley (Fig. 2).

Another important morphostructure is the Montanska one, which stretches from the Ogosta river to the river of Golyama Panega to the east. It coincides with the so-called Montanska anticlinal and represents a strongly elongated rising surrounded by depressions. To the north lies the Lomska depression, to the south – the Mezdrenska synclinal, and to the east – the Lukovitsko depression. The Montanska morphostructure is about 100 km long and up to 25-30 km wide. It is strongly partitioned by the rivers of Botunya, Skat, and Iskar.

2.3.3. Ring structures in the Srednogorie.

Within the Srednogorie, two big regional concentric structures can be outlined: the Panagyurska structure and Sarnena Gora. Among the smaller ring formations are the Chirpanski elevations, and the Manastirska structure whereas the latter one is negative. The typical thing about the first two regional morphostructures is that they are built up of magma and metamorphic rocks, and that, in the geophysical respect, they represent negative gravitational or magnetic anomalies (Fig. 2).

2.3.4. Ring structures in the Rhodopes massif.

Here, the most clearly outlined ring structure is the Rhodopes massif, and more precisely, the West Rhodopes. This structure is closed to the west and to the south by the Mesta river, to the north – by the Upper-Thracean trough, and to the east – by the valleys of the rivers Varbitsa and Borovitsa, tributaries of the Arda river. This is a big structure sized 150-90 km, built mostly of metamorphic rocks, paleogene sediments and vulcanites. The structure is a complex one, with depressed central part, where three depressions are formed: the Bratsigovo-Dospatsko, Smolyansko, and Vitinsko ones. The latter are filled with sediments, pyroclastites, and vulcanites and nowadays represent the highest terrains in the Rhodopes (Mount Perelik, 2191 m). Another similar structure in the Rhodopean massif is the Belorechko swelling, a positive structure built of pure crystalline rocks [3, 12, 13].

Another peculiarity of the Rhodopes massif and, in particular, the Eastern Rhodopes, are the volcanic structures: Dragoynovska, Nanovishka, Zvezdelska, Lozenska, Madzharovska, Irantepetska etc. Some of them are volcanic domes, others are typical volcano-tectonic depressions (Fig. 2).

3. Study of the modern geodynamics of Bulgaria.

The study of the geodynamic processes is a very topical problem, since it provides dataabout the dynamic processes taking place in the Earth's body, as well as of the dynamics of the lithospheric plates. Based on these facts, the horizontal and vertical movements of the Earth's crust can be determined with great accuracy throughout long periods of time, using various radiointerferometric, laser, or dedicated geodetic measurements. Space methods and equipment resulted in a boom of these studies, achieving in the recent years exceptionally high precision through the use of GPS measurements of the lateral and vertical position of points from the physical earth's surface. It is a great regret that the obtained data relates to the recent couple of years, covering only a short period of time which does not provide to carry out reliable analyses and interpretations.

For this reason, the vertical movements [12,14,15] on Bulgarian territory are studied by data from high-precision geodetic measurements dating since 1928 and comprising a relatively long period for which measurements throughout three epochs have been made.

At SRI-BAS, several annual measurements were performed of the neotectonics and geodynamics [12,14,15] of some detached geological structures on Bulgarian territory: namely: the Moesian platform, the Predbalkan with Stara Planina, and South Bulgaria [12,14,15]. The major objective of these studies was to reveal the correlation, if any, between the modern geodynamical processes and the relevant neotectonic and geologic structures in the mentioned regions whereas each region was studied individually and the obtained results were published.

The results were united in this paper, thereby providing a wholesome map of Bulgaria for the modern movements of the Earth's crust during the epoch 1930-1985 with isolines 0.5 mm/year apart. The neotectonic map (Fig. 2) and the map of modern movements (Fig. 2) finalize these multiannual studies. In the next study, the obtained results for the whole Bulgarian territory will be analyzed.

3.1. Reliability of the data used to determine the velocities of the vertical movements of the Earth's crust.

As already stated when discussing the study of the vertical movements of the Earth's crust, in the mentioned detached structural areas, mainly geodetic measurements were used, since the analysis of space data obtained by GPS measurements for middle-sized regions did not provide the needed accuracy to comply with the accuracy of the quantities obtained by geodetic methods.

Prior to their use, the obtained geodetic data was submitted to meticulous analysis aimed to identify potential errors caused by external factors that might deform the measurement results. Among these were the instrumentation errors obtained with the levelling procedure, the references' representativeness, the characteristics of the geological foundation (loess soils, possible slides) and for the references along the Danube river, the various water levels and, accordingly, the references' stability were studied.

To enhance data trustworthiness and to remove the possible systematic errors, initially, digital data was processed and then it was compared with the results from past epochs. Where the values' differences for two epochs with one and the same references were greater than modern movements, the data for both epochs and the references' reliability was verified.

Based on the data thus obtained, the data was processed anew and maps of the modern tectonic movements of the Earth's crust were drawn. Where deviations occurred, the references were studied anew and the factors deforming the results were removed. And only then the material was processed, the residual errors were removed and, based on these final results, the enclosed Appendixes were drawn.

3.2. Interpretation of the velocities of vertical movements.

In works [12,14,15], the velocities for three periods are interpreted: 1930-1985, 1930-1970, and 1970-1985, and the respective maps are drawn with isolines 0.1 mm/year apart. The obtained graphic material and the performed analysis revealed that the images obtained from the longest period, 1930-1985, were most trustworthy, with the least number of anomalies. This is a logical outcome since the available observed material is abundant enough to allow for occasional errors to be removed with processing. Accounting for these facts, the only drawn map of the vertical movements' velocities in Bulgaria was for the period 1930-1985 (Fig. 2).

Notwithstanding the visual idea of the modern movements on the whole territory one can get from the map, in pursuit of the set objective (to reveal the existing correlation between modern movements and neotectonic structures) we shall analyze the movements of the detached neotectonic structures.

3.2.1. Analysis of the modern movements of the Earth's crust for the Moesian platform.

The drawn map of the vertical movements' velocities displays the plane nature of the geodynamical processes taking place in the whole northern Bulgaria. It should be noted beforehand that the vertical movements comprising the Central part of the Danube plane confirm the general tendency of continuous sinking.

For the longest period (1930-1985) of generalization of the quantitative data, a general sinking (depression) of the central part of the Moesian platform is expected in the section along the Danube river, between the towns of Lom and Svishtov (Fig.2). The sinking comprises the part of the platform located between the great turns of the Danube river, at the towns of Vidin-Lom to the west and Svishtov-Russe to the east. The sinking has a clearly marked oval form (100-120 km) with elongation in the east-west direction. To the north it is parallel to the river bed of the Danube, while to the south, on Bulgarian territory, a deep bay is formed, passing through the boundary South-Moesian fault and penetrating the Predbalkan (the Balkanides). Typical of the period 1930-1985 is the tendency of increasing the Earth's crust vertical movements' velocities over a one-year period. These values are particularly great in the region of the settlements of Oryahovo and Baykal where they reach a velocity of $V_V = -2.5$ mm/year. To the north, on Roumanian territory, the isolines get quickly closer to each other. A similar pattern of the isolines with identical velocity is observed both to the east and to the west, while to the south they change smoothly, whereas the affected slowly-sinking area penetrates deep into the Predbalkan. The sinking comprises the depression that existed in the Upper Cretaceous and, in some respect, continues during the Neogene in the Lomska depression. A slightly manifested "swelling" is observed to the north-east in the Danube plane, forming the Nikopolsko-Pavlikenska, Popovska and Kubratska morphostructure.

Beyond this "swelling", eastward of the Nikopol-Gorna Oryahovitsa line, ring isolines are formed with maximal value of up to +1.0 mm/year. This formation correlates with the positive geologic structure, which comprises the whole of the Nikopol-Pavlikenska, Popovska and Kubratska morphostructure.

None of the ring arch-block and block structures within the scope of the Lomska depression affects the course of the vertical movements' velocities. The well-known South-Moesian fault is not represented on the vertical movements' velocity map, thus confirming the opinion of some researchers that it does not represent a deep-penetrating fault, but a monoclinal slope with fault manifestations in different structural-stratigraphic storeys [11,12,14,15].

3.2.2. Analysis of the Earth's crust modern movements for the Predbalkan and the Stara Planina mountain.

The study of the Earth's crust vertical movements' velocities for the regions of Kraishte, the Predbalkan, and the Stara Planina mountain for the period 1930-1985 provides a clear picture of the geodynamic processes taking place there. Thus, we have depressions in the region of Teteven-Etropole, corresponding to the central part of the sinking Teteven-Etropolska and Skravenska morphostructure. Slight sinking is observed within the scope of the Botevgradska structure, where the valley bearing the same name sinks by –1.0 mm/year. Eastward of these sinkings, within the Shipchenski and Kotlenski region, two "risings" are formed whose modern movement values reach up to +2.0 mm/year. In these regions, there is a significant correlation with the neotectonic structures.

3.2.3. Analysis of the Earth's crust modern movements for South Bulgaria.

The performed analyses of the vertical movements in South Bulgaria reveal a great variety of "sinkings" and "risings", whereas the velocities' positive values reach their maximum. In these regions we witness the greatest variety of high mountain chains: Pirin, Rila, the Rhodopes up to the Sakar mountain, plains and valleys, accordingly.

During the epoch (1930-1985). The vertical movements' velocities in the southernmost part of the Rhodopes massif reach up to +3.5 mm/year. These risings begin eastward of the valley of the Mesta river where the velocity is about +1.5 mm/year. The values in Pirin and Rila are also positive, but smaller: about 2.1 mm/year for Rila and about +4.0 mm/year for Pirin.

If we trace the isolines between the three mountains (the Rhodopes, Rila, and Pirin), we shall notice that along the valley of the Mesta river there is a clearly outlined fault band separating the Pirin mountain from the

Rhodopes, whose vertical movements are independent on each other. If we trace the isolines between the Rila and the Rhodopes blocks, we shall identify a clearly outlined "saddle" which delimits the different movement velocities of both mountains. The typical thing here is that each of them has its "own life", i.e. an individual rising velocity.

Eastward of the Pazardzhik-Chirpan line, an isoline configuration is formed which reveals a band of negative values. We point out to a feature characteristic of the period 1930-1985, namely the generation of an oval sinking with great velocity (-2.0 mm/year).

Northwards of the towns of Panagyurishte and Stara Zagora, during the same period, two closed ovals are outlined, with positive rising values of up to +1.0 mm/year (Fig. 2). In the south-east direction, a slight rising is observed, comprising the territory of part of the Zagorsko depression and the Sakar mountain, and having values of about +1.5 mm/year. Such a depression is also observed southward of the town of Burgas.

Here, yet another fact deserves to be noted, namely that in the period 1930-1985, a clear and notable tendency for severing of the West and the East Rhodopes. This saddle is observed on Bulgarian territory, in the region of the village of Podkova as well as at the town of Xanti in Northern Greece (the White Sea region).

Southward of the Nova Zagora-Elhovo line, a "sinking" starts which, in the immediate vicinity of the Burgas bay, reaches up to –3.0 mm/year.

4. Conclusion.

This work is an attempt to bind the results from the deciphering of space images and photos of the Moesian platform, Predbalkan, Stara Planina, Srednogorie, and Rhodopes, on the one hand, with the quantitative materials obtained from geodetic measurements, on the other hand. In parallel with this, the whole known data from geologic, geomorphologic, tectonic, geophysical, and geochemical data was used, as well as thematic maps of various scale and scope. The idea was to confirm or reject certain results or to show that the relation between them is not always a simple one, but various combinations or interpretations are possible. From our point of view the following more important conclusions may be made:

1. The drawn neotectonic map of the central part of Bulgaria which crosses different tectonic zones of Bulgarian territory, prepared on the basis of space images and photos, reflects the modern tectonic state-of-the-art and coincides fully or overlaps with the known neotectonic structures in the Predbalkan, Stara Planina, Srednogorie, and Rhodopes. Only for the Moesian platform it cannot be ascertained that there is complete coincidence

and that the deciphered neotectonic scheme coincides with the meso-cainosoic platform чехло.

2. The drawn maps of the vertical movements' velocities do not confirm all linear and ring structures obtained as a result of deciphering. For the Moesian platform, the existence of the Lomska depression is confirmed with respect to its area. Nowadays, it is slowly sinking with a maximal velocity of -2,5 mm/year., i.e. the neogene depression continues its development.

3. Linear structures can be passive or active. All fault linear structures in South Bulgaria (Marishka, Zadbalkanska) display typical modern activity, i.e. they are seismogenious, and in the Moesian platform such an effect is observed in the Vodoley-Draganovski segment of the South-Moesian fault.

4. The obtained map of the vertical movements' velocities for North Bulgaria reveals the slow oscillating pattern of its geodynamics, which is related mostly with its foundation and subcrust layers.

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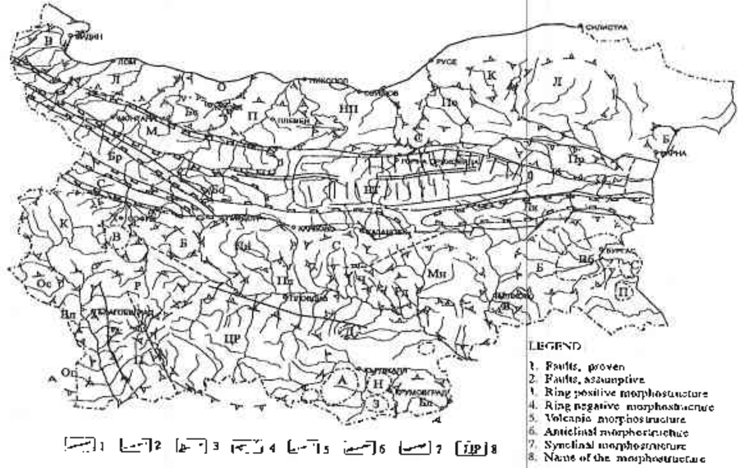
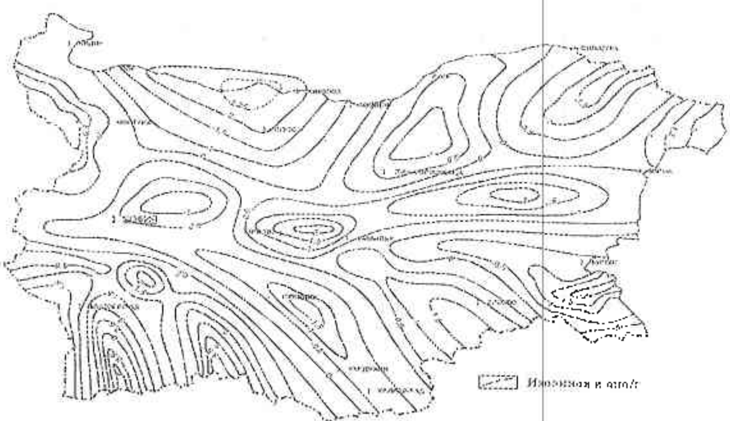


Fig. 1. A Decipherable neotectonic scheme of Bulgaria



Фиг. 2. Карта на скоростите на вертикалните движения (mm/г) за периода 1930 - 1983

ИЗСЛЕДВАНЕ НА НЕОТЕКТОНИКАТА И ГЕОДИНАМИКАТА НА БЪЛГАРИЯ

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Резюме

В публикацията се изследва съвременната тектоника и геодинамика на България. Уточняването на основните тектонски единици, тяхната разнообразна вътрешна морфоложка и тектонски изразителност, границите между тях, а така също и съвременната им геодинамика, се осъществява при съчетаване на два подхода: използване и приложение на дистанционна (аерокосмическа) информация и комплексна интерпретация на данни, получени от геодезични, геофизични, геолого-геоморфоложки наблюдения, измервания и различни по мащаб карти, снимки и др. материали.

Дистанционният (аерокосмическият) подход се основава на използването на аерокосмически данни: разнообразни по мащаб, разделителна способност и спектрален диапазон фотографии, сканерни изображения и магнитни ленти. При наличната аерокосмическа обезпеченост и при приложение на ландшафтно-индикационния метод на дешифриране успешно се оконтурват най-добре изявените по размери и площ неотектонски единици, а така също и разделящите ги главни разломни нарушения.

Вторият подход е класически и обхваща постиженията и резултатите от водените геодезични измервания, геолого-геоморфоложки, тектонски, геофизични, геотермични, хидроложки данни; наблюдения и публикувани карти, схеми и диаграми. Тук се използват както материали на редица ведомства, учени, публикации, така и собствени изследвания.