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GEOLOGY

Structure of the Ocean Floor in the Junction Area of King's Trough and the Azores–Biscay Rise (North Atlantic)

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Abstract—The structure of King's Trough and its surroundings (King's mesostructural cluster), located on the eastern flank of the Mid-Atlantic Ridge in the North Atlantic, is described in this paper. This work is based on geological and geophysical data obtained during the 55th expedition of the R/V *Akademik Nikolaj Strakhov*. Six provinces were identified within the southeastern part of King's Trough, based on the results of bathymetric survey. Each province has its own morphostructural feature resulting from multistage tectonic and volcanic processes, which alternate and conjugate with each other in time. According to seismoacoustic profiling data, three main types of seismic facies have been identified: (a) pelagic complexes; (b) deposits of turbidite flows; and (c) chaotic facies of gravity origin. It is shown that the anomalous magnetic field of the study area is the superposition of linear and isometric anomalies. The first were formed during the formation of the oceanic crust in the axial zone of spreading. The second are associated with volcanic massifs formed under intraplate conditions. The obtained data confirm the assumption that the formation of King's Trough was preceded by the formation of an elongated arched rise, which became a scene of intense intraplate volcanism that increased from southeast to northwest. This stage was followed by subsidence of the axial part of the rise with the formation of King's Trough and the Peake and Freen Troughs.

Keywords: North Atlantic, Mid-Atlantic Ridge, seismic facies, turbidite flows, King's mesostructural cluster, Azores–Biscay Rise, Peake Trough, Freen Trough, Palmer Ridge

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The flanks of the Mid-Atlantic Ridge (MAR), which occupy vast areas, have not been studied systematically. The concepts about their structure and development are based on extrapolation of processes, phenomena, and factors established in the study of the tectonics and magmatism of the axial spreading zone with the addition of satellite altimetry data. Based on theoretical concepts of the tectonics of lithospheric plates, it is considered that the MAR flanks are tectonically and magmatically passive, except for those areas, where the processes are associated with the ascension of deep mantle plumes. These processes lead to the formation of new magmatic and tectonic structures outside the axial zone of spreading. However, there are large areas of the ocean floor, where plume activity is not obvious, and the structures are formed mostly by tectonic processes.

One such region is the eastern flank of the MAR in the North Atlantic, where a cluster of mesostructures has formed. The cluster consists of King's Trough, the Peake and Freen troughs with the Palmer Ridge separating them, and the Gnitsevich Plateau (Fig. 1). This mesostructural cluster is located in unique region of the North Atlantic: it is bordered by the large near-axial rise of the MAR from the northwest and by the linear Azores–Biscay Rise from the southeast, last extends in southwestern rhumbs toward the Azores Rise formed as a result of the ascending deep mantle plume (Fig. 1).

The 450-km-long King's Trough has a southeasterly strike. It includes several echeloned troughs with

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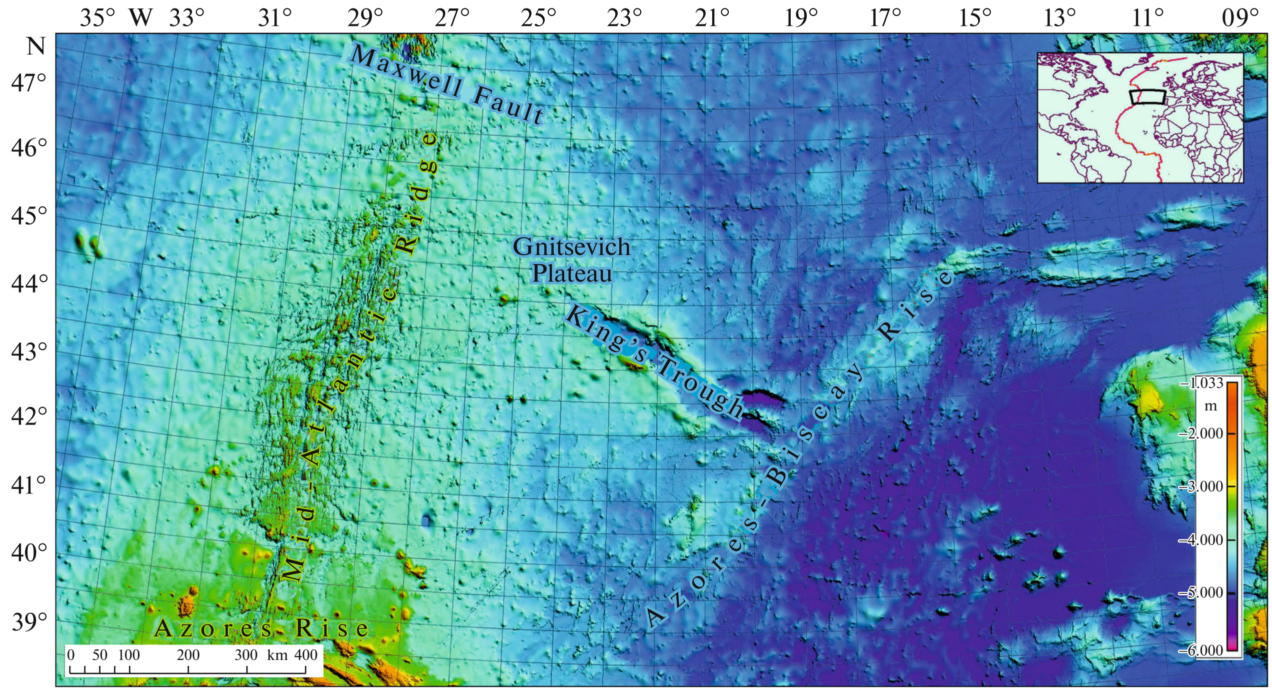

Fig. 1. Position of the study area of the 55th cruise of the R/V *Akademik Nikolaj Strakhov* (the black multangular area in the inset is the King's site).

subparallel chains of seamounts of different morphology on the flanks [1]. This area has been studied previously [2–10]; however, the geological data obtained are insufficient to build a credible model of the formation of King's Trough and its surroundings. Actually, it is impossible without detailed mapping of the ocean floor with a multibeam echo sounder.

There are several models for the formation of the King's mesostructural cluster. According to one of them, the aseismic ridge was formed in the period 56–21 Ma as a result of the ascension of the deep mantle plume, which reached a depth of about 2 km about 32 Ma ago [4, 11]. The ascension of the plume was accompanied by intense magmatism along the southern flank of the cluster with the formation of Antialtair Seamount. During the period of 20–16 Ma, the axial zone of the ridge lowered by 2–4 km. Other concepts point to attribution of King's Trough to the ancient intraplate boundary of the strike-slip type [12, 13].

In 2023, the Geological Institute of the Russian Academy of Sciences organized and conducted the 55th cruise of the R/V *Akademik Nikolaj Strakhov* (ANS) in the North Atlantic (Fig. 1). Data on the relief and sedimentary cover of the ocean floor during the cruise were collected simultaneously by the SeaBat 7150 deep-water multibeam echo sounder, EdgeTech 3300 profiler, and Parasound DS Sub-Bottom profiler P-35. Magnetic field data were recorded with the Geometrics G882 magnetometer. The hydromagnetic survey data were processed using the MATROS-IV program. Rock material was collected by dredging.

Six morphostructural provinces were identified within the study area on the basis of the bathymetric survey. Three of them directly represent King's Trough and associated structures. These are provinces of the southeastern troughs, the southeastern end of King's Trough, and the central part of King's Trough. The other three characterize the morphology of the structures framing King's Trough: the MAR flank structures and the southeastern and the central segment of the Azores–Biscay Rise (Fig. 2).

The province of the MAR flank structures is located in the northeastern part of the study area. The province borders the Peake Trough and the basin, which we will call the Eastern basin, to the south, and volcanic structures of the Azores–Biscay Rise to the southeast. Ridge relief, typical of the MAR flanks, predominates within the province. The relief slopes gently northward from the northern edge of the Peake Trough.

The southeastern province borders the Freen Trough to the north, the Azores–Biscay Rise to the northeast, and the structures of the southern flank of King's Trough to the west. The southeastern province is symmetrically located with regard to King's Trough axis in relation to the previous province. However, typical flank structures of the MAR are not found within the province. Hear, there are plateaus, ridges, plains, and basins. This province is raised relative to the province of the MAR flank structures by at least 300 m. The most remarkable structural ensemble is represented by a broad sublatitudinal basin, which in this work we will call the West basin, and by two cuesta-like ridges bor-

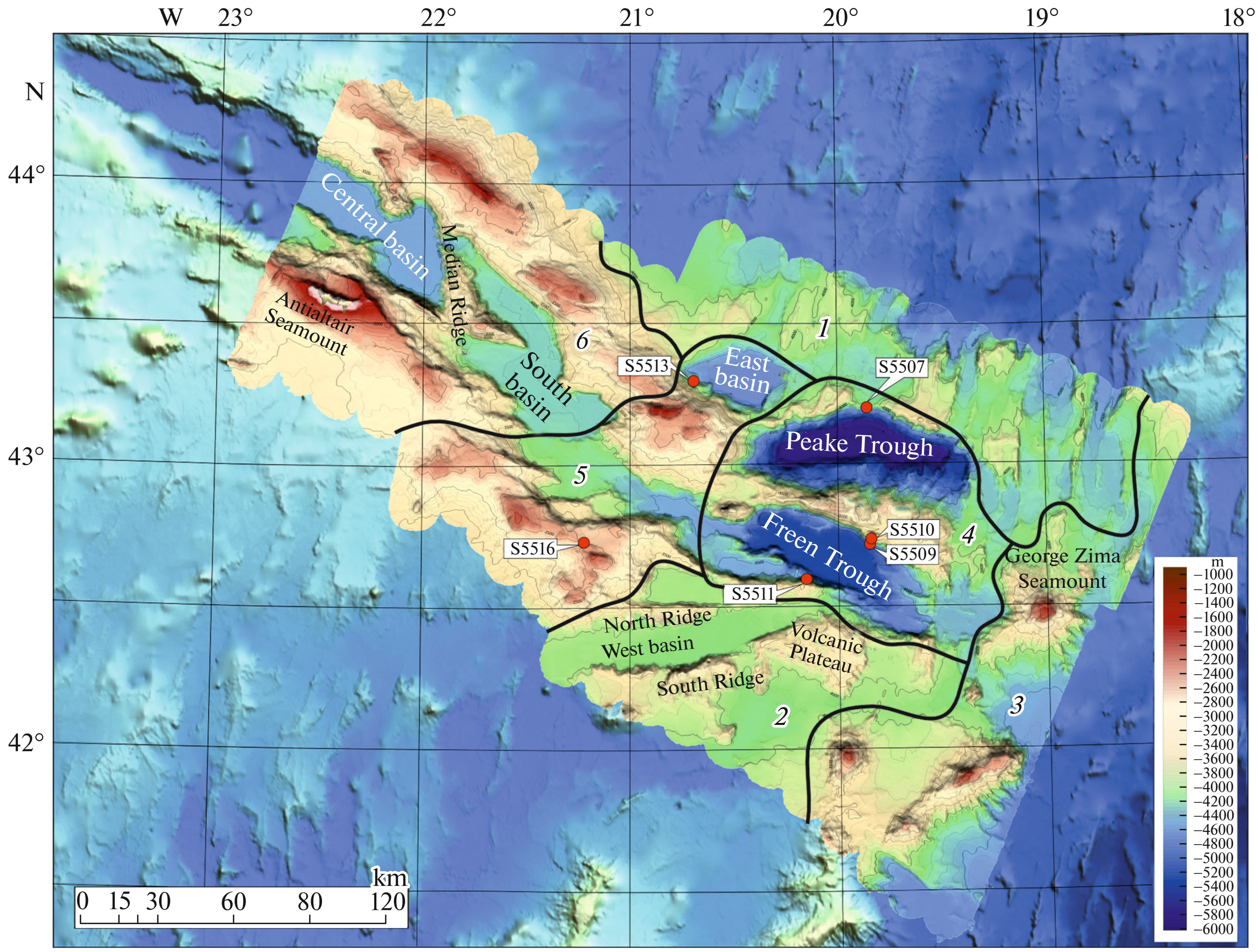

Fig. 2. Scheme of morphostructural provinces. Numbers indicate provinces: (*1*) MAR flank structures, (*2*) southeastern, (*3*) central segment of the Azores–Biscay Rise, (*4*) southeastern troughs, (*5*) southeastern end of King's Trough, (*6*) the central part of King's Trough. Black lines are boundaries between provinces. Red circles are successful dredge stations of the 55th cruise of the R/V *Akademik Nikolaj Strakhov*. The depth scale is in the lower right corner.

dering it: Northern and Southern ridges. In accordance with the character of the ocean floor relief to the west of the study area [13], the West basin is probably a fragment of a valley of the paleotransform fault, which is cut by the Freen Trough. A cuesta-like shape of the ridges indicates that the volcanic ridges were transformed by subsequent tectonic processes.

The province of the central segment of the Azores–Biscay Rise involves the southern and southeastern parts of the survey area. It is formed by individual large cone-shaped volcanic edifices and ridges. The largest structure is the George Zima Seamount. Its height is 2300 m. There are several other smaller cone-shaped edifices within the province.

The province of the southeastern troughs includes the Peake and Freen troughs and the Palmer Ridge separating them. The Peake Trough extends for 120 km. Its strike is variable: the western part is oriented on an azimuth of 75, and the eastern part, on an azimuth of 110°. The sides of the trough differ significantly in morphology. The northern flank is characterized by steep slopes. The eastern part of the northern flank is crowned by a narrow crest extending along the flank 85 km long. The Peake and Freen troughs and the Palmer Ridge inherited features of the relief of the MAR flanks. The analysis of these features suggests that a dome-shaped or arched rise of the MAR flank structures was formed in this area. In the place of these rise, there was a subsequent subsidence with the formation of two troughs. The Palmer Ridge, separating them, is a tectonic remnant of this rise.

The province of the southeastern end of King's Trough includes the narrowest part of King's Trough transited to Freen Trough, to mountain massifs on both flanks of King's Trough, and to a basin adjacent to the northern flank, which we will refer to as the East basin. King's Trough in this province consists of two troughs. The boundary between the them is formed by a series

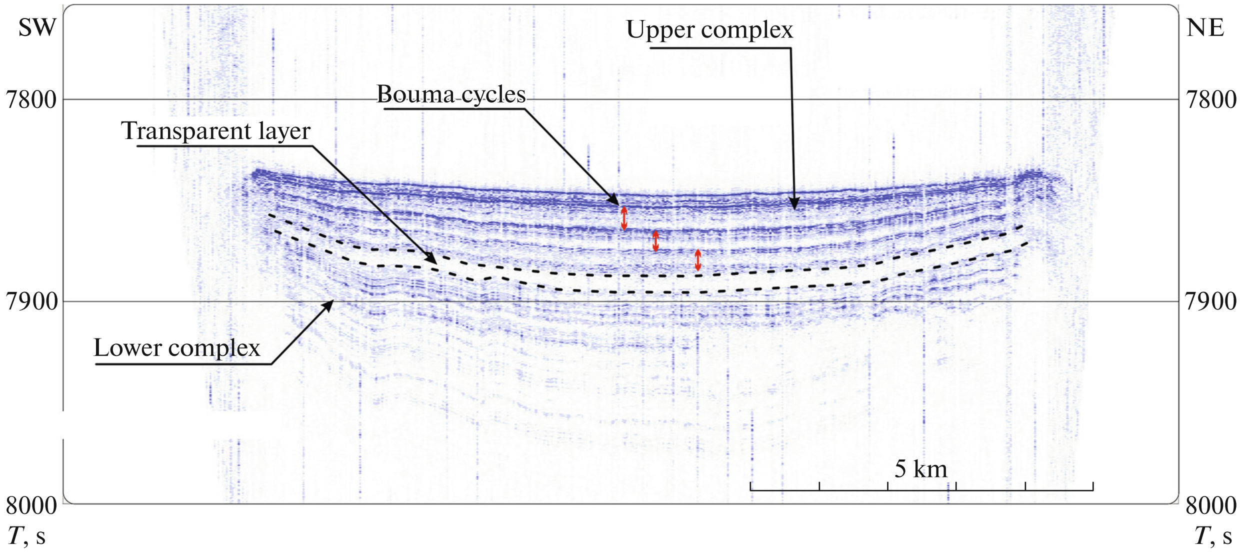

Fig. 3. Section of the upper part of the sedimentary cover in the Peake Trough.

of steps. The flanks of both basins have a complex morphology both in plan and in section due to the fact that spurs of the flank massifs enter the basins.

The province of the central part of King's Trough involves a number of basins and structures on its flanks. The South and Central basins, studied during the cruise, are separated by transverse dislocations; the large Median Ridge is attributed to them. The sides of the basins have different structures in different areas: either steep (15°–20° steepness) flat and straight, or stepped with terraces of different widths, or winding. The Median Ridge, which arose on the border of two depressions, is divided into two parts. The southern part of the ridge extends along an azimuth of 110°, while the northern part extends along an azimuth of 360°. It is volcanic in origin, as indicated by the basaltic composition of rocks dredged from its slopes [9].

According to seismoacoustic profiling data, continuous sedimentary horizons are present in depressions of King's, Freen, and Peake Troughs, in the East basin, and on the plains and plateaus surrounding the above structures. The sedimentary cover is also widespread in the basins in the province of the MAR flank structures. In the rest of the site, sedimentary formations are fragmentary, which makes it impossible to correlate the age of the horizons in different parts of the survey area. According to data of continuous seismic profiling, the sedimentary section of King's Trough contains the Pliocene–Holocene upper seismic complex 50–100 m thick [10]. The layered sequence, studied during the 55th cruise of the R/V *Akademik Nikolaj Strakhov,* is part of this seismic complex, which is interpreted as sediments of glacial and interglacial epochs [11].

The apparent thickness of the sedimentary cover in Peake Trough is up to 150 m. The sediments can be divided into two complexes. The thickness of the complexes is maximum in the axial part and decreases towards the sides (Fig. 3). This feature indicates syndepositional sedimentation in the trough and its continued submergence with a gradual decrease in the submergence rate. The upper 50 m of the section is characterized by a well-defined cyclicity of the sedimentation. It is manifested in the form of several (up to four) intervals of gradual transition from transparent chaotic reflections, corresponding to the rapid sedimentation, to bright extended horizons of the condensed section. These deposits appear to have been formed by turbidite flows that periodically descended from the sides of the trough and reflect Bouma cycles. Freen Trough has a similar structure of the sedimentary section.

The parental rocks, composing the structures of King Trough, Peake and Freen Troughs, and the Palmer Ridge, were previously sampled during several expeditions [3, 6, 9, 10, 15]. Among them, basalts dominate dramatically; they are distributed in all structures and at different depth levels. However, serpentized ultramafic rocks and gabbroids were also encountered; they are most often found in the Palmer Ridge. Chemical and petrographic data showed that the basalts are alkaline, which according to [3, 15] indicates that the basalts poured out under intraplate conditions.

We sampled the sides of Peake (station S5507) and Freen (stations S5509, S5510) Troughs, the North Ridge (station S5511), which overlies the southern side of Freen Trough, and central-type volcanic structures formed on the flanks of the southeastern end of King's

Table 1. Successful dredge stations of the 55th cruise of R/V *Akademik Nikolaj Strakhov* at the King's study area

Station number	N	W	Depth interval, m	Composition and weight (excluding precipitation and ice drift material)	Weight, kg
S5507	43.20°	19.86°	4660–4550	Ultrabasites 35%, gabbro 25%, basaltic sedimentary breccias, hyaloclastites and basalts 40%	50
S5509	42.72°	19.85°	5000–4910	Basalts 100%	30
S5510	42.73°	19.85°	4750–4600	Basalts 100%	5
S5511	42.60°	20.16°	4400–3660	Basalts 30%, calky limestones 70%	7
S5513	43.28°	20.72°	3650–3600	Basaltic and hyaloclastite sedimentary breccias and basalts 90%, limestones 10%	150
S5516	42.69°	21.14°	2500–2160	Basalt breccia 96%, Fe–Mn crusts and nodules 4%	5

Trough (stations S5513, S5516). Table 1 demonstrates the data on dredging.

The predominant rocks are basalts. Basalts from Peake and Freen Troughs are close to those widely developed in the axial and crestal zones of the MAR: they have elements of pillow lava and zones of quenching glass. Along with basalts, the rocks representing the entire section of the oceanic lithosphere were sampled on the northern side of the Peake Trough: ultrabasites, gabbroids, and dolerites. Previously, only volcanics were collected here.

The magnetic anomalies of the study area are heterogeneous in amplitude and strike. They are represented both by linear medium-amplitude (up to 400 nT)

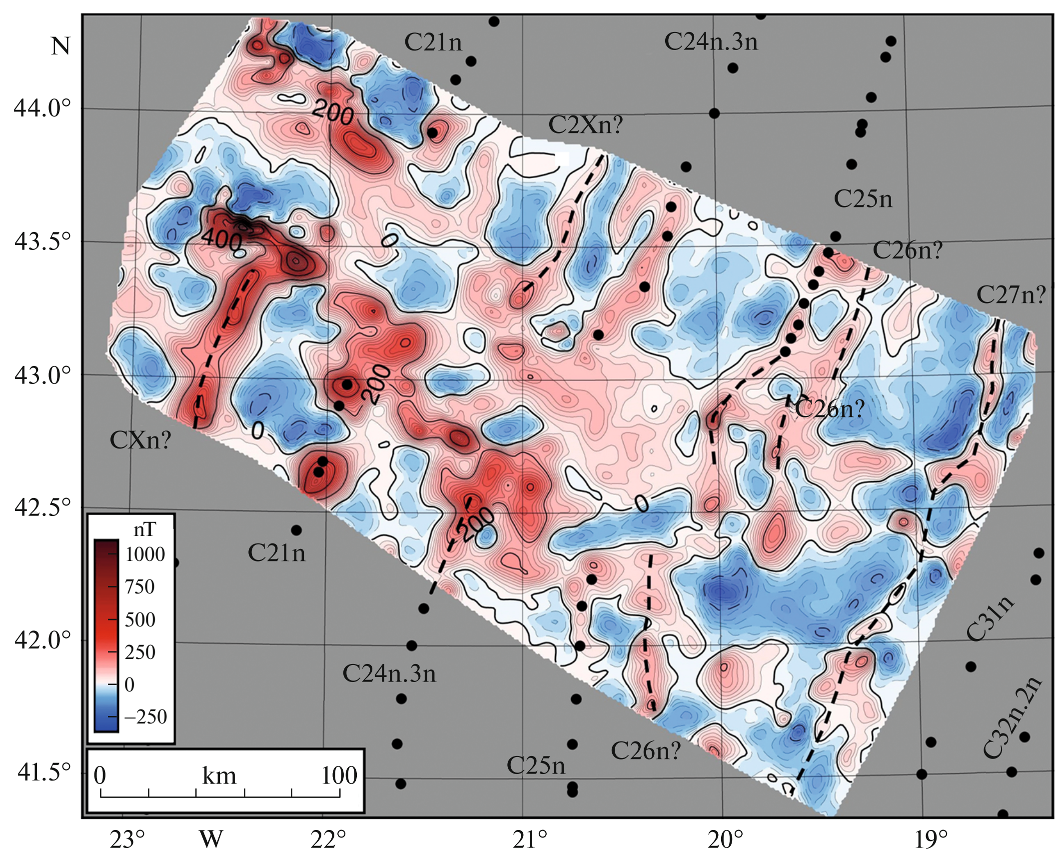

Fig. 4. Map of the magnetic survey. The axes of linear magnetic anomalies from the catalog [17] and the position of our selected linear anomalies within the study area.

anomalies of both signs of north-northeastern and partly northwestern strike, observed generally in the northern part of the study area, and by intense (up to 1200 nT) isolated anomalies also of both signs, attributed to some ridges and seamounts (Fig. 4). The observed linear magnetic anomalies to the north of King's Trough and Freen Trough agree well with the C21n, C24n.3n, and C25n reference anomalies previously identified; the positions of the anomalies are shown in Fig. 4, with ages of 45.4, 53.3, and 56.6 Ma, respectively [16].

The same anomalies are also traced south of King's Trough and Freen Trough, although less distinctly. Nevertheless, we were able to identify here the C21n, C24.3n, and C25n reference magnetic anomalies and the assumed chrons, the separation of which is not so unambiguous. This means that the oceanic crust of King's Trough, Peake and Freen Troughs, and Palmer Ridge was originally formed in an axial spreading zone. Conspicuous is the fact that the axes of the C21n anomaly are displaced in the northern and southern parts of the study area. The displacement is up to 20 km. Linear anomalies in the northern part are "cut" along the line: the northern side of the Central basin of King's Trough—the northern side of South basin of King's Trough—the northern side of Freen Trough, which may indicate the fault origin of this boundary. Intense local predominantly positive magnetic anomalies are recorded in the northwestern and western parts of the study area. They coincide with large volcanic massifs and testify to the superposition of the products of flank volcanism, formed during the positive magnetic epochs, on the oceanic crust, which appeared in the axial zone of the spreading.

Therefore, according to the results of bathymetric survey within the southeastern part of the King's mesostructural cluster, six provinces were identified. Each province has its own morphostructural feature resulting from the multistage tectonic and the volcanic processes, which alternate and conjugate with each other in time.

According to seismoacoustic profiling data, three main types of seismofacies have been identified: (a) pelagic complexes, (b) deposits of turbidite flows, and (c) chaotic facies of gravity origin. The studied Pliocene–Holocene sections demonstrate the alternation of different seismofacies, reflecting the change in sedimentation settings from the slow pelagic setting of glacial periods to the more intensive interglacial sedimentation. Dislocations and folded deformations of sedimentary layers were noted.

The obtained data support the assumptions that the formation of the elongated arch rise preceded the King's Trough formation [4, 11]. According to the position of linear magnetic anomalies in this region [18], the ocean floor uplift occurred between 33.5 and 20.1 Ma. The arched rise became a scene of intense intraplate volcanism, the intensity of which increased from southeast to northwest. This was followed by the formation of King's Trough and Peake, and Freen Troughs, most likely as a result of subsidence of the axial part of the rise.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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