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GEOLOGY

New Data on the Geological Structure of the Eastern Flank of the Charlie Gibbs Fracture Zone (North Atlantic)

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Abstract—The geological structure of a large volcanic edifice in the eastern flank of the large Charlie Gibbs Fracture Zone in the region of the Eastern Thule submarine rise (North Atlantic) is discussed. It is shown that the volcanic edifice was formed near the axial zone of the Mid-Atlantic Ridge in the interval of 64–67 Ma ago. Subsequently, its summit part was destroyed by wave abrasion, and then it sank along with the oceanic part of the plate to 2500 m deep. It was concluded that volcanism in the Rockall Rift Basin affected the region further to the south, which was already an oceanic basin and was separated from the rift basin with the Charlie Gibbs Fracture Zone.

Keywords: North Atlantic, Charlie Gibbs Fracture Zone, Eastern Thule Rise, intraplate volcanism, Rockall Plateau, plume

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One of the goals of the 53rd cruise of the R/V *Akademik Sergei Vavilov* in autumn 2021 was to study intraplate processes in the North Atlantic. These processes are usually coupled with ascending deep mantle plumes that generate intraplate volcanism, which in turn leads to the formation of individual volcanic seamounts and their chains, as well as volcano-tectonic rises, on the seafloor. The largest plumes in the North Atlantic are the Iceland and Azores plumes: the former is located beneath the axial spreading zone of the Mid-Atlantic Ridge (MAR), and the latter is situated near this axis [1]. A number of smaller plumes is reported between these two major plumes, in the eastern flank of the MAR; the activities of these minor plumes led to the formation of the Azores–Biscay Rise and volcanic seamounts near the Kings Trough. In the eastern flank of the large Charlie Gibbs Fracture Zone (North Atlantic), the Eastern Thule submarine rise is located [2]. Symmetrically to this rise, in the western flank of the MAR, the Western Thule Rise is located, suggesting that these two rises constituted a united structure in the geological past; this structure in turn was formed in the axial spreading zone of the MAR as a result of subaxial ascent of a deep mantle plume [3]. This rise is estimated to be 54–46 Ma in age (Eocene), whereas volcanic activity within its limits continued for about 8 Ma [3]. The formation of the Thule Rise is associated with the Milne hotspot, which existed beneath the axial part of the MAR beginning 76 Ma ago and migrated both southward and northward along the MAR axis [4].

During the 50th cruise of the R/V *Akademik Nikolai Strakhov*, a large seamount with the center at 51°15′ N and 19°35′ W (hereinafter, Seamount 51-19) was revealed and verified by a bathymetric survey in the area of the Eastern Thule Rise. This seamount sits on an uplifted linear topographic feature, which is a SE-

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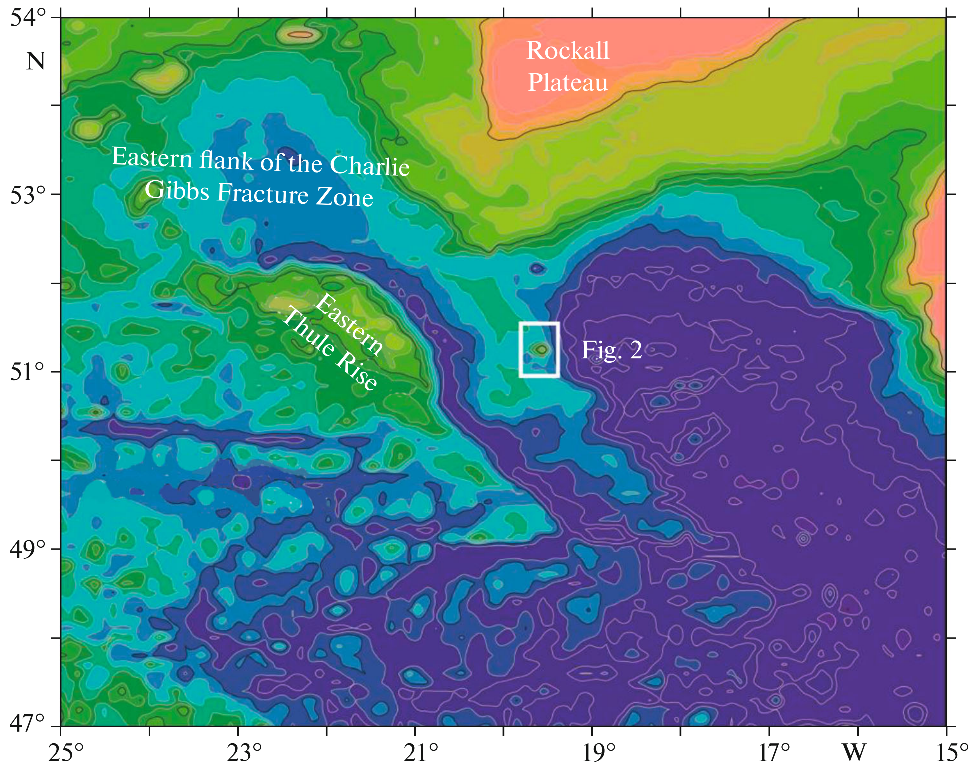

Fig. 1. Map showing seafloor topography of the eastern flank of the Charlie Gibbs Fracture Zone (North Atlantic). The white rectangle marks the area shown in Fig. 2.

directed spur of the rise that connects the Rockall Plateau and the Rockall Basin identified in seismic profiles beneath sediments [5]. This basin extends in parallel to the Eastern Thule Rise and is divided from it with a narrow deep trough (Fig. 1).

Within the Rockall Basin, there are submersed Late Cretaceous Barra volcanic submarine ridges [5]. Given the present state of knowledge, it is difficult to interpret the seamount under study unambiguously as a southwestern continuation of the Barra Ridges or as a part of the Eastern Thule Rise that was split into two by a deep trough.

On the basis of a bathymetric survey, which was carried out using a RESON SEABAT-7150 multibeam echo sounder, we constructed a middle-scale bathymetric map of Seamount 51-19 (Fig. 2a). During the 53rd cruise of the R/V *Akademik Sergei Vavilov*, a magnetic survey was carried out in this area using a SeaSpay magnetometer (Fig. 2b), and dredging was also conducted.

Seamount 51-19 has a shape similar to a truncated cone, slightly elongated meridionally. It rises by 1500 m over the seafloor at about 4000 m depth, with the flat summit being at about 2500 m depth. The diameter of the seamount base is about 18 km, and the cross size of its flat summit part (from north to south) is 8 km. The slopes of this seamount have small cone-shaped features of up to 1.5 km in diameter and 100 to 200 m high, which are especially abundant on the northeastern slope of the seamount. Thus, the submarine topography of the seamount clearly indicates this is a volcanic edifice that was once above sea level. The top part of the edifice was abraded by waves at sea level and marks the stage when the extinct volcano was destroyed before the time when the formed guyot began to submerge together with the seafloor. Small cone-shaped features are minor volcanic edifices.

Based on the results of the magnetic survey, we constructed a map of the anomalous magnetic field for the Seamount 51-19 area using the data from the GEODAS geophysical database [6]. The seamount itself corresponds to a large unipolar negative anomaly with a maximum amplitude of about –550 nT. Similarly to the seamount outline, this anomaly is also slightly meridionally elongated. The anomaly contains two clear local negative extremums of –550 and –450 nT, divided by a zone of higher values. The less intensive extremum in the northeast corresponds to the slope of the seamount, where the minor volcanic edifices are concentrated. It is therefore clear that the seamount considered is a volcano the edifice of which formed during one of the reversal polarity epochs of the past. Immediately north of Seamount 51-19, a positive anomaly of about +50 nT is distinguished, and this anomaly is seemingly caused by other sources of the anomalous magnetic field.

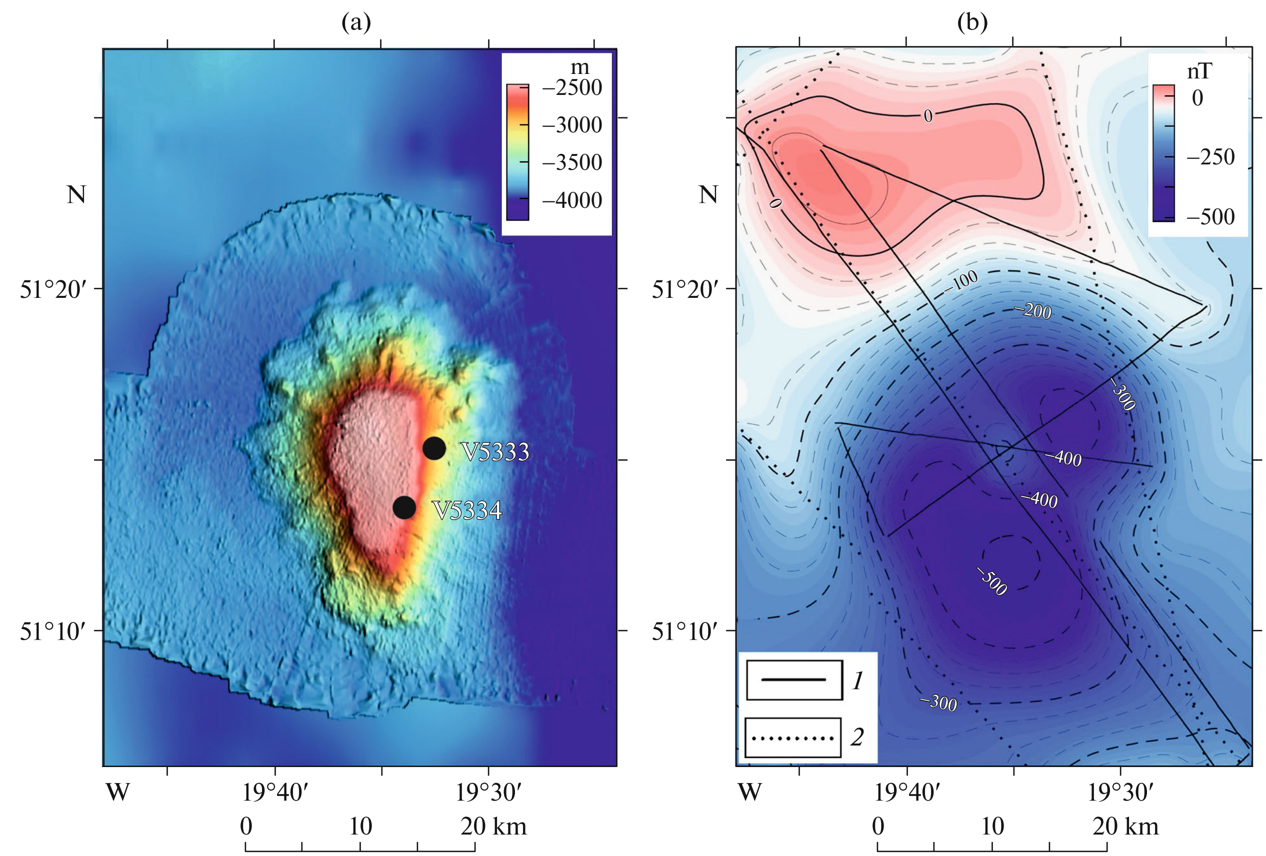

Fig. 2. Maps showing (a) the topography and (b) the anomalous magnetic field in the Seamount 51-19 area. Black circles in panel (a) denote the dredging stations. Legend for panel (b): (*1*) magnetic profiles made during the 53rd cruise of the R/V *Akademik Sergei Vavilov*; (*2*) magnetic profiles from the GEODAS geophysical database [6].

During express processing of the data by the procedure proposed in [7], we established that the anomaly of Seamount 51-19 can be approximated by a set of two dipole sources. The first source is located in the southern part of the seamount, at a depth of more than 8 km (4 km beneath the seafloor). The estimates obtained with this source for conical and cylindrical bodies yield a depth close to their base (i.e., the lower rim). The second source is located in the northeastern part of the seamount, sitting at a depth of 3.3 km, which corresponds to the northeastern slope of the edifice. This is an argument for the fact that this source is genetically related to the concentration of the aforementioned small cone-shaped volcanic edifices. Proceeding from the calculations made, we can expect that there is a solidified magma chamber beneath the seamount and that this chamber extends down to 4 km depth.

Based on the global gravity field model with a resolution of two angular minutes [8], we constructed the map of residual Bouguer anomalies for Seamount 51–19 and its surroundings, excluding the bilinear trend (Fig. 3).

These gravity anomalies show an alternating-sign, quasi-annular, concentric structure in the area. The round-shaped negative gravity in the center coincides with the outline of the seamount itself, and, hence, its presence is caused by the thicker crust in the area of the seamount that formed as a result of volcanic activity. This anomaly was surrounded by a semi-circle of positive local residual anomalies indicating a thinner crust around the volcanic edifice. Most likely, the thinner crust in the periphery of the volcano is related to the downwarping of the lithosphere due to the lithostatic load. This, in turn, suggests that the volcano formed upon a quite thin lithosphere, probably near the MAR axial zone.

In the upper part of the eastern slope of Seamount 51–19, two dredging stations were made: V5333 (51.25° N and 19.55° W, in the depth interval of 3150–2600 m) and V5334 (51.24° N and 19.54° W, in the depth interval of 2680–2630 m) (Fig. 2a). The dredging results have confirmed the volcanic nature of the seamount. Along with rocks produced by ice drift, they recovered basalts, among which aphyric and porphyric units can be distinguished (up to 10–15% of impregnations). Porphyric varieties are dominated by plagioclase impregnations, but olivine and clinopyroxene can also be found. Porous varieties of aphyric basalts appear: rounded pores of 0.5 to 7 mm in size

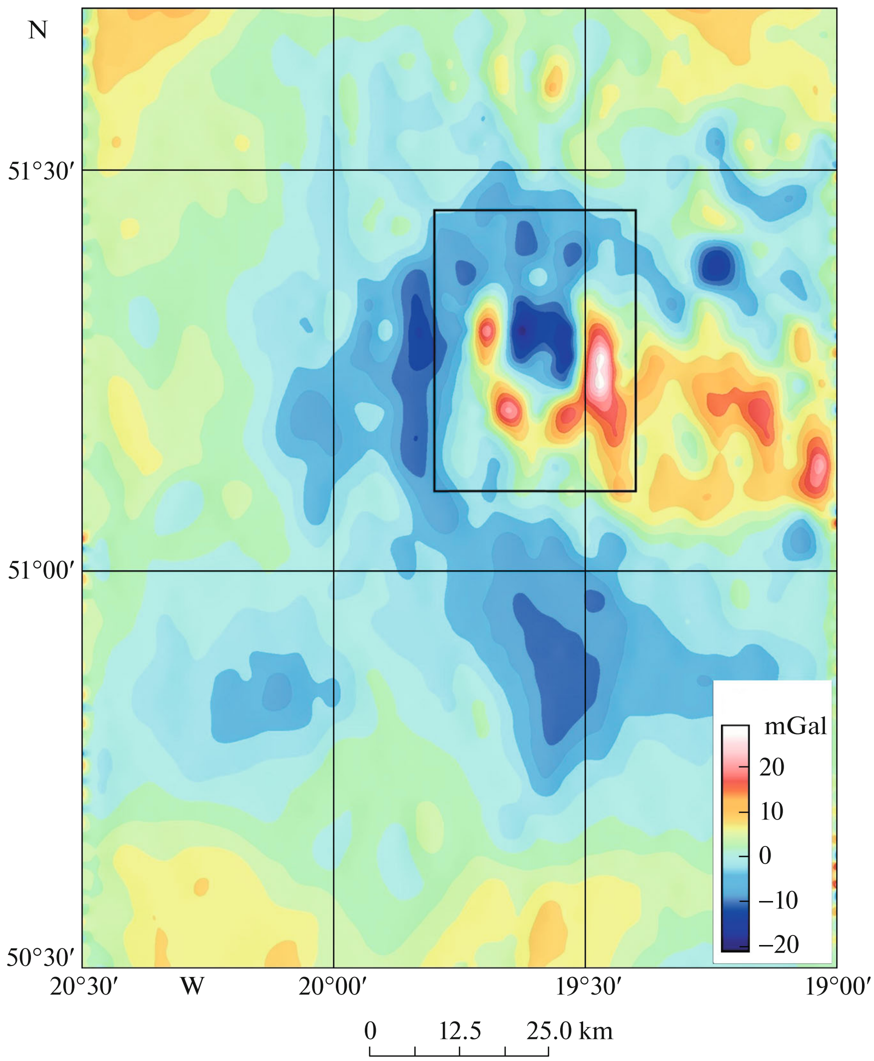

Fig. 3. Map of residual Bouguer gravity anomalies, after [8]. The rectangle marks the area shown in Fig. 2.

comprise up to 20–25% of the rock volume. It is obvious that highly porous basalts could form under either shallow-water or supraaquatic conditions.

Therefore, the studied Seamount 51-19 is a guyot that formed as a result of an intensive episode of volcanic activity. The formed volcano rose over the sea level. Once the volcano became extinct, it drifted eastwards with the Eurasian Plate and was submerging with the oceanic part of the plate. When the summit part of the volcano reached sea level, it was abraded by waves. Taking into account the present-day position of the summit (2500 m deep) and the rate of seafloor subsidence (around 0.04 mm/yr, after [9]), Seamount 51-19 appeared completely underwater about 62.5 Ma ago. Logically, it formed before that time. Assuming that Seamount 51-19 is situated between band magnetic anomalies 25 and 31 [10], and according to the magnetostratigraphic scale [11], the volcano could have formed in the interval of 64–70 Ma ago. Since the seamount corresponds to a negative magnetic anomaly, this interval can be narrowed to 64–67 Ma (Late Cretaceous), when reversal magnetic polarity took place [11]. Such an age indicates that the volcano formed near the MAR axial zone, and this is consistent with the data above on the Bouguer anomalies within the seamount limits, suggesting the relatively thin lithosphere upon which the seamount began to form.

This estimated age of volcanic activity is closer to the time of formation of the Barra Ridges, which formed, according to [5], in the Late Cretaceous. Therefore, it can be suggested that volcanism in the Rockall Rift Basin affected the region further south, which was already a marine basin and was divided from the rift basin with the Charlie Gibbs Fracture Zone.

Thus, our studies have shown that Seamount 51-19, which is located at the eastern termination of the Charlie Gibbs Fracture Zone, is a guyot that formed as a result of wave abrasion of the top part of an extinct volcano comprised of basalts and formed about 64–67 Ma ago near the axial spreading zone of the MAR. Most likely, this paleovolcano was produced by Late Cretaceous volcanic activity, which took place in this region and led to the formation of the Barra volcanic ridges in the Rockall Basin.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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