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GEOLOGY

Geological and Geophysical Studies of the Charlie Gibbs Fracture Zone (North Atlantic)

S. G. Skolotnev[a,*], A. Sanfilippo[b], A. A. Peyve[a], Y. Nestola[c], S. Yu. Sokolov[a], L. Petracchini[d], K. O. Dobrolybova[a], V. Basch[b], A. N. Pertsev[e], C. Ferrando[b], A. N. Ivanenko[f], C. Sani[b], A. A. Razumovskii[a], F. Muccini[g], A. S. Bich[h], C. Palmiotto[c], Y. V. Brusilovsky[f], E. Bonatti[c], K. N. Sholukhov[e], M. Cuffaro[d], I. A. Veklich[f], M. Ligi[c], and V. N. Dobrolybov[a]

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Abstract—The geological and geophysical data obtained during the 50th cruise of R/V *Akademik Nikolaj Strakhov* on the Charlie Gibbs megatransform system structure in the North Atlantic are presented. The structure of the Charlie Gibbs Fracture Zone was examined in detail, considering previously published data. It has been shown that the northern and southern segments of the Mid-Atlantic Ridge, separated by the Charlie Gibbs transform fault, are entirely different in morphology, and hence in terms of formation. The dredged rocks are represented by an entire spectrum from the mantle to upper crustal varieties and allow us to determine the origin of the main structures of the Charlie Gibbs megatransform system considering detailed data on the morphology.

Keywords: megatransform system, North Atlantic, Charlie Gibbs transform fault

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Most oceanic transform boundaries represent single narrow (a few km) fault zones, offsetting two rift segments of mid-oceanic ridges. However, there are also more complex structural ensembles, including several contiguous faults separated by short intra-transform rift segments, called megatransform systems (MTSs) [1]. Such systems include the Charlie Gibbs Fracture Zone in the North Atlantic. This zone is unique due to its location in the area between two large structures of the Atlantic Ocean, which have noticeable differences in the development of the crustal magmatic accretion. The crustal formation in the northern structure is largely controlled by the influence of the Iceland plume on the processes occurring in the axial structure of the spreading zone.

The main goal of the expedition work performed during the 50th cruise of R/V *Akademik Nikolaj Strakhov* was to obtain new data on the geodynamic conditions of formation of the oceanic crust and magmatic and tectonic processes within the Charlie Gibbs MTS. The works within the Charlie Gibbs survey area were carried out, taking into account previously obtained data [2–5]. This is the first detailed study of the entire active part of the Charlie Gibbs Fracture Zone (54500 km^2), including two adjacent rift segments, southern and northern. About 5500 km of profiles of the bathymetric survey using the RESON Seabat-7150 deepwater multibeam sonar system and the hydromagnetic survey using the SeaSpy and Geometrics G882 magnetometers were made at the survey area. The structure of the upper part of the sedimentary cover was studied with an EdgeTech 3300 profiler along the same profiles. Basalts (65%), dolerites (6%),

[a] *Institute of Geology, Russian Academy of Sciences, Moscow, 119017 Russia*
[b] *Dipartimento di Scienze della Terra e dell'Ambiente, Universita' di Pavia, via Ferrata 1, 27100 Pavia, Italy*
[c] *Istituto di Scienze Marine – CNR, Bologna, via Gobetti 101, 40129 Bologna, Italy*
[d] *Istituto Geologia Ambientale e Geoingegneria – CNR, P.le A. Moro 5, 00185 Roma, Italy*
[e] *Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Russian Academy of Sciences, Moscow, 119017 Russia*
[f] *Shirshov Institute of Oceanology, Russian Academy of Sciences, Moscow, 117218 Russia*
[g] *Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata 605, 00143 Roma, Italy*
[h] *VNIIOkeangeologia, Ministry of Natural Resources and the Environment of the Russian Federation, St. Petersburg, Russia*
**e-mail: sg_skol@mail.ru*

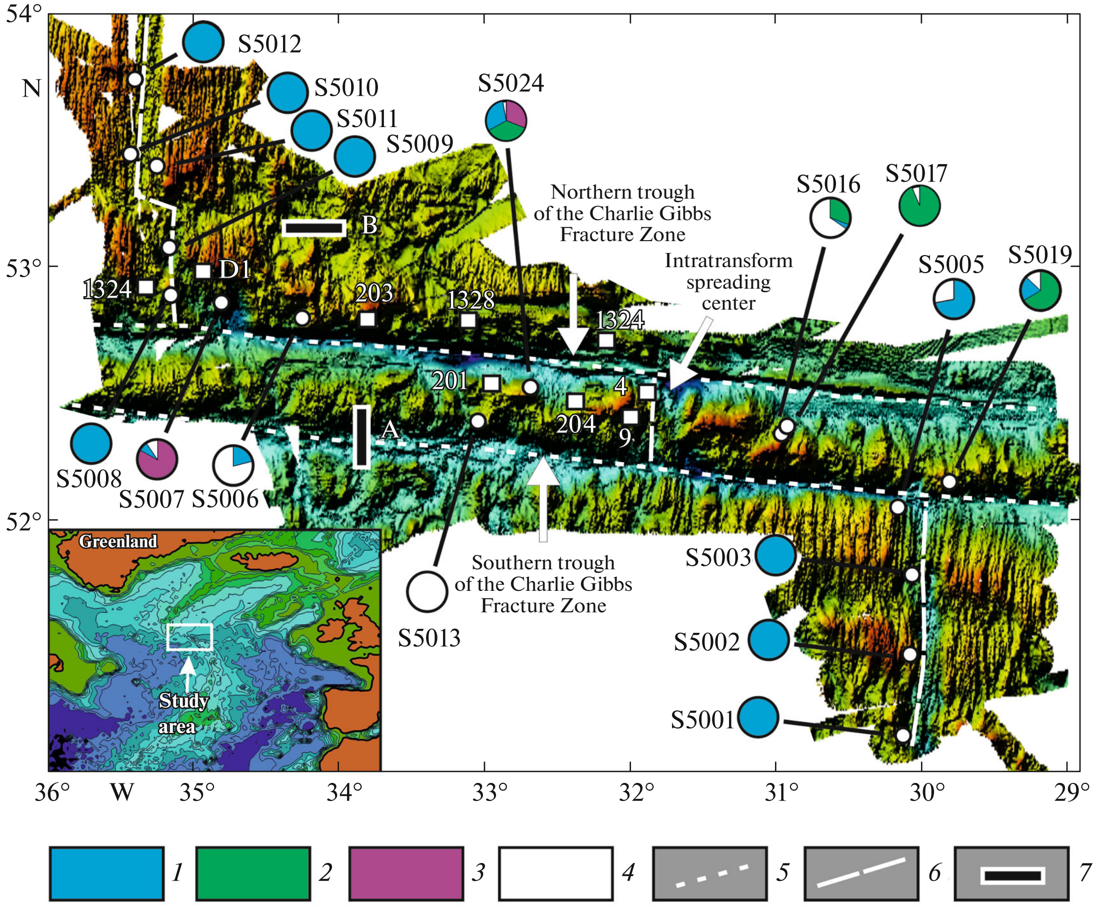

Fig. 1. The geological scheme of the bottom topography of the Charlie Gibbs Fracture Zone (North Atlantic) constructed based on the bathymetric survey data obtained during the 50th cruise of R/V *Akademik Nikolaj Strakhov* and the data in [10]. Dredging stations marked by white squares are after [4, 5, 11]; dredging stations of the 50th cruise of R/V *Akademik Nikolaj Strakhov* are marked by white circles. The ratios of the collected rocks are shown as sectors. Legend: (*1*) basalts and dolerites, (*2*) gabbro, (*3*) ultramafic rocks, (*4*) ice-rafted material, (*5*) axes of fault zones, (*6*) axes of rift segments, (*7*) the position of sections, shown in Fig. 2.

gabbros (11%), dunites (1%), harzburgites (11%), and continental ice-rafted material (6%) from the various structures were sampled during 17 successful dredgings (Fig. 1).

The Charlie Gibbs survey area includes three structural–tectonic areas: the Charlie Gibbs double transform fault and the adjacent rift segments to the north and south. The northern rift segment within the study area is divided by well-defined nontransform displacements into three structurally different blocks. The depth and width of the rift valleys increase northward towards the southern block, i.e., towards a transform fault. The axial zone of the southern block consists of several echelon rift troughs, separated by neovolcanic ridges and traced in the southeasterly direction. The southernmost trough is connected with the nodal basin one in the intersection zone. Beyond the axial zone, the structure of the Mid-Atlantic Ridge (MAR) in the two northernmost blocks is typical of slow-spreading ridges. It is characterized by the development of rift mountains occurring as extended rift ridges and ridges separated by narrow and shallow troughs parallel to the rift valley. Beyond the axial zone, OCC structures (oceanic core complexes) are developed in the near-fault southern block. This structure is also typical of the near-fault segments of other MTSs (for example, Romanche [1, 2] or Doldrums [3]). The MAR structure to the north of the Charlie Gibbs Fracture Zone indicates a decrease in the intensity of magmatism and an increase in the role of tectonic extension during the spreading towards a transform fault. It is also evidenced by the results of dredging. Only fresh basalts were dredged in the two northern blocks; in the near-fault block, deep rocks (ultramafics and gabbros) prevail among the dredging material (Fig. 1). Based on the previously obtained data, ultramafic rocks are also widespread on the northern flank of the northern transform valley (dredging station 203 [4]).

The rift segment located to the south of the Charlie Gibbs Fracture Zone is divided into three blocks by nontransform displacements. The most completely studied two more northerly blocks, including the near-fault block, are characterized by a structure that is similar to the MAR. There is a deep rift valley with small neovolcanic ridges in the axial zone; typical rift mountains are developed beyond its borders. The rift mountains, located to the south of the Charlie Gibbs Fracture Zone, are significantly lower than those located to the north. Basalts dominate in the dredged material from all axial zones of the three blocks, including the nodal depression formed at the intersection between the rift zone and the southern branch of the Charlie Gibbs Fracture Zone. Note that such a structure of the near-fault block is not typical of the MTS and indicates the atypically high intensity of magmatism under such conditions.

The Charlie Gibbs Fracture Zone consists of the northern and southern fault valleys separated by the intra-transform ridge. Compared with the southern one, the northern valley is more extended and deeper in its active part and consists of alternating uplifts and basins. It is complicated by a median ridge extending from the active part to the passive eastern one. The intra-transform ridge is cut by an intra-transform spreading center of about 40 km long at 31.8° W. It represents a wide rift valley, ending at both ends with nodal depressions. There are ridges in the rift valley. According to dredging data [5], one of these ridges is of volcanic origin. Both flanks of the intra-transform ridge (to the east and west of the rift valley) consist of block mountain structures separated by shallow elongated depressions. In general, the strike of the depressions coincides with that of the present-day intra-transform spreading center. The height of the uplifts regularly increases towards this spreading center. The highest uplifts on both flanks, adjacent to the rift valley, are OCC structures. According to [6, 7], it is confirmed by the presence of corrugated surfaces, parallel to the spreading direction, and the results of dredging, showing that they are composed of gabbros and ultramafic rocks. The dredged structures of the intra-transform ridge are composed mainly of gabbros. All these data indicate that the tectonic extension under the conditions of the so-called dry spreading played a key role in forming the lithosphere of the intra-transform ridge.

According to the hydromagnetic survey results, a distinct pattern of linear magnetic anomalies is established within the MAR, to the north and south of the Charlie Gibbs Fracture Zone. The magnetic anomalies in the area of the Charlie Gibbs MTS have a small amplitude and are arranged irregularly. The only exception is the high-amplitude positive anomaly confined to the intra-transform spreading center.

The location of the earthquake foci and their focal mechanisms, given in the Earthquake Catalog, are consistent with the regional structure and correspond to dextral lateral strike–slip faults along transform valleys and faults both within the northern and southern segments of the Mid-Atlantic Ridge and in the intra-transform spreading center.

Most of the basalt samples were dredged from axial structures of the spreading zone. These are fresh basalts with abundant quenched glassy fragments, with no signs of secondary alteration. Olivine gabbros typical of the oceanic crust (63%) prevail among gabbro samples dredged only within the Charlie Gibbs Fracture Zone. Ore gabbro (22%), gabbronorite (15%), and gabbro itself (<1%) were dredged in smaller amounts. All these rocks are isotropic and show no evidence of tectonic deformations. Peridotites are mainly represented by harzburgites (94%); dunites (6%) are also found. Rocks are highly serpentinized; the less serpentinized varieties have undergone intensive halmyrolysis.

Analysis of the acoustic profiling data on the upper parts of the sedimentary section showed four Quaternary seismic complexes. The formation of these complexes is associated with glacial cycles [8, 9], controlling the supply of the terrigenous material from the Arctic waters. There are also sedimentary bodies in the form of seismic facies draping structures, formed mainly by contour currents in the abyssal zone adjacent to the study area from the northeast, as well as currents along fault troughs, with the formation of seismic facies similar to near-channel facies, called "channel drifts" [8]. There are numerous sedimentary bodies with a chaotic internal structure and a higher degree of acoustic turbidity. They were also accumulated due to landslide processes at the foot of the slopes during the descent of weakly consolidated sediments in a seismically active region (Fig. 2a). The deviation of the acoustic stratification from the subhorizontal bedding is due to a combination of two factors: the enveloping of the basement heterogeneities with the sedimentary material transported by currents with an average sedimentation rate of 45 m/Ma [9] and tectonic deformations. The latter are found within fault troughs in the form of stamp folds confined by reverse faults, the axes of which are traced along the troughs at distances of up to 100 km. They recall piercement structures at a distance from the sides of fault troughs (Fig. 2b). Beyond their borders, the deformations are likely associated with the strike–slip fault paragenesis arising under the Riedel shear mechanism. Within the first and third complexes are areas with amplified reflection coefficient values, indicating an admixture of the volcanoclastic material in the sediments. Note that the sediment-filled fault troughs show signs of neotectonic dislocations in the sediments in both the active and passive parts.

Thus, the comprehensive geological and geophysical study, carried out within the Charlie Gibbs MTS, has provided extensive factual material. Subsequent detailed analysis of the material obtained will enable us to characterize and clarify the reasons for the differences in the tectonic structure and accretion condi-

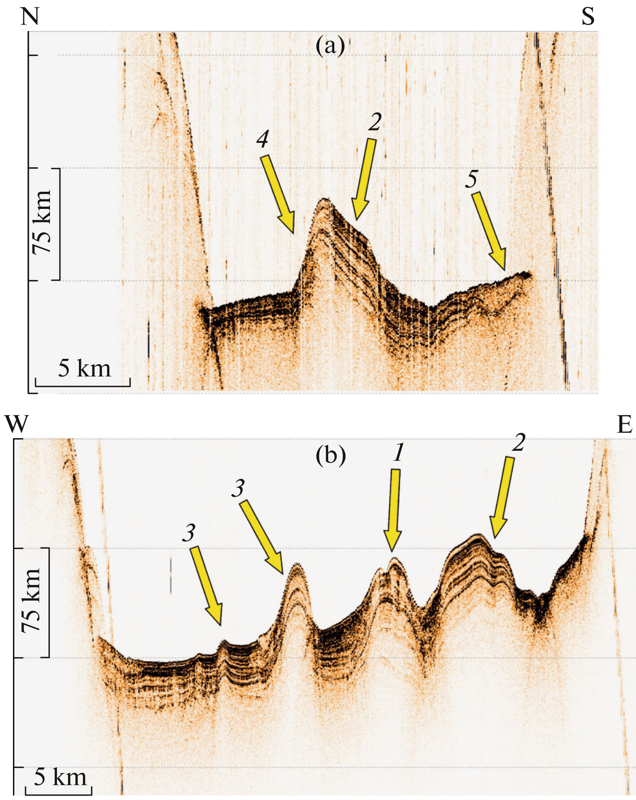

Fig. 2. The structure of the upper part of the sedimentary cover in the area of the Charlie Gibbs megatransform system. The position of sections in the bathymetric scheme: (a) in the passive part of the southern trough; (b) on the flank of the northern trough. Numbers in the scheme: (*1*) "canal drift," (*2*) stamp fold, (*3*) piercement structure, (*4*) reversed fault, (*5*) a sedimentary body with a chaotic structure.

tions of the oceanic crust and sedimentary cover in both the Charlie Gibbs MTS and the adjacent rift segments. It was established that the northern and southern segments of the MAR, separated by the Charlie Gibbs Fracture Zone, are two completely different structures in terms of morphology and, therefore, in the formation conditions. The dredged rocks are represented by an entire spectrum from the mantle to the upper crustal varieties and allow us to determine the origin of the main structures of the Charlie Gibbs MTS, taking into consideration detailed data on the morphology.

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