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GEOLOGY

# New Data on the Geological Structure of the Junction of the Cape Verde Rise, Cape Verde Abyssal Basin, and Bathymetrists Seamounts (Central Atlantic Ocean)

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According to the plate tectonics concept, Atlantic-type oceanic margins belong to tectonically passive margins. However, many observations indicate that some segments of these margins are characterized by intense tectonic and magmatic activity [1]. Cruise 23 of the R/V *Akademik Nikolai Strakhov* was accomplished in one such region at the junction of the continental slope and Atlantic Ocean structures south of the Cape Verde Islands (Fig. 1). The scientific supervisors of the cruise were Academician Yu.M. Pushcharovsky and Yu.G. Leonov. In the cruise, the bottom topography and acoustic profiling were studied with a RESON (SeaBat 8150) multibeam echo sounder, continuous seismic profiling (CSP) was carried out, magnetic and gravitation fields were measured, and dredging and sampling of bottom sediments were also conducted.

The survey area was divided into four morphostructural provinces: the southern edge of the Cape Verde Rise [2], the Cabo Verde Ridge, the Cape Verde Abyssal Basin [2], and the Carter Seamount. The second structure (we propose to name it ‘Cabo Verde Ridge’), which represents an extended mountain ridge, is situated at the extension of the Cabo Verde Scarp located on the western side and investigated during previous expeditions [3]. The NW-trending scarp cuts flanks of transform faults of the Mid-Atlantic Ridge south of the Cape Verde Islands [4]. The Carter Seamount belongs to the chain of the Bathymetrists Seamounts [2].

The southern edge the Cape Verde Rise occupies the northern part of the survey area (see Fig. 1) where the ocean bottom gently submerges southward from 4700 to 5130 m. The even bottom covered with sediments is complicated by ridges and rises (15–300 m high and 1–15 km wide), which are united into NW-trending chains in some places. According to CSP data, the apparent thickness of the sedimentary cover (~450 m) slightly increases in depressions between ridges and rise chains. One of the CSP profiles in the depth section of the northernmost ridge shows a thrust fault (Fig. 2). Its surface plunges in the northward direction. According to acoustic profiling data, in the section rises and ridges represent anticlines, horsts, and diapirlike structures crosscut by folds of a higher order and normal faults (Fig. 3). Sedimentary layers near submerged flanks of these structures are deformed. A positive anomaly (~20 mGal) is recorded in the gravity field at average values of 10–20 mGal.

The Cabo Verde Ridge (~50 km wide) stretches out between structures of the Cape Verde Rise and the Cape Verde Abyssal Basin (Fig. 1). The ridge summit rests at a depth of 4200–4300 m and inclines northward. The relative height of the ridge is about 800 m in the north and 300–400 m in the south. The sedimentary cover of the ridge is similar in structure to the cover of the southern edge of the Cape Verde Rise (Fig. 4). Hence, the Cabo Verde Ridge, which represents a horst in terms of tectonics, was formed during the rise of the edge of the Cape Verde Rise. According to [5], this horst already existed as a mountain ridge in the Oligocene–Early Miocene. At the top of the ridge, the Quaternary (upper horizontally bedded) sequence 50–80 m thick [6] discordantly overlies deformed deposits about 400 m

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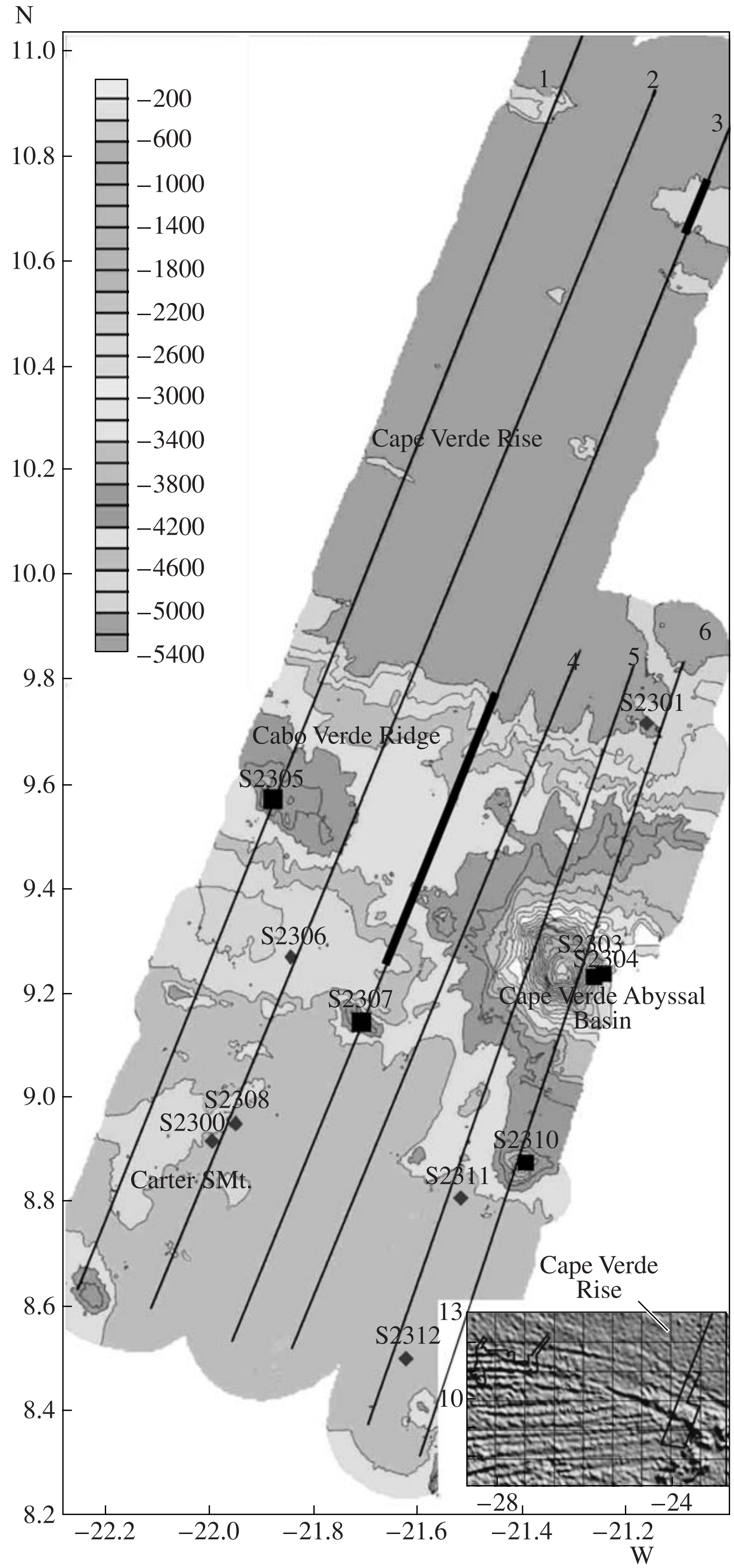


**Fig. 1.** Bathymetric map of the study area, compiled by N.N. Turko, Yu.E. Baramykov, and A.S. Ponomarev. Boxes denote dredging sites; diamonds, sampling sites for bottom sediments. Figures near them are station numbers. Straight lines denote profiles of the bathymetric survey and geophysical profiling. Figures near them are traverse numbers. Thick lines mark out areas of profiles presented in Figs. 2–4. The upper left corner shows the depth scale; the lower right corner, the position of the study region in the structure of the Central Atlantic Ocean. Black lines on the satellite altimetry map [4] show contours of sites of Cruise 22 in the west [3] and Cruise 23 of the R/V *Akademik Nikolai Strakhov* in the east.

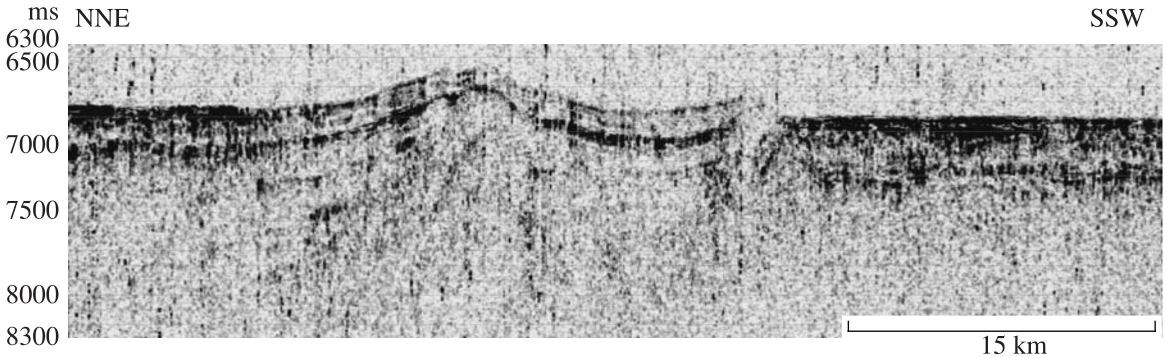


**Fig. 2.** Cross section of the northern ridge at profile 3 based on CSP data. The lower line denotes the horizontal scale.

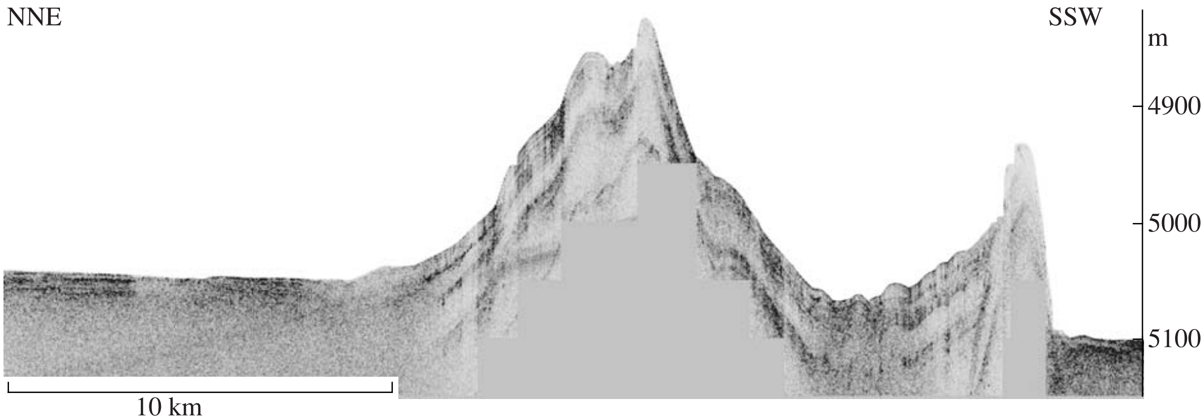


**Fig. 3.** Cross section of the northern ridge at profile 3 based on data of acoustic profiling carried out with an EdgeTech 3300 (United States) profiler. One can see a two-summit rise. The northern summit represents an asymmetric anticline deformed by folds of a higher order. The southern summit is a monocline cut by a diapirlike structure.

thick. It is likely that the ridge was uplifted in the pre-Quaternary time, probably in the Early Pliocene. This is suggested by the similar age of breccias (see below) on slopes of the Carter Seamount and the structural unity of the Cabo Verde Ridge and the Carter Seamount. In some places, the upper sequence is broken by small horsts and diapirlike structures, which are associated with normal faults deforming the sedimentary cover. The ridge is expressed in the gravity field by a positive anomaly (up to 60 mGal).

The Cabo Verde Ridge passes in the east into the large Carter Rise, which is crowned by the cone-shaped Carter Seamount (see Fig. 1). The relative height of the rise is about 5000 m in the north. The height of the seamount is ~3500 m, and the diameter of its even summit is ~500 m. Slopes of the seamount include steep scarps formed by normal faults. According to the results of dredging (S2303, S2304), the Carter Seamount is composed of (a) bioherm limestones, (b) graywacke sandstones, (c) basalts and andesites, and (d) carbonate–basalt breccias (Fig. 1). Bioherm limestones comprise Middle Eocene nannoflora assemblages. The carbonate matrix of some breccias contains a representative nanoplankton assemblage, which allows us to correlate with the Lower Pliocene (identification by L.A. Golovina). Thus, the Carter Seamount represents a Middle Eocene volcano and its extinct summit hosts a carbonate bank. The abundance of breccias on its slopes suggests active tectonic movements in the Early Pliocene. The summit is marked by a positive gravity anomaly (up to 200 mGal). South of the Carter Seamount, one can see a cone-shaped rise (~600 m high, diameter at the base ~2.5 km), which is also likely to be a volcanic edifice.

The southern part of the survey area occupies the northeastern flank of the Cape Verde Abyssal Basin (Fig. 1). The bottom of this area includes the northern and southern depressions separated by an intermediate ridge. The southern depression is bounded on the south by a discontinuous southern ridge. Ridges are expressed in the gravity field by positive anomalies with amplitudes up to 20 mGal. All of the distinguished structures, except the northern depression, exhibit a sublatitudinal strike. The northern depression (15 km wide and subparallel to the Cabo Verde Ridge) pinches out in the west near the Carter Seamount, and its depth

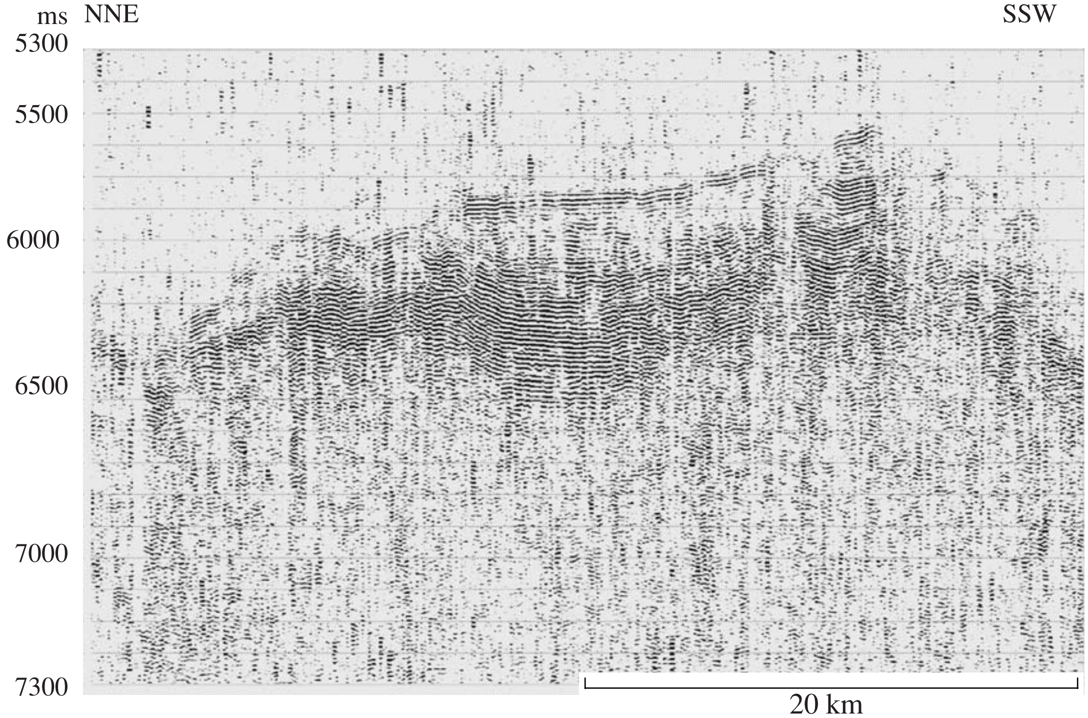


**Fig. 4.** Cross section of the Cabo Verde Ridge summit at profile 3 based on CSP data.

decreases from 4850 to 4400 m. The intermediate ridge in the west includes two summits, which merge into a single rise (about 800 m high) on the eastern flank. The northern slope of the ridge is steeper than the southern one. The steep slope is crosscut by normal faults, where the gentle slope is composed of sedimentary layers that make up a southward-dipping monocline. The southern depression is about 25 km wide, and its depth decreases eastward from 4630 to 4350 m. Beneath the sedimentary cover of the depression bottom, sedimentary layers of underlying sections (below 50–100 m) are deformed into gentle small folds. Rises of the southern ridge represent gentle symmetrical anticlines with limbs crosscut by normal faults.

Thus, numerous newly formed tectonic morphostructures have been revealed in the survey area. The sedimentary layers near them are deformed into small folds and flexures or crosscut by fractures. According to the DSDP Hole 367 data, upper deposits of the study region are composed of Quaternary sediments [6]. However, acoustic records of some areas show a lenticular and undeformed sedimentary layer (up to a few meters thick), which occupies the highest position in the section. Results of the study of recovered sediments show that they are not older than the Late Pleistocene. Thus, tectonic movements responsible for deformation of the sedimentary cover and formation of new morphostructures in the study area were terminated in the pre–Late Pleistocene time.

Bottom sediments 4.5–5 m thick were recovered by corers (Fig. 1). They are represented by gray and greenish gray clay–carbonate and carbonate–clay oozes with homogeneous, lumpy, and bedded structures. The structural diversity of the oozes is related to displacements of sediment masses along the slope. Lumpy oozes with clay pellets (from 1–2 mm to 3 cm in size) were recovered from bottom areas close to the Carter Seamount (S2301) and the Cabo Verde Ridge (S2306). The carbonate ($CaCO_3$) content in the sediments varies from ~0 to 65%. Based on XFA data obtained with a MAKS-GF2E Spectroscan, the sediments exhibit an inverse correlation between Ca and Si; the behavior of Ti, Fe, Ba, Rb, and Zr is similar to that of Si; and Sr correlates with Ca. The contents of Cu, Ni, and Cr sharply increase in green layers and pellets. This is probably related to underwater erosion of products of hydrothermal activity. The sediments are mainly characterized by neutral pH values (about 7–7.5). The medium is more acid (pH = 6.2–6.8) only in cores S2311 (level 150–240 cm) and S2312 (50–100 cm). The Eh value in the sediments varies from –200 to +250 mV. The *Eh* value shows more conservative variation in cores S2308 and S2309. Sections of the remaining stations exhibit layers with high *Eh* values. The composition of gases in sediments identified with a Kristal 2000M chromatograph is characteristic of oxidative and weakly reductive conditions of early lithogenesis. The methane content varies from 0.00028 to 0.0052% (average 0.00096%). Oxygen is present in almost all samples, and its concentration decreases with depth. However, an anomalous high concentration of $O_2$ is recorded in the middle parts of cores at all stations.

The study of nannoplankton and foraminifers from sediments revealed in the corer bottom allowed us to establish that the age of these deposits corresponds to transitional layers between the *Pseudoemiliana lacunosa* and *Geophyrocaspa oceanica* zones and the *Globigerina calida calida* Subzone (0.6–0.8 Ma, Late Pleistocene/Holocene).

Thus, the investigation of the bottom topography and internal structure of sedimentary sequences suggests a wide development of tectonic movements within the four distinguished morphostructural provinces. The motions started in the Early Pliocene (?) and terminated in the Quaternary (pre–Late Pleistocene). They produced new morphostructures (e.g., the Cabo Verde Ridge and Carter Seamount), as well as smaller anticlines, horsts, and diapirlike structures. Sedimentary layers were folded and faulted near these structures.

We have unraveled the volcanic nature of the Carter Seamount composed of basalts and andesites. Its extinct summit was crowned by the carbonate bank in the Middle Eocene.

## ACKNOWLEDGMENTS

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