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GEOLOGY

New Data on the Structure of Sedimentary Cover at the Cape Verde Seamount and the Cape Verde Basin (Central Atlantic) Based on Continuous Seismic Profiling Data

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The transition zones between oceanic and continental lithospheres at Atlantic-type margins remain poorly studied. The data available indicate that these regions are distinguished by specific tectonic [1] and igneous [2] activity. The results of several expeditions conducted by the Geological Institute near the rise of the African continental slope south of Cape Verde Islands support this statement. The systems of transform fracture zones (TFZ) that extend to the south of the Fifteen Twenty TFZ pinch out in this area [1, 3]. The near-latitudinal linear ridges and troughs that serve as the eastern flanks of the Vema, Doldrums, Arkhangelsky, and Vernadsky TFZs of the MAR are cut off by the WNW-trending Cabo Verde Escarpment near the African continental slope. This escarpment probably lies at the extension of the Mercury TFZ [4]. Therefore, continuous seismic profiling (CSP) was carried out during Cruise 16 of the R/V *Akademik Ioffe* (2004) along the 11°31.2′ N, 22°40.2′ W–10°7.8′ N, 24°4.2′ W profile in order to study the structure of sedimentary cover and its basement at the African continental slope south of the Cape Verde Islands, where the manifestation of tectonic activity was expected with certitude. The SW-oriented 220-km-long profile (Fig. 1) crosses the transition zone between the Cape Verde Seamount and the Cape Verde Basin divided by the Cabo Verde Escarpment.

The CSP system in this expedition comprised the following components: air guns (Southern Division of the Institute of Oceanology, Russian Academy of Sciences), single-channel streamer (Geological Institute, Moscow), the major CSP SA-01 digital system (Southern Division of the Institute of Oceanology), and the standby CSPS-2001MC digital system (Geological Institute). Seismic waves were generated at a working pressure of 120 atm with a main interval of 10 s. The length of the active antenna was 25 m. The records on laser discs have been obtained in SGY format.

The signal processing of Profile 1 was carried out by S.Yu. Sokolov (Geological Institute) using a RadExPro v. 3.1 DEKO-GEOFIZIKA software package by the following computation graph: 2D filtering along X of 3 tracks (median); band-path filtering (25–150 Hz, 10–20 dB/oct); predictive deconvolution (window length 100 ms, predictive depth 2 discretes, 1 ms); band-path filtering (15–150 Hz, 10–20 dB/oct); 2D triangular filtering by scanning along 3 discretes; and slant stacking by matrix (3 tracks for 5 time discretes). The bitmapped images in TIF format of the complete computation graph and its particular successions have been obtained for further interpretation. Some fragments of realizations of the seismoacoustic profile processing are shown in Figs. 3 and 4.

The bottom surface, three key horizons that divide four sedimentary units, and acoustic basement surface have been outlined on the basis of the seismic record. Hereinafter, sedimentary beds that lie between key horizons are called sedimentary units. The time and seismogeological sections have been compiled (Fig. 2). The horizons shown in Fig. 2 have been identified and indexed according to [5–7]. The indices of key horizons are italicized, while the units lying below the respective horizons are boldfaced: **F** is the bottom surface, a roof of recent unconsolidated sediments (roof of Unit **F**); **A** is the roof of semiconsolidated sediments (roof of Unit **A**); **β** is the roof of consolidated sediments (roof of Unit **β**); **B** is the roof of presumably older consolidated sediments (roof of Unit **B**); and **Bs** is the acoustic basement, a roof of presumably oceanic basalts (roof of Unit **Bs**).

The layer that comprises sedimentary units **F**, **A**, **β**, and **B** is often named the first oceanic layer, while layer **Bs** is called the second oceanic layer.

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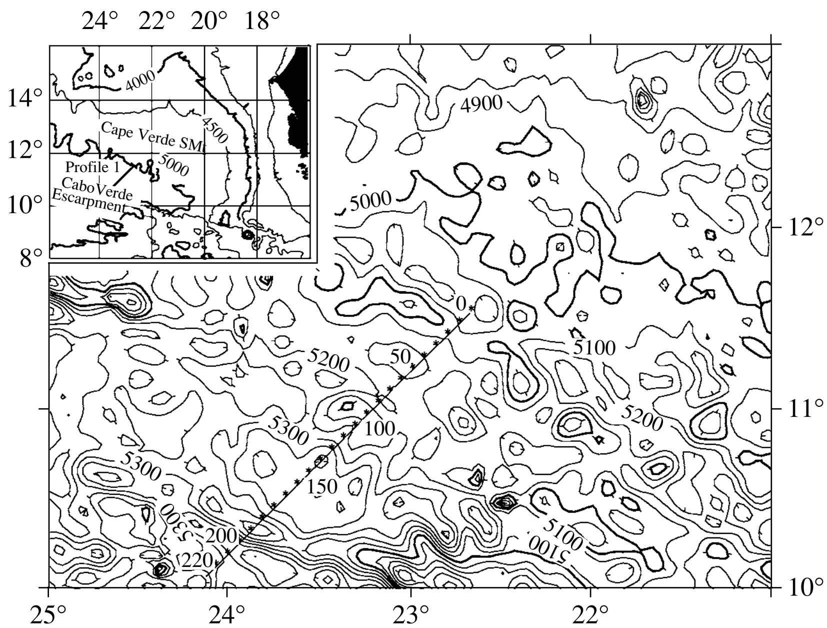

Fig. 1. Index map of the seismic profile. Solid line indicates the profile location. Stakes along the profile are shown with a spacing of 10 km; numerals nearby are distances from the beginning of profile, km. The map of satellite altimetry [10] was used as a base; isobaths are drawn at 100 m. Inset map demonstrates the profile location relative to the Cape Verde Seamount and Africa (black).

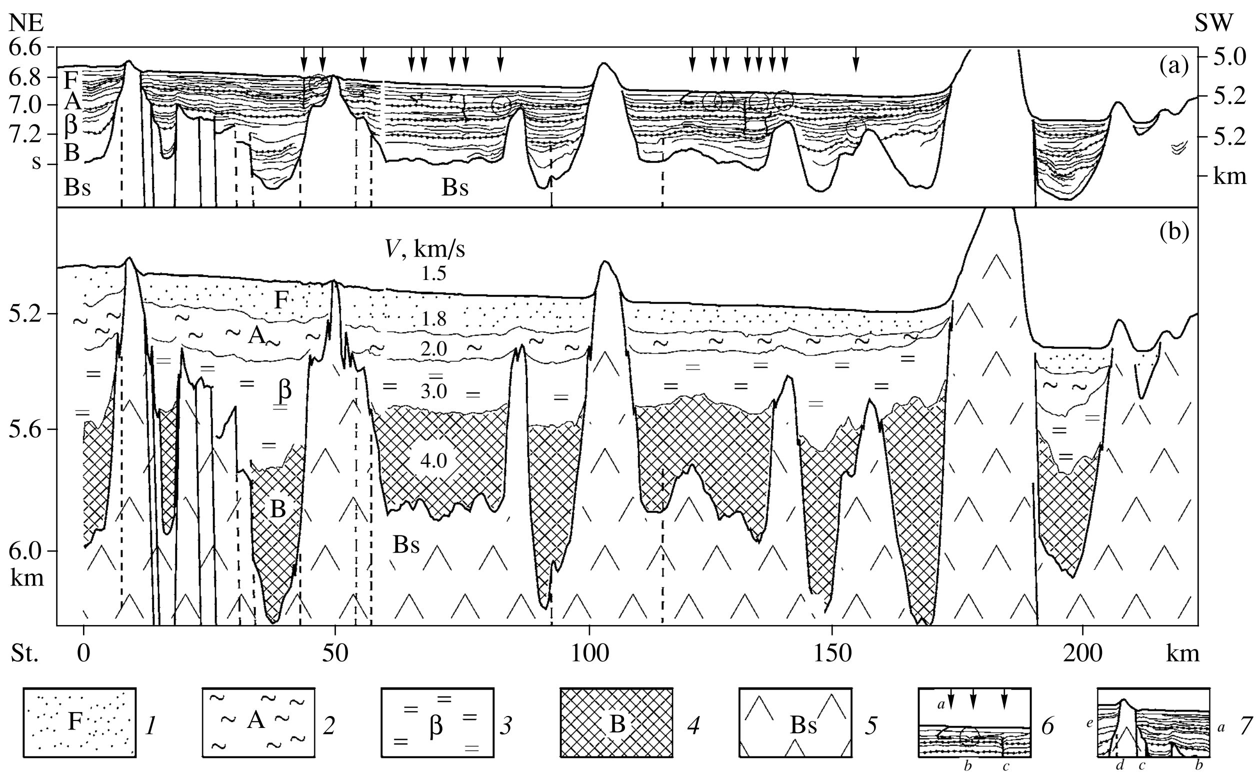

Fig. 2. CSP sections along profile 1: (a) seismoacoustic time section; (b) inferred seismogeological section; the accepted average *P*-wave velocities, sedimentary units, and their indices are indicated: (*1*) unconsolidated sediments (F); (*2*) semiconsolidated sediments (A); (*3*) consolidated sediments (β); (*4*) presumably older consolidated sediments of unknown nature (B); (*5*) basement, presumably oceanic basalts (Bs); (*6*) buried channels of suspension flows: (*a*) projection on seafloor, (*b*) path in the section, (*c*) local; (*7*) structural elements: (*a*) key seismic horizons, (*b*) basement surface, (*c*) proved and (*d*) inferred faults, (*e*) intermediate horizons. Stakes along the profiles are shown with a spacing of 10 km in compliance with Fig. 1.

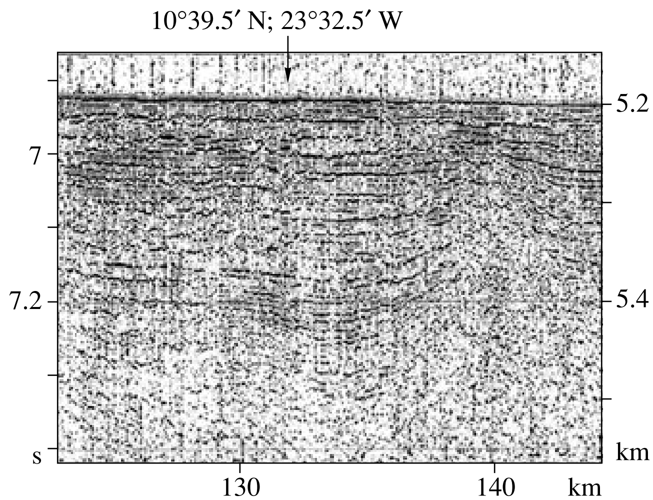

Fig. 3. A fragment of CSP profile with the greatest extent of suspension flow channels.

The effective average *P*-wave velocities in sediments obtained from radio-buoy measurements [6, 7] and taken from generalizations [8, 9] were used for imaging of the seismogeological section.

The bottom topography in the area crossed by the profile is flat with a slight slope to the southwest and is complicated by a few small rises.

The basement surface **Bs** is vague and most likely is a diffuse, highly dissected and spatially inhomogeneous scatterer. Eight depressions are delineated, taking into account the mode of occurrence of sedimentary beds (increasing sagging with depth) and the basement topography. Their axes are located at the 0th, 17th, 37th, 90th, 134th, 146th, 166th, and 195th km of the profile. The 195th km area is a TFZ valley located immediately to the south of the Cabo Verde Escarpment.

The sedimentary units bounded by the extended and consistent horizons differ in the degree of stratification, the attitude of inner beds, the amplitude of reflected signal, and the extent of correlation of inner boundaries. The thickness of sediments attains the maximal value of 1140 m (750 ms) in the depression located at the 37th km at the point with coordinates 11°17.4′ N and 22°54′ W (Fig. 2). Within an interval of the 60–80 km, the thickness of sediments may be still greater. The basement is shown here conditionally based on the last diffuse scatterers.

Unit **F** is largely characterized by a quiet horizontal attitude of inner reflectors. The pinching-out beds are recorded. Substantial deformations are noted only near the 50th and 85th km area. In the first locality, the basement forms a small rise above the seafloor. In the second locality, a buried diapir-like rise is recorded. The relationships between sedimentary beds and basement within the interval 0–60 km are characterized by buttress unconformity, while further to the southwest, the sediments lean against the basement. Unit **F** overlaps Unit **A** unconformably along the whole profile. The thickness of Unit **A** decreases in the southwestern direction from 90 m (100 ms) to 70 m (80 ms). Local maximums are recorded in depressions at the 0th km with a thickness of 123 m (137 ms), between the 33rd and the 44th km with a thickness of 135 m (150 ms), and between the 52nd and the 82nd km with a thickness of 137 m (152 ms).

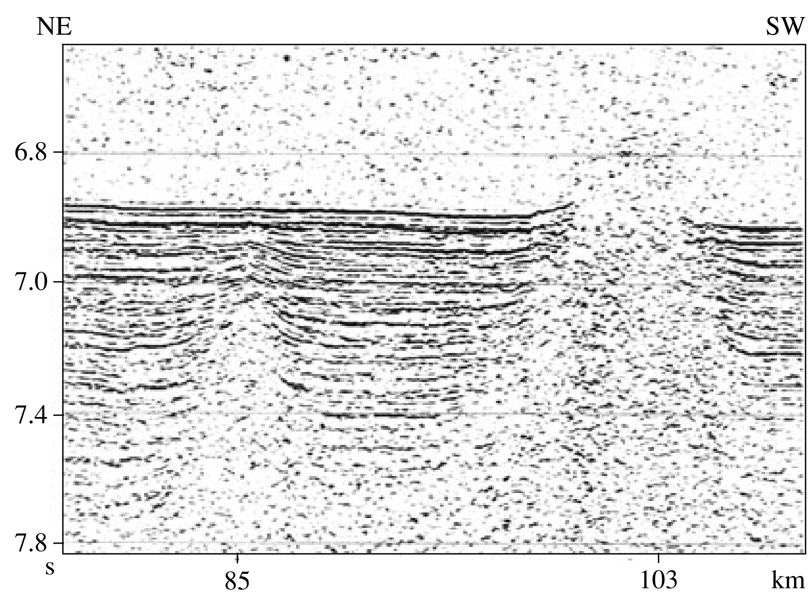

Fig. 4. A CSP profile fragment that demonstrates recent deformations of sedimentary cover above a diapir-like structural feature in the basement.

Horizon **A** (roof of Unit **A**) drapes salients of basement surface along the entire profile. Unit **A** is clearly stratified. Deformations of inner beds allow us to trace faults, e.g., at the 18th km (11°24.6' N and 22°47.4' W). The phase correlation disappears at these localities, and the inner beds pinch out. Unit **A** commonly leans against basement rocks, but the buttress unconformity is recorded at 5–15 km. Like Unit **F**, the thickness of Unit **A** decreases from 145 m (145 ms) in the northeast to 45 m (45 ms) at the 163rd km and attains 0 m at the 173rd km. Here, Unit **A** pinches out and approaches the basement near the Cabo Verde Escarpment. The number of inner layers is systematically reduced with decreasing thickness. The inner beds commonly lie conformably with roof and base of the unit. In the TFZ depression at the 195th km, the thickness attains 145 m (145 ms).

The roof **β** of the third Unit **β** also lies synchronously with the basement surface **Bs** and shows synclinal sagging of inner beds within depressions. The stratification is approximately the same as in Unit **A** except the depression at the 37th km, where it is markedly decreased, probably due to the rapid subsidence of basement in this interval during sedimentation. The conjugation of the inner beds of Unit **β** commonly demonstrates buttress unconformity except at the depressions at the 0th and 195th km. This unit is virtually the same in attitude as the overlying Unit **A**. However, in contrast to Unit **A**, Unit **β** does not pinch out near the Cabo Verde Escarpment. The average thickness of Unit **β** is 220 m (147 ms). In depressions, the thickness is as much as 350 m (246 ms). The fourth Unit **B** directly overlies the basement and is stratified much less distinctly in comparison with all overlying units except for depression at the 37th km, where Unit **B** is stratified better than Unit **β**. The inner boundaries are recorded fragmentarily and are conformable with the basement surface. The relationships with basement are commonly characterized by buttress unconformity. In depressions, the beds lean against the basement. The thickness of Unit **B** is 300 m (150 ms) on average and attains 750 m (375 ms) in depressions.

The buried channels of suspension flows are traceable in two segments of the profile (intervals 43–83 and 119–155 km). A relatively narrow zone of such channels, which is recorded at the 132nd km, embraces units **β**, **A**, and 50 m of Unit **F**. The channels migrated through time insignificantly (~1 km). Coordinates of the last channel projected on the bottom surface are 10°39′ N and 23°32.7′ W (Fig. 3). Such stability is possible under conditions of stable sedimentation environment or control of a fault, which was not revealed in the CSP record.

The **Bs** surface is complicated by juts of variable shape along the profile: symmetric cone-shaped projections resembling paleovolcanic edifices, diapir-like juts, and blocks with rugged summits.

The buried block salients are located at 0–60 km of the profile. At 10–25 km, a 1-km-high (880 ms) salient dissected by numerous faults is outlined from deformation of sedimentary beds, disappearance of phase correlation between boundaries, and stepwise morphology of the basement surface. The vertical displacements probably ceased before the deposition of Unit **F**, which demonstrates undisturbed bed attitude. A similar 1.1-km-high (780 ms) salient, which is recorded at 40–60 km, is crowned by a diapir-like cap. The summits of both blocks tower above the bottom surface. A stepwise uplifted basement block is buried at a depth of 305 mbsf (195 ms) at 147–164 km (coordinates of its summit are 10°30′ N and 23°42′ W). The Cabo Verde Escarpment is situated at 170–190 km. The bottom surface to the southwest of this escarpment is subsided for 124 m. The escarpment is probably controlled by an asymmetric tectonic 600-m-high uplift of the basement at the depth of 4.6 km (coordinates of its summit are 10°20.2′ N and 23°52′ W). The maximal height of this escarpment is 1.3 km (1100 ms). Its length along the profile is 20 km. Asymmetry of the escarpment is caused by its steeper southwestern slope.

A diapir-like salient with summit buried at a depth of 175 m (146 ms) is located at the 85th km (Figs. 2, 4). Deformations in sediments above the summit in the lowermost Unit **F** (between the summit and the first boundary with the seafloor) indicate the vertical uplift of this salient. At the same time, this structure is not expressed in the bottom topography and the recent sediments. The deformation is indicated by the fact that intermediate beds with persistent thickness are inconsistent with the draping structure. The movements stopped, at least, before the deposition of the uppermost 27 m (30 ms) of recent sediments.

A symmetric 970-m-high (840 ms) basement projection is recorded at 170 masf. The pinchout of beds in the framework of this structure suggests that it is a volcanic edifice. This volcano became extinct, at least, before the deposition of the uppermost 30 m of recent sediments. A buried salient at the 140th km with a maximum height of 640 m (470 ms) probably has the same nature. Its summit is located at a depth of 230 masf (190 ms).

The faults shown in Fig. 2 have been established from the stepwise surface of basement, displacement or bending of the correlated sedimentary beds, discontinuity of the traced boundaries, and presence of scarps on the seafloor.

CONCLUSIONS

Thus, a sedimentary cover with average apparent thickness of 672 m (523 ms) and maximal thickness of 1.14 km (776 ms) in depressions occurs in the transition zone between the Cape Verde Seamount and typical oceanic structural features. The cover is largely composed of horizontally bedded sediments locally deformed at diapir-like and block uplifts of acoustic basement.

The upper sedimentary units **F** and **A** make up a structure opposite to the draping: the thickness of each of these units and their total thickness decrease with increasing depth of the seafloor.

The projections of acoustic basement tower above the bottom surface or do not reach this surface.

Judging from satellite altimetry [10], the salients that jut out above the seafloor like the Cabo Verde Escarpment extend in the west-northwestern direction. The considerable length of these structures indicates their regional importance and formation as a result of intense tectonic movements in the recent time. Their growth is likely continuing.

Three upper sedimentary units **F**, **A**, and **β** are similar in many features of seismic record and may be correlated with the lower Miocene–Recent marl, clay, and sand penetrated by DSDP Hole 367 [11]. These deposits are of the turbidite origin. Numerous buried channels of suspension flows were also recorded. The thickness of the lower Miocene–Recent penetrated by DSDP Hole 367 is 290 m, while the total average thickness of units **F**, **A**, and **β** in the studied profile is ~320 m (~430 m in depressions). The uppermost Unit **F** may be referred to as the Quaternary. The lowermost Unit **B** probably comprises the Upper Jurassic–Eocene sediments in compliance with the section in DSDP Hole 367. However, we failed to subdivide this unit into particular stratigraphic horizons.

As follows from correlation of the studied section with sediments penetrated by DSDP Hole 367, the vertical movements of basement blocks and related deformations most likely began before the Quaternary and periodically resumed until now. As has been established by Pushcharovsky et al. [12], one of the stages of neotectonic activity in the Atlantic began 2.5–2.0 Ma ago in the Pliocene. It may be suggested that the neotectonic movements at the southern extremity of the Cape Verde Seamount were related precisely to this stage and started just 2.5–2.0 Ma ago.

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