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GEOLOGY

Investigation of the Andrew Bain Transform Fault Zone (African–Antarctic Region)

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Study of the ocean floor structure is impossible at present without medium-scale regional geological investigations. Such integrated geological–geophysical investigations were carried out in 2006 in the joint expedition of the Geological Institute (Moscow, Russia) and the Institute of Marine Sciences (Bologna, Italy) during Cruise 23 of the R/V *Akademik Nikolai Strakhov* under the supervision of Academician Yu.M. Pushcharovsky and Prof. E. Bonatti. We studied the Andrew Bain Fracture Zone (FZ) incorporated into the system of faults separating the floors of the Atlantic and Indian oceans (Fig. 1). The bathymetric survey was conducted with a RESON SeaBat 8150 multibeam echo sounder. Analysis of new data with the results of the earlier bathymetric survey in this region on the R/V *Knorr* [1] made it possible to compile a bathymetric map for the whole Andrew Bain FZ (Fig. 1). Acoustic and single-channel continuous seismic profiling, the study of geophysical fields, dredging, and seismic works with a multichannel streamer were also carried out during the cruise.

The Andrew Bain FZ is among the longest oceanic faults with the active part extending over about 750 km. Since this mid-oceanic ridge (MOR) region is characterized by very low spreading rates (16 mm/yr), its active part is one of the oldest in the whole MOR system [2]. The study of the fault is of great importance for understanding the geodynamics and evolution of Circum-Antarctic regions of the World Ocean [3]. The results of previous bathymetric and magnetic investigations and the spatial distribution of earthquakes showed that the Andrew Bain FZ includes numerous different second-order structures. This feature is typical of continental strike-slip fault zones [1, 4]. According to [5], such megatransform fault zones can emerge in slow-spreading ridges at a relative displacement of the lithosphere, which is thicker and colder than in most transform faults [4]. The aim of the present work was to substantiate this suggestion with factual material.

The NNE- to SSW-extending Andrew Bain FZ separates the EW-trending northern and southern MOR segments (West Indian Ridge and Africa–Antarctic Ridge, respectively) sometimes identified as the Southwest Indian Ridge (SWIR). The strike of segments is not rigorously perpendicular to the FZ. Three echelon areas are distinguished in the rift valley of the southern segment. The strike of all morphostructures (ridges and depressions) of the southern segment gradually changes from the EW to ENE direction toward the western trench of the Andrew Bain FZ (Fig. 1). The western framing of structures of the Andrew Bain FZ is represented by a transverse ridge rising up to 3500 m above the trench bottom in the southern area (Fig. 1). The minimum water depths above the ridge range from 1800 to 2200 m. The summit surface located at a depth of 3000–3500 m is composed of gentle WE-trending ridges with their height increasing toward the trench slope. The fracture zone includes three trenches separated by median ridges. The main (western) trench

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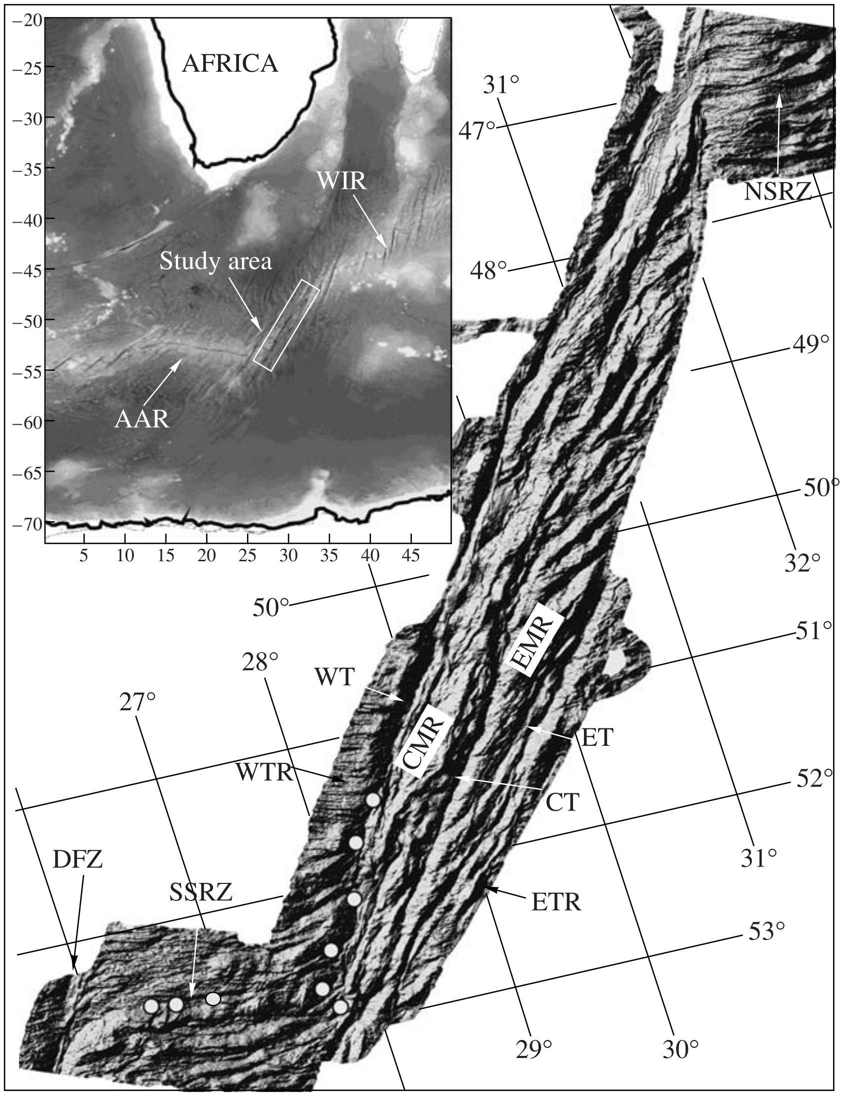

Fig. 1. 3D image of the Andrew Bain FZ based on the bathymetric survey with the R/V *Knorr* [4] and Cruise 23 of the R/V *Akademik Nikolai Strakhov*. Circles denote dredging stations. Letter symbols: (DFZ) Dutoit Fracture Zone, (SSRZ) southern segment of the rift zone, (NSRZ) northern segment of the rift zone, (WTR) western transverse ridge, (ETR) eastern transverse ridge, (CMR) central median ridge, (EMR) eastern median ridge, (WT) western trench, (ET) eastern trench, (CT) central trench. The inset shows the scheme of the study area based on the GEBCO map [6]: (AAR) Atlantic–Antarctic Ridge, (WIR) West Indian Ridge.

extends at the foot of the transverse ridge. The depth exceeds 6000 m in the southern part. North of 51.5° S, the trench is shallower and its bottom includes NE-trending thresholds, which separate the trench into individual depressions. The height of obliquely oriented ridges gradually increases, and they completely partition off the trench at 49.5° S. Further, the western trench is traced to the northern rift segment as a narrow chain of depressions 4500–5000 m deep, turning eastward by ~10°. A narrower trench 4000–4500 m deep extends parallel to and 30 miles east of the western trench. The median (western) ridge separates both trenches and rises for more than 2500 m above the western trench bottom. Western slopes of the median ridge are parallel to the trench, whereas spurs of the eastern slope exhibit a northeastern strike. North of 51.5° S, the western median ridge rises and extends north of the junction with the northern segment of the rift. The central trench pinches out at ~51.5° S, where the western trench is shallower. North of 48.6° S, the central trench reappears, extends parallel to the western trench, and gives way to the western median ridge in a deeper zone located at a distance of 130 km. Spurs and summit ridges of the next median (eastern) ridge also demonstrate the northeastern strike. The eastern trench, which is separated by these spurs into isolate depressions with depths varying from 5000 to 6000 m, extends eastward relative to two previous trenches. Its eastern slope is composed of the eastern transverse ridge bounding the fault zone in general.

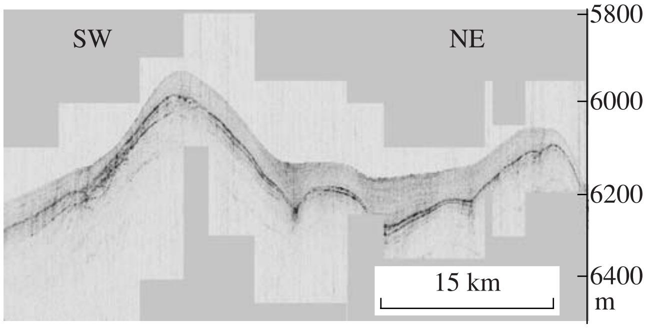

Fig. 2. Fragment of the acoustic profile within 51.13° S × 28.43° E–51.8°8 S × 28.51° 8 E located along the western trench bottom. The lower line shows the horizontal scale.

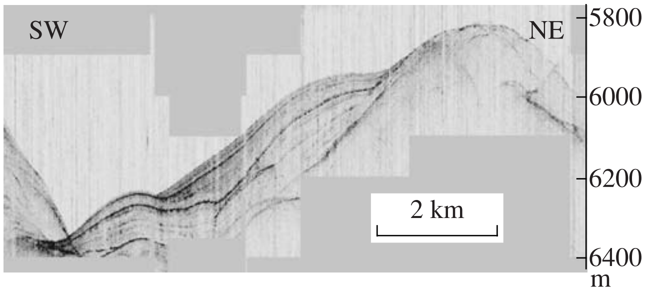

Fig. 3. Fragment of the acoustic profile within 52.35° S × 27.52° E–52.27° S × 27.58° E located along the western trench bottom.

The above-listed distinctive features of variations in the strike, dimension, and height of the morphostructures suggest that the strike of the FZ axis gradually changed from northeastern to northern. In this case, we may anticipate that extension and compression conditions existed in the southern and northern parts of the FZ, respectively. These conditions promoted the formation of oblique structures, the role of which gradually increased from south to north.

According to acoustic profiling data, sediments are absent in the western trench in the southern rift segment. At the northern foot of the transverse ridge, the trench bottom is covered in many areas with sediments with an apparent thickness up to 250 m (Fig. 2). The moderately dissected upper part of the section is marked by a weakly reflecting thin stratified sedimentary cover with thickness varying along the strike from 50 to 120 m. The middle part of the section includes a lenticular-beaded acoustically transparent section bounded by intensely reflecting surfaces. The section is 35–40 m thick and pinches out on rises. The overlying sections are conformable with each other. The base of the section includes vaguely stratified sediments (apparent thickness ~100 m) deformed into gentle folds. The large area of the upper section (as compared to the middle one) and thickening of sediments in depressions of the relief indicate the accumulation of sediments in these areas under conditions of bottom downwarping that started after formation of the lower sedimentary section. Sediments are absent or irregularly distributed on rises with steeper slopes. It is evident that such areas represent uplift areas of the bottom. A complicated (in structure and morphology) sedimentary body is observed on the southwestern slope of one such uplift (Fig. 3). The thickness of the body varies along the strike and reaches 200 m in the central part. The body includes three distinct sequences separated by intensely reflecting boundaries. Interrelations of the sequences allow us to correlate them with deposits of the NE- to SW-oriented bottom currents. The downsection decrease in the thickness and dimension of the sequences indicates uplift of the bottom in this area of the western trench. Sediments up to 120 m thick were found in the eastern trench. These sediments were not studied in the central trench. The eastern trench is also complicated by inner rises, which formed during the neotectonic stage and affected the formation of the sedimentary cover in the trench. Four sedimentary sections were deciphered on the slope of an uplift located across the strike of the trench (Fig. 4). Pinchout of the sections toward the uplifted part of the slope and their downsection thickening indicate synsedimentary inclination of the slope surface.

Sediments are found on the summit of the transverse ridge, which represents a block of separate cuesta-shaped rises. The gentle western slope of these rises is armored by roughly stratified deposits with an apparent thickness up to 100 m. The tectonic nature of boundaries between the blocks is suggested by the following fact: stratified deposits on the gentle slopes are truncated at the base of neighbor steep scarps. Slopes of transverse and median ridges are complicated by numerous morphostructures of a higher order with tectonic (normal fault and reversed fault) boundaries. Sediments are virtually absent on slopes. Only some steps are covered with a high-reflection unstratified sediments about 10 m thick.

The distribution of sediments described above indicates that the Andrew Bain FZ evolved under different tectonic regimes. These regimes are typical of shear zones with local transpression and transtension varying through time.

Dredging of the southern segment of the rift zone mainly yielded fresh basalts. Primarily harzburgites and lherzolites were recovered from the corner uplift. At the same time, mainly basalts and dolerites were recovered from the eastern slope of the western transverse ridge of the Andrew Bain FZ. In addition, a small volume of different gabbroids, sedimentary breccia, metamorphic rocks, and ferromanganese crusts and nodules were also recovered. The location of dredging stations is shown in Fig. 1.

Thus, Cruise 23 of the R/V *Akademik Nikolai Strakhov* provided us with essential materials on the struc-

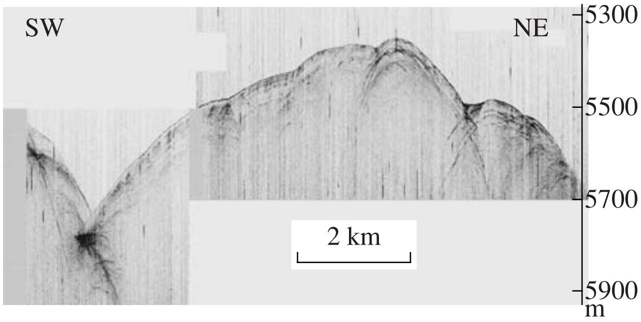

Fig. 4. Fragment of the acoustic profile within 49.49° S × 29.57° E–49.44° S × 29.54° E located across the eastern trench bottom.

ture, rock composition, and geodynamics of one of the largest faults of the tectonic system developed between the Atlantic and Indian oceans. Comprehensive bathymetric data along with previously obtained materials make it possible to compile an integral picture of the bottom topography in the Andrew Bain FZ.

Specific structural features of the sedimentary cover in trenches and on ridges of the Andrew Bain FZ indicate the active formation of structures in the zone under conditions of compression and extension varying with space and time.

It has been established that moderately serpentinized lherzolites, harzburgites, and gabbroids played a significant role in the structure of the Andrew Bain FZ. Its southern rift segment is mainly composed of fresh basalts.

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