ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 409, No. 5, pp. 713–716. © Pleiades Publishing, Inc., 2006.
Original Russian Text © Yu.M. Pushcharovsky, 2006, published in Doklady Akademii Nauk, 2006, Vol. 409, No. 1, pp. 90–93.

GEOLOGY

Comparative Tectonics of Deep Basins of the Atlantic, Pacific, and Indian Oceans

Academician of the RAS Yu. M. Pushcharovsky

Received March 21, 2006

DOI: 10.1134/S1028334X06050072

The author of the present paper started systemic studies of deep oceanic basins several years ago, when *special* tectonic works were scarce (see, for example, [1]), except for geomorphologic publications with elements of geotectonics (see, for example, [2]) and more or less detailed sections in works dedicated to tectonics of either spacious oceanic realms or the earth as a whole (see, for example, [3]). At the same time, it is impossible to understand tectonic processes in oceanic domains and their structural evolution unless we carry out special analyses of deep basins that occupy the vast regions of the World Ocean bottom.

Previous researches have revealed that major tectonic structures in the oceans correspond to bottom topography. Therefore, morphostructural analysis is one of the most important tools in their study. In this case, the General Bathymetric Chart of the Oceans [4] and various geophysical (seismic, gravimetric, and magnetic) data are of significant value. Among the geophysical review materials, the Gravimetric Map of the World Ocean [5] is very important.

Tectonics of deep oceanic basins has been considered in several recent articles [6–9]. In the present paper, we propose a classification of these structures based on their comparative tectonic analysis. In total, 45 basins were analyzed.

Deep oceanic basins, distinctly manifested in the bottom relief, are called depressions in geomorphology. They have bottoms and walls that represent certain elements of the relief. Central parts of basins are occupied by abyssal plains located at great depths. The basins are most expressive along the isobath of 5000 m supplemented sometimes by the isobath of 4000 m (Figs. 1–3).The size of basins varies from several hundred to several thousand kilometers. The largest of them are located in the Pacific. The table presents average sizes of basins in the Atlantic, Pacific, and Indian oceans.

The table demonstrates that basins of the Atlantic and Indian oceans show certain similarities in terms of

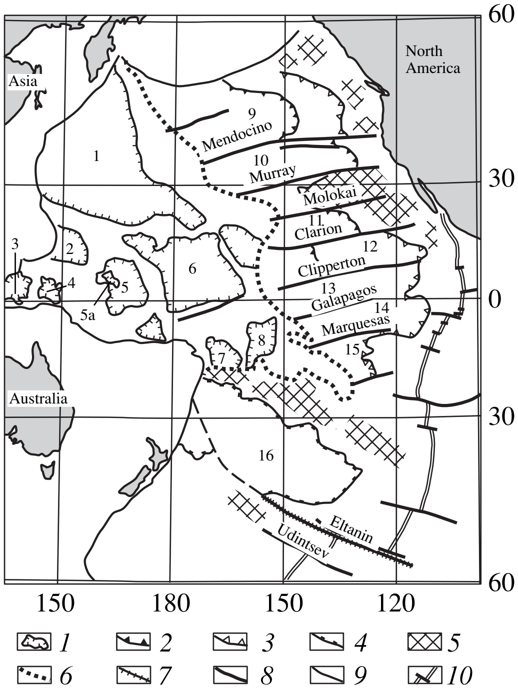

Fig. 1. Structural position of deep basins in the West Pacific thalassogen and their major tectonic types. (*1*) Contours of intermontane abyssal basins; (*2, 3*) contours of interfault basins along 5000- and 4000-m isobaths, respectively; (*4*) contour of thalassogenic syneclise; (*5*) deep-water rises; (*6*) major geostructural boundary; (*7*) Eltanin demarcation fault; (*8*) faults; (*9*) deep peripheral trenches; (*10*) axial zone of the East Pacific and South Pacific rises. *Intermontane abyssal basins*: (1) Northwest, (2) East Marian, (3) West Caroline; (4) East Caroline, (5) Melanesian; (5a) Nauru, (6) Central, (7) Samoa, (8) Penrhyn. *Interfault basins*: (9) Northeast, (10) Mendocino, (11) Clarion, (12) Clipperton, (13) Galapagos, (14) Marquesas; (15) Tiki; (16) South Pacific thalassogenic syneclise.

Geological Institute, Russian Academy of Sciences, Pyzhevskii per. 7, Moscow, 119017 Russia

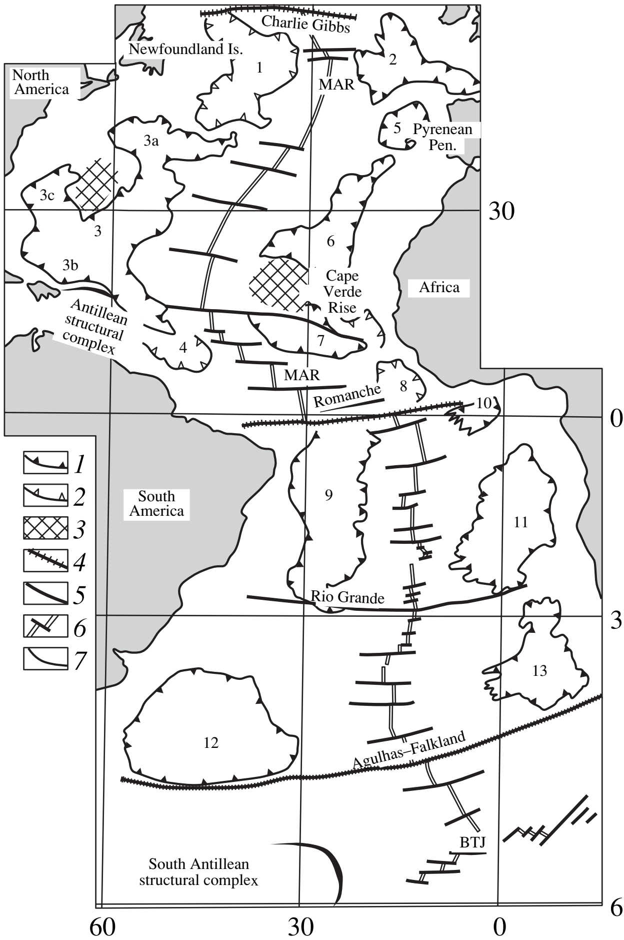

Fig. 2. Structural position of deep basins in the Central and South Atlantic. (*1, 2*) Contours of basins along 5000- and 4000-m isobaths, respectively; (*3*) underwater rises; (*4*) demarcation fault zones; (*5*) faults; (*6*) axial zone of the Mid-Atlantic Ridge; (*7*) deep trenches. Basins of the Central Atlantic: (1) Newfoundland, (2) West European, (3) North American, (4) Demerara, (5) Iberian, (6) Canary; (7) Cape Verde, (8) Sierra Leone. Abyssal plains: (3a) Sohm, (3b) Hatteras, (3c) Nares. Basins of the *South Atlantic*: (9) Brazil, (10) Guinea, (11) Angola, (12) Argentine, (13) Cape. (BTJ) Bouvet triple junction.

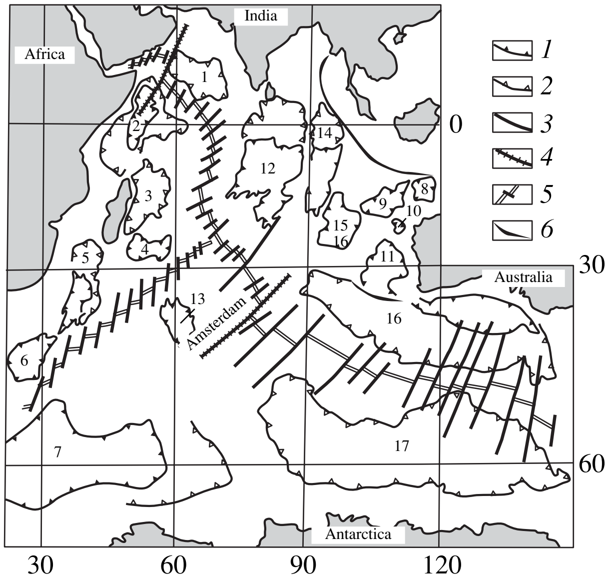

Fig. 3. Structural position of deep basins in the Indian Ocean. (*1, 2*) Contours of basins along 5000- and 4000-m isobaths, respectively; (*3*) faults; (*4*) demarcation fault zones; (*5*) axial zones of spreading ridges; (*6*) deep trenches. *Pericontinental* basins: (1) Arabian, (2) Somali, (3) Mascarene, (4) Madagascar, (5) Mozambique, (6) Agulhas, (7) Enderby, (8) Argo, (9) Gascoyne, (10) Cuvie, (11) Perth; *central oceanic* basins: (12) Central Indian, (13) Crozet, (14) Cocos, (15) Wharton; *perispreading* basins: (16) South Australian, (17) Australian–Antarctic.

size. At the same time, internal sectors of oceans display some differences. Basins in the South Atlantic are larger than those in the Central Atlantic. In the Indian Ocean, the size of basins decreases successively from its southern sector to western and eastern sectors. The southern sector is also distinguishable in this respect in the Pacific Ocean (Western thalassogen).

All this indicates that tectonic movements in the Southern Hemisphere were substantially more intense during the formation of these basins in the Mesozoic–Cenozoic, as compared with the Northern Hemisphere.

Let us look at the spatial orientation of the basins. This parameter provides insights into the distribution of geodynamic fields (forces, their vectors, and stresses) in oceans. In the Pacific, the basins located in its eastern sector are characterized by sublatitudinal orientation. In the Indian Ocean, such an orientation is typical of its southern sector. The near-meridional strike is characteristic of the Atlantic Ocean, as well as western and central sectors of the Indian Ocean. The northwestern direction is typical of the western and southern sectors of the Pacific. The subordinate west-northwestern direction is observed in the eastern sector of the Indian Ocean (Australian–Antarctic Basin). In total, we can outline seven different-size and spatially isolated geodynamic provinces. The maximal diversity in their distribution is typical of the Indian Ocean. The largest geodynamic provinces are represented by the Atlantic (Central and South Atlantic), West Pacific (up to 40° S), and East Pacific zones.

These data make the tectonic–geodynamic disharmony of the World Ocean a particularly acute issue, which requires special modeling.

Inasmuch as the tectonic statute of depressions is still vague, it is necessary to discuss briefly their structural constraints.

The Pacific Ocean demonstrates the development of six types of structural boundaries. In the north and west, deep trench–marginal oceanic swell systems serve as tectonic boundaries. In the western sector, they are represented by underwater tectonovolcanic seamounts and separate massifs. In the eastern sector, basins are bordered by large latitudinal faults, spacious underwater rises, and western slope of the East Pacific Rise. We should particularly mention the main geotectonic

Comparison of average sizes of deep basins in oceans (km)

	Atlantic Ocean		Indian Ocean		Pacific Ocean	
In the latitudinal direction	Central Atlantic	850	Western sector	1180	Western sector	1350
	South Atlantic	1230	Eastern sector	820	Eastern sector	3480
			Southern sector	3125	Southern sector	3125
In the meridional direction	Central Atlantic	1250	Western sector	1350	Western sector	1600
	South Atlantic	1550	Eastern sector	1485	Eastern sector	850
			Southern sector	1075	Southern sector	2250

boundary separating structures of its major (western, eastern, and southern) sectors.

In the Atlantic Ocean sector located between the Charlie Gibbs (52° N) and Bouvet triple junction, one can distinguish three main types of structures bordering deep basins: transform faults, slopes of the Mid-Atlantic Ridge, and passive continental margins. Underwater rises and trenches represent particular cases.

In the Indian Ocean, we can define five types of boundaries: (1) passive continental margins in the African, Australian, and Antarctic regions; (2) microcontinents within peripheral tectonic systems west and east of the deep oceanic basin; (3) the huge linear tectonovolcanic horst-shaped Ninetyeast Ridge; (4) large underwater (Kerguelen, Del Cano, and Conrad) rises near 30°C with young volcanoes; and (5) slopes of spreading ridges.

Thus, deep basins surrounded by tectonic structures and their systems are distinctly recognizable as a specific category of oceanic tectonic domains. This inference is important for tectonic zoning of the oceanic bottom.

Many of these deep basins were studied by deep-sea drilling. However, the number of holes is insignificant against the background of the huge size of the basins. In terms of tectonics, holes that reached the basaltic basement are of great interest. Due to the wide distribution of basaltic sills in the sedimentary cover, particularly in Lower Cenozoic and older sediments, it is often difficult to identify the basement. The basement is most distinct when basalts underlie shallow-water sediments or bear signs of effusion in shallow-water settings. Such facts are recorded in all three oceans. The basalts occur at the base of Late Jurassic sediments only in rare cases. In general, they are overlain by Early and Middle Cretaceous rocks. In some boreholes, they are overlain by Late Cretaceous and Paleocene sediments. Some boreholes have penetrated sills. Nevertheless, a lot of data indicate that the basins are different in age and the scenario of their development does not fit the rigorous spreading model, although the spreading-related subsidence mechanism is undoubted. It appears that, in addition to spreading, tectonic subsidence was also involved, resulting in intricate structural development of the oceanic floor.

In all the oceans under consideration, one can note the stepwise style of subsidence, which reflects the discrete geodynamic regime of descending movements. In [7], we noted the following features of Atlantic basins. The presence of large faults at the continental margin suggests the possibility of rapid subsidence. Normal faulting is documented in the southern Argentine, eastern West European, western Newfoundland basins, and some others. The same mechanism might be responsible for the formation of continental slopes of the Atlantic (at least, its steep zones). Boundaries of basins recorded as tectonovolcanic ridges also indicate their subsidence. Magma of deep lithospheric levels was squeezed from the subsidence zone toward the periphery and accumulated in permeable zones. The Walvis, Cameroonian Line, Discovery–Heezen, Canary, Azores–Biscay-Shona, and other ridges are such structures.

In the Pacific, stepwise subsidence-related tectonic structures in deep basins are observed in both western and eastern sectors. The analysis of bottom depths in deep basins of the western sector revealed significant depth differences between neighboring basins. For example, the West Pacific Basin demonstrates successive northward deepening by approximately 1 km in the meridional system of basins: the West Caroline (depth 4 km), the East Mariana (5 km), and the Northwestern (6 km) basins [6]. A similar situation is also observed along the latitudinal profile (East Caroline, Melanesian, and Central basins). Moreover, the depth difference between their central parts is approximately 1 km.

Profiles across successive basin systems separated by giant faults [11–13] also indicate the formation of basins according to the stepwise subsidence mechanism in the eastern sector. The steps have the same amplitude (~1 km). However, their formation mechanism is different (reverse faulting).

In the Indian Ocean, stepwise subsidence is recorded in the Central, Cocos, Argo, Somali, and Mozambique basins [2, 10].

Thus, it should be noted that the stepwise subsidence of deep basins is a widespread phenomenon. In general, the stepwise subsidence is related to two main factors: reverse faulting (e.g., the eastern sector of the Pacific) and local transformations of deep geodynamic mediums in other areas, resulting in the development of quasi-mosaic tectonic patterns. In all the cases, steps reflect the discrete mode of relevant processes.

CONCLUSIONS

The comparative study of deep basins of the Pacific, Atlantic, and Indian oceans reveals their significant structural uniqueness. The Pacific (Western thalassogen) comprises basins of three types: intermontane abyssal basins, interfault basins, and "thalassogenic syneclises" (a specific type of synform). In the Central and South Atlantic, the basins mainly surround the Mid-Atlantic Ridge and generally occur near passive continental margins. Basins of the Indian Ocean form three groups: (i) basins located in the central part of the ocean, but they lack spatial or genetic relations with spreading ridges; (ii) basins forming together with adjacent uplifts tectonic systems that extend along African, Australian, and Antarctic continental margins; and (iii) basins conjugated with the Southeast Indian spreading ridge (together with the ridge, the basins create the undulating bottom structure).

The data discussed allow us to propose the following preliminary tectonic classification of deep basins in the three largest oceans of the earth: intermontane abyssal basins, interfault basins, thalassogenic syneclises, central thalassogenic basins, pericontinental basins, and perispreading basins. Basins of the first three types are developed in the Pacific. Basins of the fourth and fifths types occur in the Indian Ocean. Basins of the sixth type are observed in the Atlantic and southeastern Indian oceans.

The proposed classification allows us to exploit real specific features of the tectonic position and structure of deep oceanic basins for further geological, tectonic, and geodynamic investigations of the ocean bottom. For example, this classification offers a new approach to the elucidation of relationships between ferromanganese formations and regional tectonic structures.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project no. 06-05-64152), the Ministry of Education and Science of the Russian Federation, and the Presidium of the Russian Academy of Sciences.

REFERENCES

1. Yu. N. Raznitsyn and A. I. Pilipenko, in *Tectonic and Geodynamic Phenomena* (Nauka, Moscow, 1997), pp. 104–128 [in Russian].
2. G. B. Udintsev, *Relief and Structure of the Oceanic Floor* (Nedra, Moscow, 1987) [in Russian].
3. V. E. Khain, *Tectonics of Continents and Oceans (Year 2000)* (Nauchnyi Mir, Moscow, 2001) [in Russian].
4. *General Bathymetric Chart of the Oceans. 5th Ed.* (Ottawa, 1984).
5. D. T. Sandwell and W. H. F. Smith, *Marine Gravity Anomaly from Satellite Altimetry. Map* (La Jolla, 1997).
6. Yu. M. Pushcharovsky, Dokl. Akad. Nauk **318**, 400 (1991).
7. Yu. M. Pushcharovsky, Dokl. Akad. Nauk **389**, 790 (2003) [Dokl Earth Sci. **389**, (2003)].
8. Yu. M. Pushcharovsky, Ross. Zh. Nauk Zemle **6** (2), 1 (2004).
9. Yu. M. Pushcharovsky, Geotektonika, No. 5, (2006) [Geotectonics, No. 5, (2006)].
10. *Information Resources and Results of Geological–Geophysical Studies along the Mascarene–Australian Geotraverse across the Indian Ocean*, Ed. by V.S. Shcherbakov, and V.N. Zhivago (GUGP GlavNIVTS, Moscow, 2001) [in Russian].
11. Yu. P. Neprochnov, G. M. Valyashko, L. P. Volokitina, et al., Okeanologiya **33**, 253 (1993).
12. Yu. P. Neprochnov, V. V. Sedov, G. M. Valyashko, et al., Okeanologiya **33**, 589 (1993).
13. Yu. D. Markov, A. V. Mozherovskii, V. S. Pushkar, et al., Tikhookean. Geol. **24** (4), 24 (2005).