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GEOLOGY

New Data on the Structural Geometry of Lineaments in the Western Pacific Ocean and the Southeastern Indian Ocean

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Structures of the continental lithosphere characterized by vortex geometry were originally revealed in the first third of the 20th century [1]. According to [2, 3], vortex motions determine the specific character of the geodynamics and structural geometry of ocean basins during spreading of lithospheric plates. The question arises as to whether vortex structures exist beyond spreading zones in island-arc and intraplate conditions. In order to elucidate this issue, we have analyzed geological and geophysical materials (bottom relief, gravity field, geoidal rises, and so on) in the western Pacific Ocean and the southeastern Indian Ocean.

The ocean floor in this region is the oldest in the World Ocean (Late Jurassic–Late Cretaceous). The geological history of this region is characterized by an abundance of volcanism of different types (island-arc and rift volcanism at the junction of the Pacific and Indian oceans with Eurasia and Australia and rather intense intraplate volcanism in abyssal areas of oceans). This feature is reflected in the relief structure. The region incorporates both linear morphostructures (island-arc systems, volcanic ridges, and chains of seamounts) and isometric uplifts (solitary volcanoes, massive plateaus, and highlands). The presence of morphostructures of different ranks and shapes hampers the elucidation of peculiarities in their plane geometry. Therefore, we carried out the frequency analysis of underwater relief based on satellite altimetry data [4]. The long-wave component of the relief was eliminated in the course of frequency filtering. The short-wave component ("residual" relief) includes relatively small (from <30 to 100–150 km across) isometric rises of the floor (islands included) and seamounts dominating over the flat relief level by more than 500 m, as well as oceanic trenches with a depth of more than 500 m bsf (figure). The largest structures of the residual relief are distinctly recorded in the air-free gravity anomalies [5], confirming the reliability of the identification of such structures.

Examination of the residual relief shows that it is dominated by linear morphostructures (lineaments) of both negative (oceanic trenches) and positive (elevations) types. Elevations are represented by linearly distributed islands, seamounts, and rises. Since the linear morphostructures are rather numerous and diverse (in morphology), it is impossible to characterize each of them within one paper. Therefore, we subdivided lineaments into categories depending on their structural geometry and inferred nature. References in the text in

"Residual" (high-frequency) relief of the western Pacific Ocean and southeastern Indian Ocean and lineaments composed of individual rises, seamounts, and oceanic trenches. Inset shows the scheme of geoidal rises. (1) Bottom rises, islands, and seamounts dominating over the flat relief by more than 500 m; (2) trenches and basins with depths exceeding 500 m relative to the flat relief; (3) lineaments formed by island-arc systems: (*1*) Aleutian, (*2*) Shirshov–Bowers, (*3*) Kuril–Kamchatka, (*4*) Japan, (*5*) Nankai–Ryukyu, (*6*) Kyushu–Palau, (*7*) Yap, (*8*) Izu–Ogasawara, (*9*) Mariana, (*10*) Philippine, (*11*) Sunda, (*12*) New Guinea, (*13*) Solomon, (*14*) Samoan, (*15*) Loyalty, (*16*) New Hebrides, (*17*) Lord Howe, (*18*) Norfolk, (*19*) Colville-Lau, (*20*) Tonga–Kermadec; (4) lineaments formed by seamounts and isometric rises (presumably of volcanic nature): (*21*) Pribylof, (*22*) Yamato, (*23*) Emperor, (*24*) Chinook, (*25*) Mendocino, (*26*) Hawaiian, (*27*) Marcus–Necker, (*28*) Line, (*29*) South China, (*30*) Marshall, (*31*) Gilbert, (*32*) Tuvalu, (*33*) Tokelau, (*34*) Cook, (*35*) Louisville, (*36*) Vening Meinesz, (*37*) Investigator, (*38*) Argo, (*39*) East Indiaman, (*40*) Broken, (*41*) Hartog, (*42*) Diamantina; (5) lineaments formed by rises presumably of tectonic nature. The scale of the geoidal rises in the inset: (6) from –70 to –5 m, (7) from –5 to 30 m, (8) from 30 to 60 m, (9) from 65 to 90 m.

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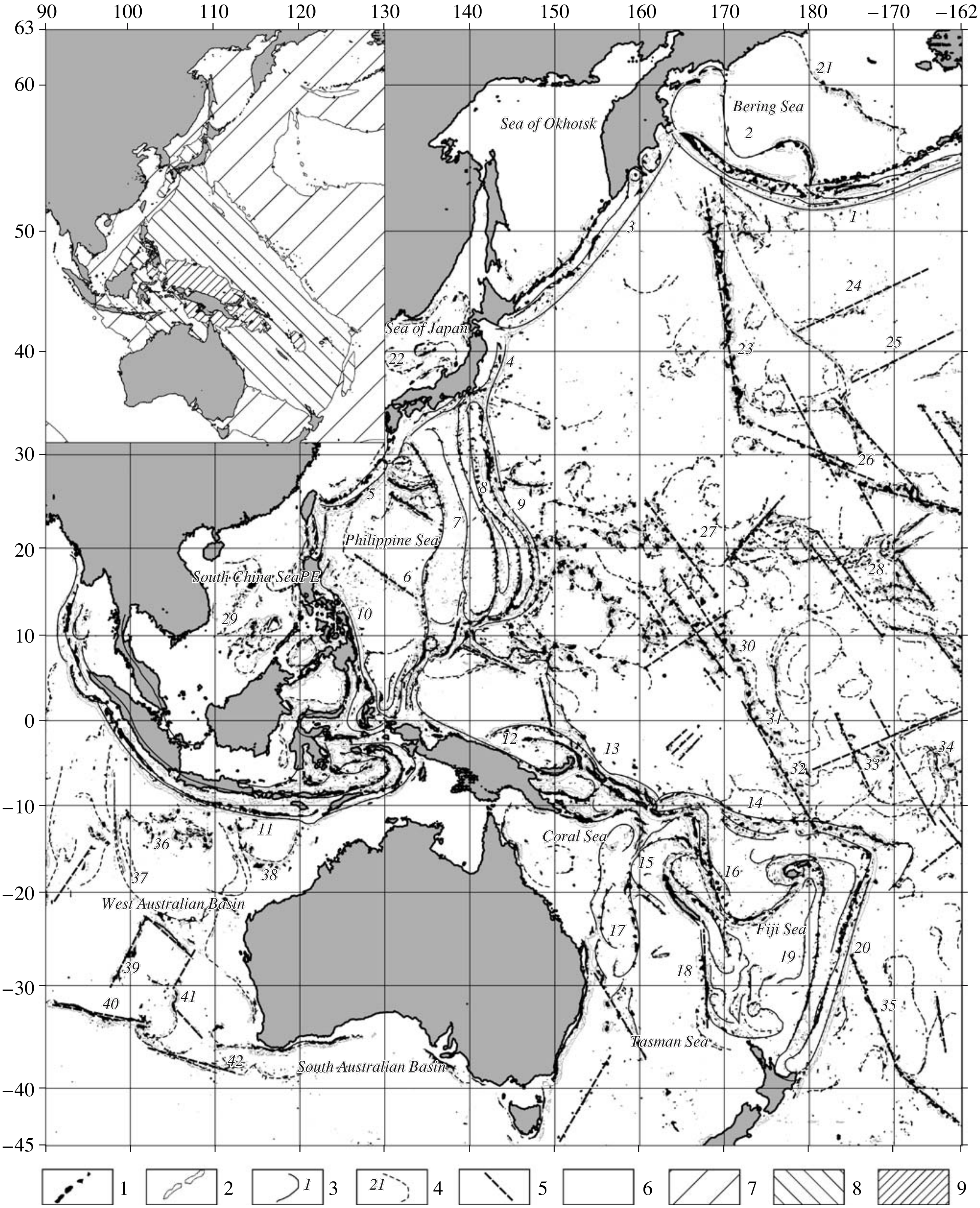
Bering Sea
Sea of Okhotsk
Sea of Japan
Philippine Sea
South China Sea
Coral Sea
Fiji Sea
Tasman Sea
West Australian Basin
South Australian Basin

this paper are given only for lineaments with typical features (figure).

The first category of lineaments is represented by oceanic trenches and both active and extinct island-arc systems. They extend from the Aleutian and Kuril–Kamchatka regions on the north to the Sunda and Tonga–Kermadec regions on the south (figure, nos. 1–20). They are all characterized by the arc shape, but asymmetry is typical of most of them: one of the arc edges is more twisted than the other edge. Consequently, the edge of a volcanic arc or oceanic trench is transformed into a spiral or vortex structure. The vortex twisting of island-arc structures is observed in the western Aleutian, northern Kuril–Kamchatka, southern Philippine, Kyushu–Palau, Yap, and Mariana arcs, among others. Of special interest in this respect are the Sunda, New Guinea, Solomon, Samoa, New Hebrides, Fiji, Colville-Lau, and Tonga–Kermadec island-arc systems. The junction of the northern Colville-Lau Ridge with the Fiji Islands is marked by unique geometry owing to the convergence of island arcs and linear volcanic ridges. Therefore, the geometry of vortex lineaments is similar to the morphology of an atmospheric cyclonic vortex. This similarity is very essential for elucidation of the formulated issue. In general, a set of island arcs and oceanic trenches can be regarded as a giant system of vortex structures extending for many thousands of kilometers at the zone of junction of the Pacific Plate with Eurasia and Australia.

The second category of lineaments includes chains of isometric local seamounts in the Pacific and Indian oceans and deep-sea back-arc basins (figure, nos. 21–42). Among them, one can see prominent systems of seamounts (Emperor–Hawaiian, Marcus–Necker–Line, Marshall–Gilbert–Louisville, Investigator–Diamantina, and others) distinguished by a common socle and arrangement along nearly straight or slightly bending lines. In the opinion of most researchers, intraplate volcanism is responsible for their formation. The study region also incorporates many seamounts and isometric rises characterized by the lack of a common socle but by the arrangement around vortex or semiring lines. According to the available data, most of them are also related to intraplate volcanic activity. These lineaments correspond to a unique structural geometry of intraplate volcanism. Lineaments composed of seamount chains are rather abundant. They are found within both the ocean floor and back-arc basins. Despite the morphological similarity, their cross dimensions vary within a wide range (from 150 to more than 1000 km). The largest lineaments are prominent in gravity anomalies. Data on the age of individual seamounts within the intraplate volcanic structures vary from the Early Cretaceous to the Eocene.

The third category includes nearly rectilinear lineaments, most likely associated with tectonics, since they are related to fault scarps. They form a nearly orthogonal system of SW–NE- and SE–NW-oriented structures (figure). Judging from their strike, the SW–NE-oriented structures correspond to western edges of the Great Pacific Fault System extending from the Mendocino Fracture Zone on the north to the Galapagos Fracture Zone on the south. The SE–NW-oriented structures are likely to be related to the system of younger transform faults developed after the rearrangement of the spreading system on the East Pacific Rise.

The vortex, spiral, or semiring structures are most interesting among the lineaments discussed above. When considering the problem of their nature, it should be noted that the junction of the Pacific Ocean with Eurasia and Australia is noted by a substantial gravity gradient and high geoidal rises [5]. The highest geoidal rises (>80 m, see inset in figure) on our planet tend to the junction zone with the most prominent vortex systems, e.g., the Sunda, New Guinea, New Hebrides, and Colville-Lau island-arc systems, as well as some vortex structures of abyssal basins. Like anomalies of geoidal rises, gravity anomalies can reflect an intense convection current directed from the Pacific Ocean toward Eurasia and Australia. Judging from the data obtained, such a current is accompanied at present (probably, in the geological past as well) by a vortex component of substance motion and the subsequent formation of vortex structures of different ranks. This fact confirms the previous inference that mantle convection has a substantial vortex constituent, which is reflected in structures of the crust and lithosphere [2, 3]. Thus, new data on the structural geometry of volcanic and tectonic lineaments are additional indications of the diversity of motions (forward, rotary, and vortex) in the Earth's crust.

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