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GEOLOGY

Latitudinal Activation of Magmatism As a Response to Cyclic Tidal Evolution in the Earth–Moon–Sun System

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The oscillatory, cyclic tidal evolution of the Earth–Moon system influences the stress state of the lithosphere. The periodicity of the tidal evolution is close to the periodicity of Bertrand cycles, while the time intervals between peak deformations of the lithosphere 40–60 Ma ago correspond to Stille cycles. This regime was revealed during investigation of solar disturbances of the Earth's orbital motion around the Earth–Moon center of mass [1].

In [2], we indicated certain relations of periodicity between endogenic and exogenic phenomena in the Earth related to external (cosmic) factors that bring about a variation of rotation velocity and the position of rotation axis. As was shown by one of the authors of the present paper in [1], the influence of the Sun on orbital motions of the Earth and the Moon around the center of mass in the Earth–Moon system is such a factor, which eventually gives rise to the oscillatory tidal evolution of the Earth–Moon–Sun system and, in turn, provokes periodic changes of rotation velocity and the rotation axis angle.

As has been established, the variation of the rotation regime of the Earth inevitably leads to a change in the stress state of the Earth's interior from pole to equator, modifies the planet configuration and topology of its surface, and so on.

V.A. Tsaregradsky pointed out that "large-scale emplacements and eruptions of magma, mainly basic in composition, evidently dominate in some epochs in polar countries and migrate to the equatorial belt in other epochs" [2, p. 152]. He emphasized that "large-scale magma eruptions, as a rule, coincide with epochs of the Earth's crust extension of the sector characterized by these eruptions." In other words, attention was paid to the periodical latitudinal distribution of magmatism under the influence of changes in the regime of the Earth's rotation governed by the tidal evolution of the orbital rotation parameters of the Earth–Moon system.

Specific features of the latitudinal variation in transgression and regression areas on a geological time scale in the course of changes in the angular velocity of the Earth's rotation are discussed in [3]. On the basis of [4], we calculated the areas of igneous activity within latitudinal intervals 60°–40°, 40°–20°, and 20°–0° N and S. The relative intensity of igneous activity was estimated as the ratio of magmatically active areas to the total land and shelf area in the respective interval of latitudes.

The results obtained (Fig. 1) clearly show a correlation between latitudinal shifts of igneous activity for different epochs and the parameters of the Earth's rotation at the same geological time. This is especially evident for the Northern hemisphere, as was mentioned in the discussion of transgressions and regressions [3]. More intense magmatism in high latitudes (less intense magmatism in equatorial zones) corresponds to the acceleration of rotation in the Triassic and Jurassic. The opposite relationship is observed during retardation of the Earth's rotation: magmatism becomes more intense in low latitudes. This correlation is more prominent for specific geological epochs, e.g., the Late Triassic and the Late Cretaceous (Fig. 2).

At first glance, these relationships contradict the expected latitudinal distribution of igneous (volcanic) phenomena as a response to tensile and compressive stresses in the lithospheric surface structures [2]. However, one has to keep in mind the vertical and, probably, lateral redistribution of hot masses (plumes and superplumes) within the Earth's silicate shell. The peaks of mantle-derived magmatism with variable periodicity are precisely related to the origin and evolution of superplumes [5]. Vigorous episodes of flood-basalt volcanism at the Permian–Triassic boundary (Siberian and Emeishan traps) and in the Cretaceous (Ontong Java, Kerguelen, and Maranhão oceanic basaltic plateaus; basalts of Broken Ridge, Caribbean, Rio Grande, and Paraná Plateau) coincide with periods of drastic variation of the Earth's rotation velocity (acceleration and deceleration). Thus, one must speak about the global impact of tidal forces owing to substantial changes in the Earth's rotational regime.

While considering the variation of igneous activity intensity in each selected latitudinal zone from the Triassic to the Neogene, one can record its continuous

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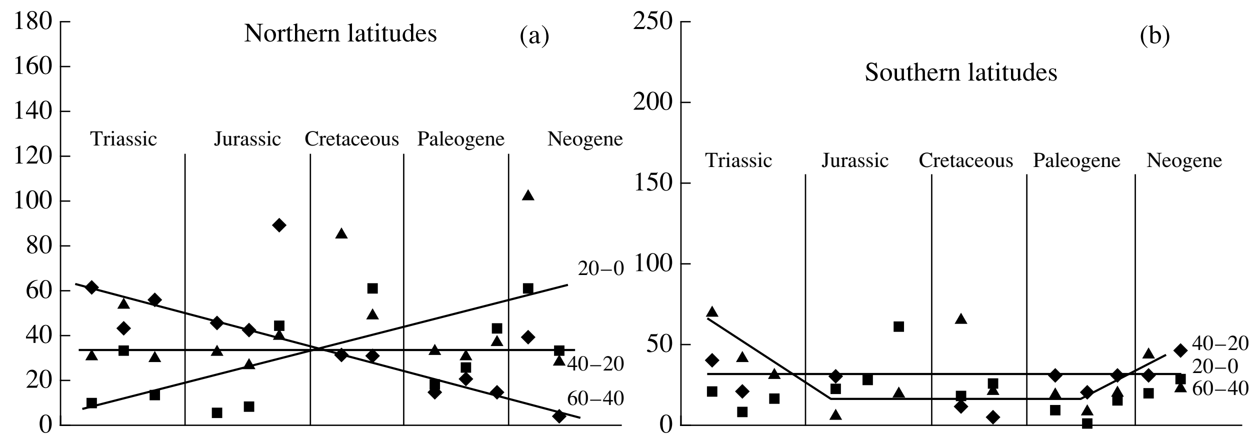

Fig. 1. Variation of relative intensity of magmatism in latitudinal intervals (a) northward and (b) southward from the equator: 0°–20° (boxes), 20°–40° (triangles), and 40°–60° (diamonds) in the Early Triassic–Neogene.

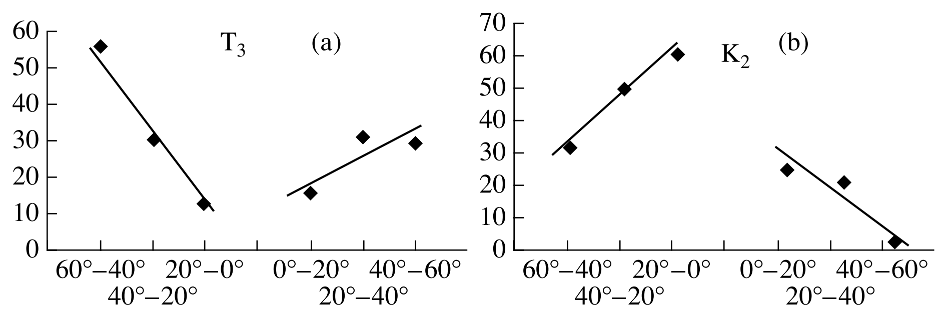

Fig. 2. Latitudinal variations of relative intensity of magmatism in (a) the Late Triassic and (b) the Late Cretaceous.

decrease in interval 60°–40° N, the increase in interval 20°–0° N, and virtually stable activity in interval 40°–20° N (Fig. 1a). In the Southern Hemisphere, the distribution of igneous activity is not so clear. A minimum probably exists in the Jurassic–Paleocene interval (Fig. 1b). However, both hemispheres are characterized by a distinct maximum of igneous activity in the Late Jurassic–Cretaceous. This conclusion is consistent with the aforementioned outburst of the Cretaceous igneous activity in the Earth.

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