ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 416, No. 7, pp. 1000–1003. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © V.P. Utkin, 2007, published in Doklady Akademii Nauk, 2007, Vol. 416, No. 1, pp. 86–90.

GEOLOGY

Rotation Nature of Tectogenesis of Continental Margins and Breakdown of the Laurasian and Gondwanan Supercontinents

V. P. Utkin

Presented by Academician Yu.M. Pushcharovsky August 25, 2006

Received September 13, 2006

DOI: 10.1134/S1028334X07070045

Numerous fundamental works, published mainly prior to the domination of the plate tectonics paradigm in science, are devoted to the role of Earth's rotation in planetary tectonics. The problem of shearing levels of continentals existed in the rotation model of the continental drift suggested by A. Wegener. Based on the analysis of voluminous materials, first of all, seismotomography, Pushcharovsky [9] elaborated a new model of the mantle structure with its tectonically isolated geospheres. According to Peive, slippage of the geospheres relative to each other is governed by rotation factors. We believe that this model eliminates the problem of shearing levels of continental mass and allows us to solve global tectonogeodynamic problems by developing the continental drift theory suggested by A. Wegener.

Strike-slip faults are an incontestable fact of lateral displacements of major lithospheric blocks. As is well known, the amplitude of displacement along such faults reaches many hundred kilometers, while the total amplitude of displacement reaches several thousand kilometers. There are grounds to believe that strike-slip faults reflect the directions, magnitude, and time of displacement of the fault-bounded continental fragments and whole continents. Such an approach was used in substantiating lateral displacements of continents in the Northern Hemisphere [1, 11]. By now, these long-term investigations have resulted in elaboration of a new geodynamic model of tectogenesis of continental margins and breakdown of the Laurasian and Gondwanan supercontinents as a consequence of nonuniform rotation of the Earth.

According to the classification of strike-slip faults proposed by Voronov [1], the Northern Hemisphere incorporates perioceanic global fault zones (GFZ) of dextral and sinistral types that do not intersect each other. They formed synchronously due to rotation-related flow (geofluction) of continental masses toward the equator. The tracing of strike-slip fault systems along continental margins made it possible to distinguish continental-margin dextral (NE-oriented) and sinistral (NW-oriented) GFZs, which converge at right angle near the equator [11, 12] (Fig. 1). Superposition of the GFZ on zones of continental-margin orogenic piling of continental masses, which corresponds to dislocation of frontal compression belts (FCB), and the inverted sequence are distinctive features. At the same time, activation of the GFZ of one continental margin shows general synchronism with formation of the FCB on an adjacent margin. For instance, the piling of masses in the Alpine–Himalayan FCB (Fig. 1) mainly proceeded from the first half of the Cretaceous to the Miocene [6] synchronously to the most intense activation of the East Asian GFZ [11, 12]. Sinistral faulting of the latter GFZ over hundreds of kilometers (Central Sikhote-Alin, Tan Lu, and other faults) can be attributed to the southward displacement of the Asian continent toward the FCB. Contraction of the Alpine–Himalayan FCB is estimated at 1000 to 3000–4000 km [5, 10]; the total displacement along the East Asian GFZ, from 1500 to 3000–6000 km [12, 15]. The complete identity of quantitative assessments of lateral displacements in the FCB and the GFZ confirms their possible development as structural parageneses. In the Arctic Ocean, tectonic destruction of the continental crust in the form of rifting, extension, disintegration, and subsidence that took place in the Mesozoic and Cenozoic led to the formation of the Beaufort, Nansen, and Amundsen basins, which can be regarded as rear tension structures (RTS) formed mainly synchronously with the GFZ and FCB due to the SSW-oriented displacement of Eurasia (Fig. 1).

Far East Geological Institute, Far East Division, Russian Academy of Sciences, pr. Stoletiya Vladivostoka 159, Vladivostok, 690022 Russia
e-mail: stakhor@yandex.ru

The Euramerican GFZ is represented by systems of NE-striking sinistral strike-slip faults of the eastern margin of North America and the western margin of Europe (Fig. 1). This is the Appalachian transcontinental system of deep-seated faults (TSF) [7], which includes faults of Newfoundland (Cobat, Rich, Lux-Arm, and others); faults of Scotland, including the best known Great Glen Fault; faults along the coasts of Norway and Spitsbergen; and faults on the Baltic Shield. The faults began to form in the Late Paleozoic, but they also remained active at a later time, including the Cenozoic. Sinistral faults are related to the SW-oriented displacement of North America mainly prior to formation of the Atlantic Ocean rift, which is superimposed on the GFZ. The North American FCB formed synchronously (Fig. 1). The piling of continental masses in the latter FCB began in the Paleozoic. The main orogeny and formation of the Cordilleras, which proceeded in the late Mesozoic and Early Cenozoic, reflected the timing of the most substantial displacements of continents along the Euramerican GFZ. In synchronism with these events, the formation of RTS zones fostered the separation of Greenland from North America. The space between them was occupied by a system of grabens filled with Mesozoic sediments with the manifestation of Paleogene basaltoid magmatism on the floor of Baffin Bay and the Davis Strait.

Unlike the NE-oriented sinistral GFZs, the NW-oriented GFZs are characterized as systems of mainly dextral faults (Fig. 1), which were active from the Paleozoic to the Pleistocene. The North American GFZ is represented by dextral strike-slip faults (amplitude, km): San Andreas (725), Tintina (425–500), Northern Rocky Mountain (750–900), Thibert and Kutcho (200), Fraser River (110–190), Denali (400), Chatham Strait (150–200), and others. Recent activation of dextral strike-slip faults along the San Andreas FZ is widely known. The amplitude of the Tintina and Northern Rocky Mountain dextral faults (up to 900 km) was established by the displacement of the boundary of Middle Devonian carbonate and shale facies with the *Stringocephalus* fauna [14]. Late Cretaceous and Cenozoic displacements along these faults are fixed by Santonian–Campanian, Paleocene, and Eocene sediments in near-fault basins. Evidently, this period reflects the last activation pulses of dextral strike-slip faulting of the North American GFZ, where the main displacements probably occurred in the Middle–Late Paleozoic. This assumption is confirmed by synchronous formation of the Appalachian–Scandinavian FCB oriented normally to the GFZ (Fig. 1).

The Eurasian GFZ (Fig. 1) is considerably veiled by Mesozoic–Cenozoic nappe–thrust structures of the Alpine–Himalayan FCB and is characterized mainly by dextral faults. For instance, the North Pyrenean Fault is one of the retained faults superimposed by dextral dislocations. Displacement along this fault over several hundred kilometers took place at the end of the Hercynian epoch [4]. Displacement of Eurasia to the southeast in the Paleozoic is confirmed by synchronous formation of the Uralian and East Asian FCB oriented normally to the GFZ (Fig. 1). The Uralian FCB formation is reflected in subduction of the East European crystalline platform under nappe structures of the western Urals. The East Asian FCB was probably manifested in obduction of the continent over the Pacific Plate along Benioff zones. This inference is confirmed by development of the NS-trending folded system at the eastern margin of Asia in the Paleozoic. Structures of this system are considerably disintegrated and veiled by superimposed Mesozoic–Cenozoic sinistral dislocations of the East Asian GFZ [13].

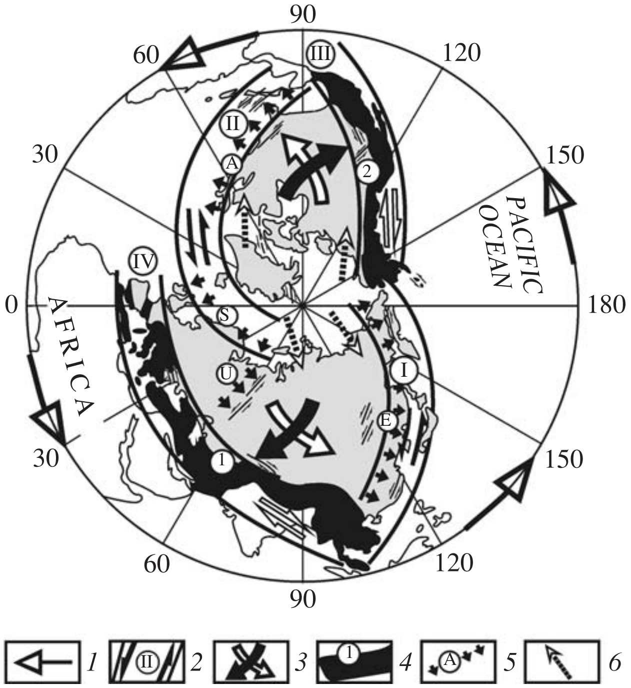

Fig. 1. Global fault zones (GFZ) and reversible transformation of geodynamic regimes of continental margins. (*1*) Direction of the Earth's rotation; (*2*) sinistral and dextral GFZs: (I) East Asian, (II) Euramerican, (III) North American, (IV) Eurasian; (*3*) direction of displacement of continents upon acceleration of the Earth's rotation in the Mesozoic–Cenozoic (filled arrows) and deceleration in the Paleozoic (hollow arrows); (*4, 5*) frontal compression belts (FCB): (*4*) formed in the Mesozoic–Cenozoic under conditions of acceleration of the Earth's rotation: (1) Alpine–Himalayan, (2) North American; (*5*) formed in the Paleozoic under conditions of deceleration of the Earth's rotation: (E) East Asian, (U) Uralian, (AS) Appalachian–Scandinavian; (*6*) rear tension structures (RTS).

As was mentioned above, amplitudes of the GFZ reach several thousand kilometers and imply the existence of horizontal detachments of continental masses at different levels [9]. Together with the GFZ, FCB, and RTS, the detachments make up global structural parageneses (GSP). All specific features of the GSP development are explained by the Earth's nonuniform rotation.

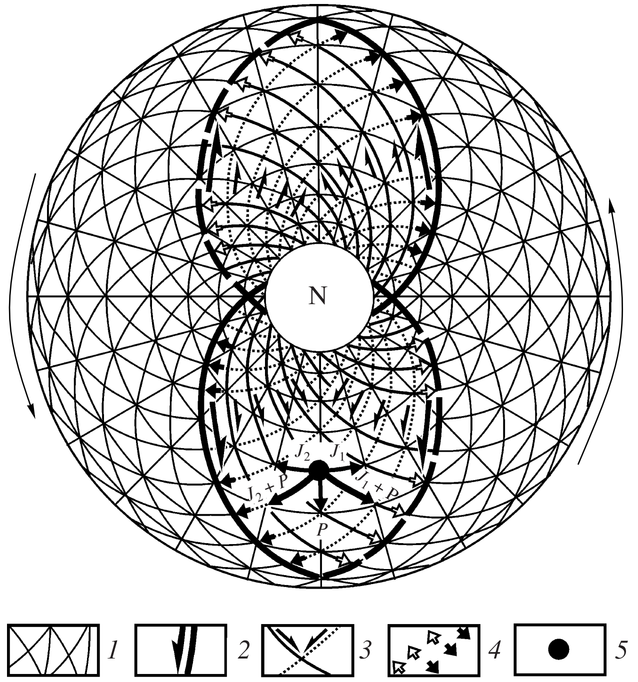

Fig. 2. Physical model of the formation of planetary fracturing in a nonuniformly rotating sphere [2, 3] and the development of the GFZ and FCB under these geodynamic conditions. (*1*) Planetary systems of diagonal and normal fracturing; (*2*) continental-margin GFZ and directions of motion of continents along them depending on acceleration ($J_2 + P$) or deceleration ($J_1 + P$) of the Earth's rotation; (*3*) intracontinental strike-slip faults synchronous to activation of continental-margin GFZ of similar orientation; (*4*) continental-margin FCB formed under conditions of acceleration (filled arrows) and deceleration (hollow arrows) of the Earth's rotation; (*5*) elementary unit of continental mass, the direction of displacement of which is determined by the total effect of equator-oriented (P) and inertial (J) forces; (J_1, J_2) the vector of inertial forces under conditions of deceleration and acceleration of the Earth's rotation, respectively.

The position of the GFZ relative to the Earth's rotation axis, like their conjunction at a right angle near the equator (Fig. 1), differ little from similar characteristics of diagonal systems of global fracturing related to rotation strains [2, 3, and others] (Fig. 2). The convergence of the GFZ near the equator at one and the same meridian does not seem to be accidental from this standpoint (Fig. 1). Along with constant pole-directed forces directed from the poles to the equator, inertial forces acting along parallels are known to emerge under conditions of the Earth's nonuniform rotation. Vectors of the inertial forces depend on acceleration or deceleration of the Earth's rotation: they are directed westward in the first case and eastward in the second case (Figs. 1, 2). The total effect of the pole-directed forces and inertial forces is reflected in alternating displacements of continents along the GFZ of different directions (Fig. 2). Acceleration of the Earth's rotation fosters reactivation of the NE-trending sinistral GFZs. In addition to the pole-directed motion, the westward constituent is also present in the displacement of continents along the latter GFZs. By contrast, deceleration of rotation fosters reactivation of the northwest-trending dextral GFZs accompanied by the eastward drift of continents. In both cases of GFZ reactivation, the fault-related geodynamic regime of adjacent GFZs is transformed into the FCB with a significant contribution of reactivation of intracontinental strike-slip faults parallel to the strike of synchronously activated GFZs of continental margins (Fig. 2). Lateral displacements are accompanied the successive reactivation of only two systems of sinistral and dextral GFZs, which are sufficient for continents to respond rapidly to new geodynamic environments created by variations in the Earth's rotation rate (energy expediency). Continents displaced along the GFZ retain the orientation of diagonal fracturing systems, resulting in planetary stability of the GFZ. This process is erroneously used as a fact contradicting the principle of mobilism. Under conditions of deceleration of the Earth' rotation, the vector of inertial forces is directed to the east. This situation may result, for instance, in transformation of the dextral Eurasian GFZ and sinistral East Asian GFZ into sinistral and dextral zones respectively. Such indications of fault transformations are manifested in the GFZ.

Based on palinspastic reconstructions of Mesozoic sinistral displacements of North America along the American–European GFZ, Laurasia is restored to its pre-Mesozoic contours. The North American and Eurasian GFZs are united into the Laurasian GFZ, which extends along the margin of the reconstructed Gondwanaland to make up the Laurasian–Gondwanan GFZ. Deceleration of the earth's rotation promoted the SE-oriented motion of Laurasia in the Paleozoic along the Laurasian GFZ. This was accompanied by synchronous formation of continental-margin FCBs: American–European (Appalachian–Scandinavian), Eurasian (Uralian), and East Asian (Fig. 3). The breakdown of supercontinents proceeded in the Mesozoic under conditions of acceleration of the Earth's rotation and reactivation of the GFZs, along which a western constituent of motion also existed in addition to the equator-oriented continental drift in the Northern and Southern hemispheres. When drifting along the Laurasian–Gondwanan GFZ, separate parts of the Gondwanan supercontinent (Antarctica, Australia, India, and Africa) were lagging behind in the listed order. The rotation-related breakdown of Gondwana into separate continents and the formation of RTS between them is also confirmed by the following fact: except for the Andean FCB, which formed from the Triassic to the Cenozoic, all other fragments of the paleocontinent lack any traces of frontal orogeny and bear indications of tensile boundaries. Acceleration of the Earth's rotation also stimulated the breakdown of Laurasia with reactivation of the sinistral NE-trending GFZs (Fig. 3). In this process, Europe and Asia drifted to southwest and collided with fragments of Gondwana fragments, whereas

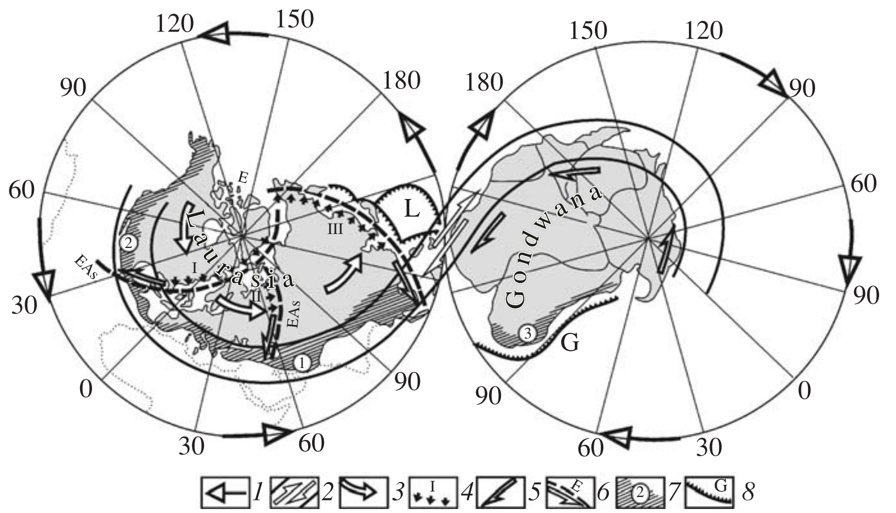

Fig. 3. Rotation model of the breakdown of Laurasia and Gondwana. (*1*) Direction of the Earth's rotation; (*2*) dextral Laurasian–Gondwanan GFZ; (*3*, *4*) direction of Laurasia displacement under conditions of deceleration of the Earth's rotation in the Paleozoic (*3*) with synchronous formation of the continental-margin FCB (*4*): (I) Euramerican, (II) Eurasian, (III) East Asian; (*5–7*) direction of displacement of Gondwanan (*5*) and Laurasian (*6*) continents under conditions of acceleration of the Earth's rotation in the Mesozoic–Cenozoic along the (EAm) Euramerican, (EAs) Eurasian, and (E) East Asian GFZs, with synchronous formation of FCBs (*7*): (1) Alpine–Himalayan, (2) North American, (3) Andean; (*8*) Laurasian (L) and Gondwanan (G) FCBs, the relation of which to lateral displacements of supercontinents of the same name accounts for the uniqueness of East Asian and Andean Benioff zones.

North America did not encounter such a barrier, resulting in its considerable displacement and breakdown of the Laurasian GFZ into two parts: North American and Eurasian.

It has been established that the long-term, relatively gradual variations in the Earth's rotation rate were complicated by sudden and irregular variations of different values and signs in the rotation rate, probably resulting in multiple transformations of geodynamic regimes of continental margin evolution. The model proposed is based on the analysis of only general differences in tectogenesis of continental margins (primarily, in the Paleozoic and Mesozoic).We believe that a detailed correlation of the synchronously formed GFZ, FCB, and TSF would allow one to refine geochronological boundaries of variations in the direction of continental drifts related to the Earth's nonuniform rotation. Undoubtedly, the analysis should also take into account different-vector lateral displacements of continental blocks related to within-mantle convective flows [8], first of all, at the stage of oceanic rifting.

REFERENCES

1. P. S. Voronov, *Essays on Regularities in the Morphology of the Earth's Global Relief* (Nauka, Leningrad, 1968) [in Russian].
2. I. V. Galibina and G. N. Katterfeld, in *Problems of Planetology* (Akad. Nauk Arm. SSR, Erevan, 1977), Vol. 2, pp. 90–96 [in Russian].
3. A. V. Dolitskii and I. A. Kiiko, in *Problems of Planetary Geology* (Gosizdat, Moscow, 1963), pp. 291–311 [in Russian].
4. M. Mattawer and G. Anri, in *Mesozoic–Cenozoic Orogenic Belts*, Ed. by E. Spencer (Scottish Academic Press, Edinburg, 1974; Mir, Moscow, 1977).
5. S. V. Meien, Geotektonika, No. 5, 3 (1969).
6. A. V. Peive, A. L. Mishkin, L. P. Zonenshain, et al., Geotektonika, No. 5, 6 (1976).
7. A. B. Peive, in *Deep-Seated Faults and Mobilism* (Nauka, Moscow, 1977), pp. 5–47 [in Russian].
8. Yu. M. Pushcharovsky, Geotectonics, No. 3, 157 (2004) [Geotektonika, No. 3, 3 (2004)].
9. Yu. M. Pushcharovsky, *Tectonics of the Earth* (Nauka, Moscow, 2005), Vol. 1: *Tectonics and Geodynamics* [in Russian].
10. R. Trumpy, in *Tectonics of the Alpine Area* (Springer, Berlin, 1962; Mir, Moscow, 1965), pp. 173–197.
11. V. P. Utkin, Dokl. Akad. Nauk **249**, 425 (1979).
12. V. P. Utkin, Vestn. DVO RAN, No. 4, 23 (1994).
13. V. P. Utkin, P. L. Nevolin, and A. N. Mitrokhin, Dokl. Earth Sci. **389**, 171 (2003) [Dokl. Akad. Nauk **389**, 75 (2003)].
14. H. Gabrielse, Geol. Soc. Am. Bull. **96**, 1 (1985).
15. J. W. Xu, G. Zhy, W. Tong, et al., Tectonophysics **134**, 273 (1987).