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GEOLOGY

Role of Strike-Slip Faulting of the Oceanic Lithosphere in the Formation of Pacific Volcanic Belts

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The Pacific volcanic belts that extend over thousands of kilometers are formed on abyssal plates above the deep linear fault systems [3]. Linearity is primarily typical of the deep strike-slip faults. The crucial role of strike-slip structural assemblages has been established in the evolution of the East Sikhote-Alin volcanoplutonic belt formed on the continental lithosphere [8]. These facts were used as a basis for setting the following problem: study of the infrastructure of volcanic belts from the point of view of their possible development above the deep strike-slip faults in the lithosphere. The deciding role of reactivation of deep strike-slip faults of the oceanic lithosphere in formation of intraoceanic volcanic belts has been established for the first time.

In order to solve the problem, we used the concept of differential motion of intralithospheric sheets (lithic sheets) that gives rise to the tectonic delamination of the lithosphere [3, 5]. We also used the method of morphological analogy of the development of structural assemblages of the continental and oceanic crusts. This method was successfully applied for studying the Magellan Seamounts [7].

The Magellan Seamounts traced over more than 1000 km are related to the NW-trending Ogasawara Fracture Zone [10]. The most compact guyot clusters of the Magellan Seamounts make up the latitudinal fields (Fig. 1). Their en echelon arrangement is identical to the orientation of folds related to a potential (incipient) shear formed above a deep dextral strike-slip fault during meridional compression of the crust (Fig. 2). The equal spacing between the axes of inferred folds (in our case, ~250 km) is a well-known feature in structural geology. Results of the reconstruction showed that the primary antiform structure of folds is caused by the exhumation of guyots (together with their basaltic basement) from a depth of 1.5–2.5 km to the abrasion level. This conclusion is also supported by the following modeling result. If the whole bulk of volcanic edifices is placed under the abyssal plate, this hypothetical process will result in the rise of the plate for 1.5–2.0 km and the emergence of antiforms within the latitudinal volcanic fields (Fig. 2). The slope of brachyanticline limbs does not exceed 8°, indicating only insignificant warping of the abyssal plate. However, the warping was sufficient for the formation of lens-shaped cryptic decompression chambers beneath the brachyforms (Fig. 2), where asthenospheric magmatic melts were localized and the deep fluids provided magma generation under conditions of low pressure. The main mass of magma was confined to axes of brachyanticlines, as indicated by the growth of the largest volcanic edifices in the area (Fig. 1).

Within the latitudinal brachyanticlines, the guyots are mainly concentrated along the NE- and NW-trending fractures (Fig. 1). In the best studied guyots, such fractures are defined as sinistral and dextral strike-slip faults, respectively, that arose under meridional compression [7]. The shear systems correspond to the well-known diagonal faults that cut the folds. Thus, the fold-related nature of the latitudinal volcanic fields is confirmed. The guyots were largely formed at intersections of the conjugated shears, which opened up magma chambers, first of all, close to the duplexes and other forms of transtension of abyssal plates [7]. The subsidence of brachyanticlines after the abrasion of volcanic edifices was probably caused by the release of meridional compression and the exhaustion of magma chambers as a result of volcanic activity and the subsequent exhumation of large piles of volcanic rocks that made up the seamounts.

The en echelon arrangement of volcanic islands in the French Polynesia (Fig. 3) is a counterpart of the infrastructure of the Magellan Seamounts. Furthermore, the seafloor topography and fields of maximum concentration of volcanoes have shown that the linear Marshall–Gilbert and Line volcanic belts are also char-

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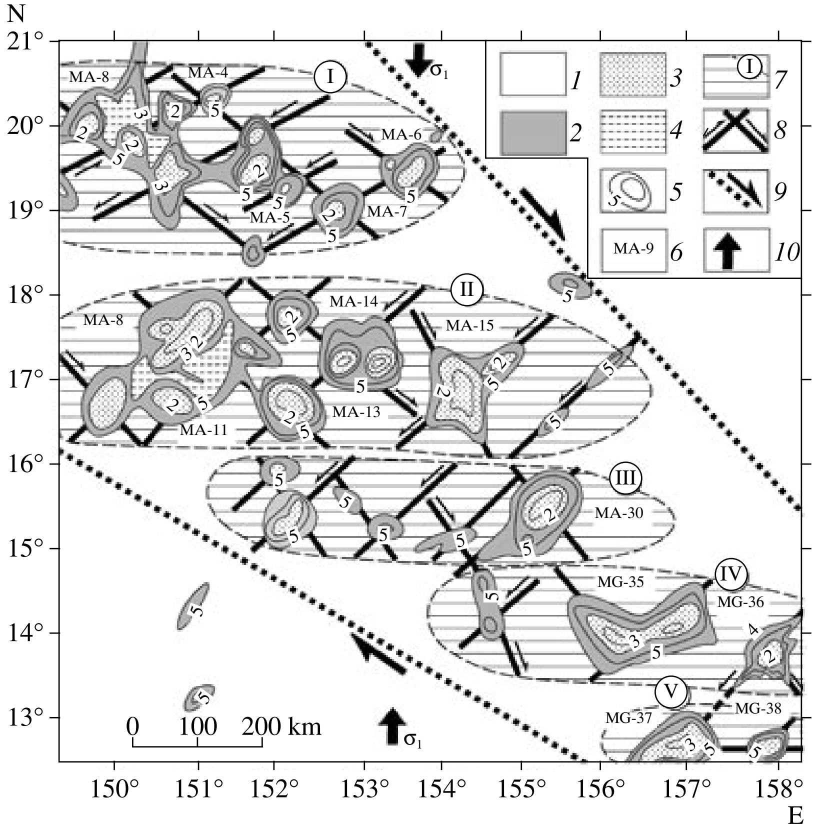

Fig. 1. Folds and faults that control volcanic edifices of the Magellan Seamounts and the Dutton Ridge (compiled after [1]). (*1*) Abyssal plate, (*2*) igneous rocks of guyots (subalkali basaltoids); (*3*) sedimentary complexes of summit plateaus; (*4*) overlying lower stages of volcanic edifices; (*5*) generalized isobaths, km; (*6*) guyot numbers; (*7*) latitudinal volcanic fields (brachyanticlines): (I) Dutton, (II) Alba, (III) Nakhodka, (IV) Fedorov, (V) Ita-Maitai; (*8*) diagonal systems of conjugated dextral and sinistral strike-slip faults that control volcanic edifices; (*9*) boundary of the Magellan Seamounts (potential dextral strike-slip fault zones); (*10*) direction of the oceanic crust compression.

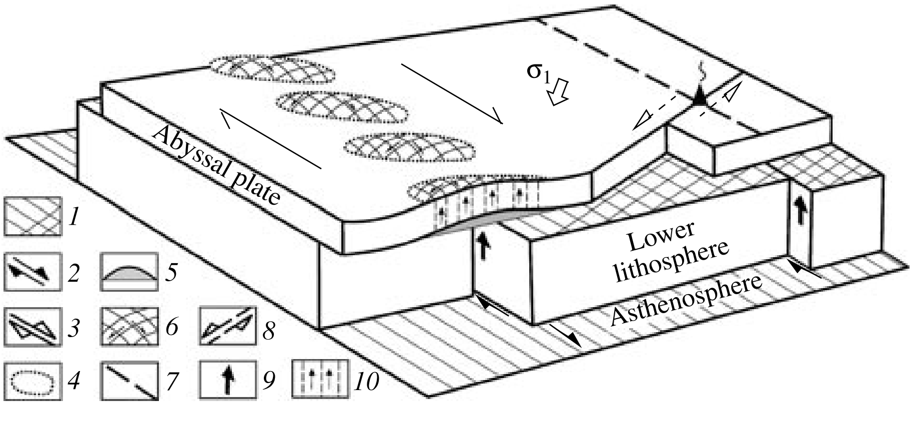

Fig. 2. Geodynamic model of volcanic belt formation under conditions of the delaminated lithosphere. (*1*) Surfaces of horizontal slip of the lithosphere and particular lithic sheets; (*2*) strike-slip faults in the lower lithosphere; (*3, 4*) strike-slip fault: (*3*) potential, (*4*) expressed as en echelon brachyanticlines; (*5*) magma chambers formed beneath brachyanticlines under decompression; (*6*) diagonal systems of dextral and sinistral strike-slip faults in brachyanticlines that served as magma conduits; (*7*) projection of a strike-slip fault in the lower lithosphere on the surface of an abyssal plate; (*8*) strike-slip fault in the abyssal plate (volcanism takes place at the intersection of this fault with strike-slip fault in the lower lithosphere); (*9*) ascent of asthenospheric mafic rocks and fluids along the strike-slip faults in the lower lithosphere; (*10*) farther propagation of matter from a magma chamber toward the surface of an abyssal plate.

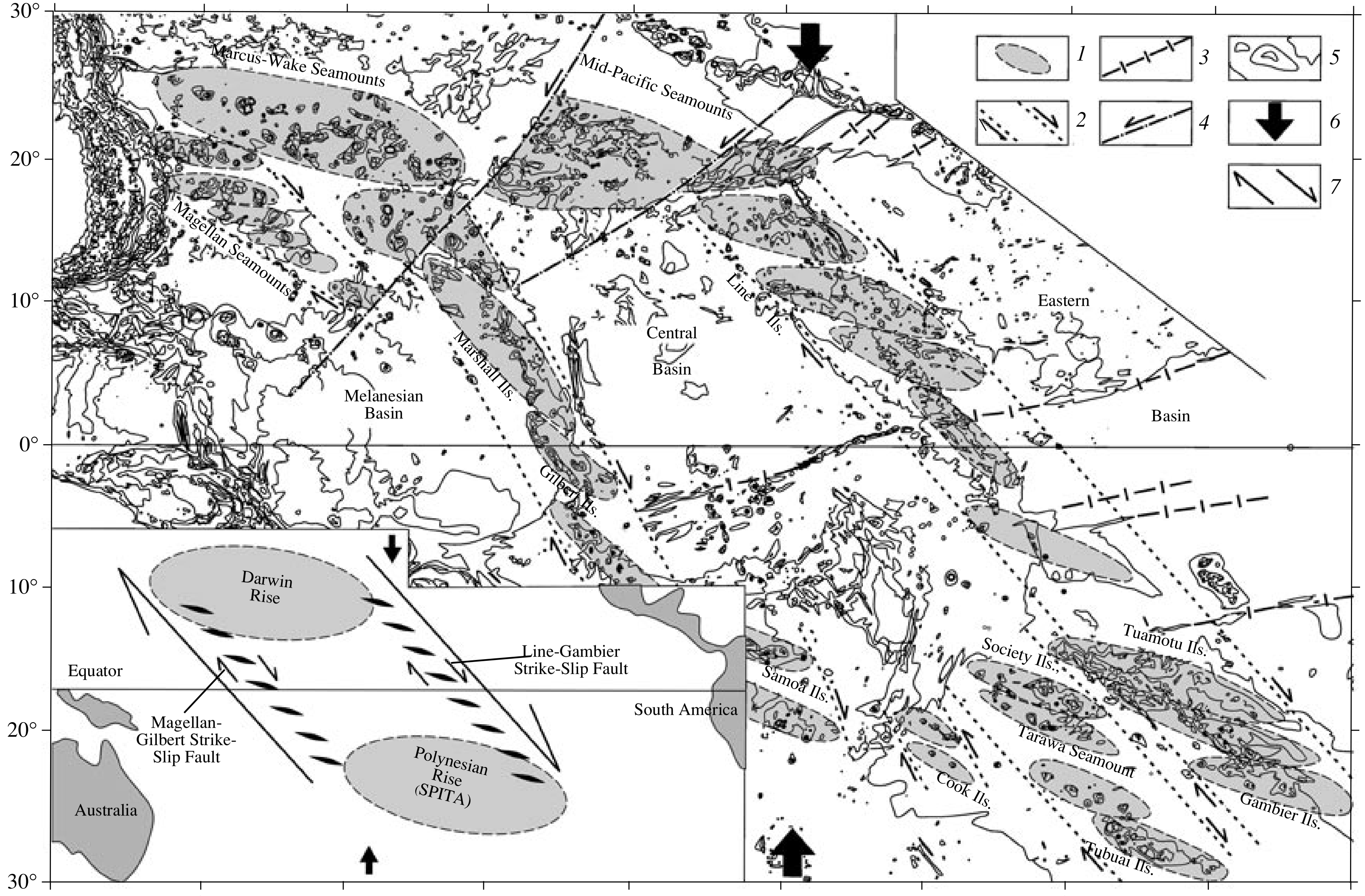

Fig. 3. Control of Pacific volcanic belts by lithospheric strike-slip faults. (*1*) Linear arches and en echelon brachyanticlines that control the fields of volcanic edifices; (*2*) boundaries of linear echelons of brachyanticlines (potential strike-slip fault zones); (*3*) transform faults; (*4*) strike-slip faults that offset volcanic belts; (*5*) isobaths (after [4]); (*6*) directions of longitudinal compression of the lithosphere; (*7*) Equatorial Strike-Slip Fault Zone (see inset).

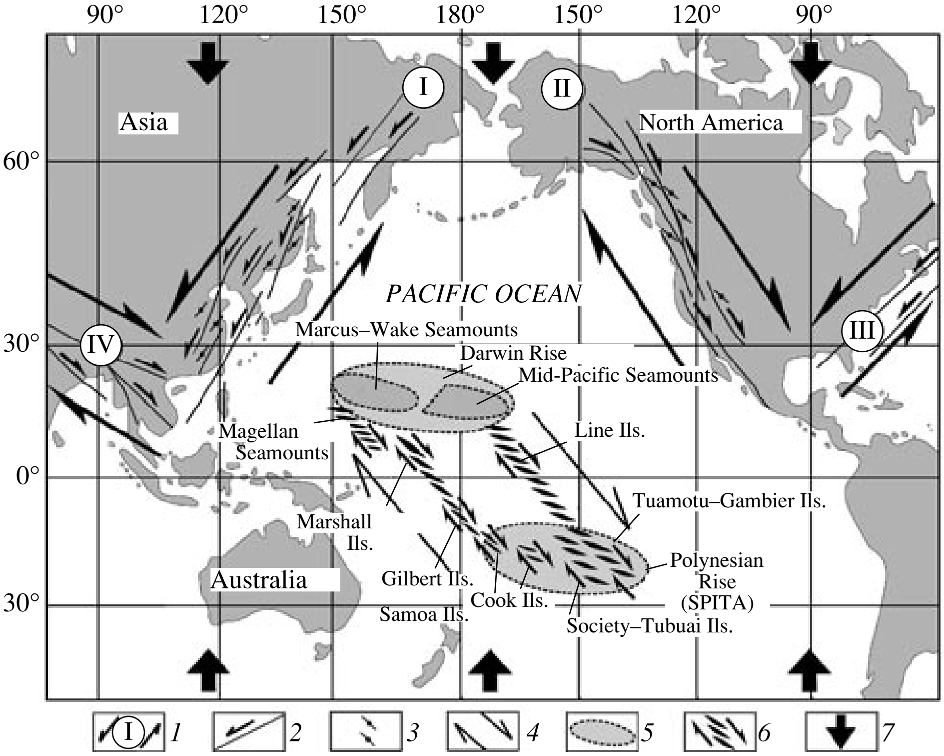

Fig. 4. Strike-slip fault zones in the oceanic lithosphere and at continental margins. (*1*) Continental-margin strike-slip fault zones, (after [6] and others]: (I) East Asian, (II) North American, (III) Newfoundland–Appalachian, (IV) Eurasian; (*2*) particular strike-slip faults; (*3*) orientation of folds related to strike-slip fault zones; (*4*) Equatorial Strike-Slip Fault Zone; (*5*) magma-controlling arches of the oceanic lithosphere; (*6*) strike-slip faults controlling volcanic belts; (*7*) direction of rotational shear stresses in the lithosphere of the Northern and Southern hemispheres.

acterized by en echelon infrastructure. By analogy with Magellan Seamounts, this infrastructure was formed above the NW-trending deep dextral strike-slip faults. The difference consists only in orientation of brachyanticlines relative to the strike-slip fault: 45° in the Magellan Seamounts and 30° in the Marshall–Gilbert, Line, and French Polynesia (Fig. 3). This is related to different degrees of the development of potential shears. As is known, the reactivation of strike-slip faults in the basement is first accompanied by echelons of folds in the overlying cover (abyssal plate, in our case) oriented at an angle of 45° to the fault. Further, the folds rotate (clockwise in the case of a dextral strike-slip fault) and may be oriented almost parallel to the fault strike.

The near-latitudinal mega-arches of the Darwin Rise, which incorporate the Marcus–Wake and Mid-Pacific seamounts (Fig. 3), and the near-latitudinal Polynesian Rise complicated by echelons of magma-controlling structures (Tuamotu, Gambier, Society, Tubuai and other islands) are likely genetic counterparts of the latitudinal antiforms of the Magellan Seamounts. Large dimensions of these rises and anomalous structure of their crust suggest that they were formed as a result of emergence of the oceanic lithosphere as a whole. Under conditions of meridional compression of the lithosphere, the ongoing decompression beneath the Polynesian Arch initiates activation of the asthenosphere with the formation of the so-called South Pacific Isotopic and Thermal Anomaly (SPITA). According to [9], this anomaly existed during ~120 Ma [9]. Seamounts on the Marcus–Wake and Mid-Pacific mega-arches were probably formed under similar conditions, mainly in the Cretaceous. Asynchronous development of volcanic activity at the Polynesian and Darwin rises requires special consideration.

The system of E- and NE-trending faults (Fig. 3) is a continuation of transform fracture zones that are widespread in the East Pacific. They are clearly expressed in the topography of the oceanic floor but poorly developed as magma conduits. The igneous activity is inadequate relative to their length and role in fragmentation of the abyssal plate into blocks. These faults probably cut oceanic plates but do not penetrate into the asthenosphere, the main source of mafic magmas. Therefore, the volcanic activity was developed only at intersections of these faults with faults that cut through the lower lithosphere and serve as conduits of asthenospheric magmas (Fig. 2).

The NE-trending fault expressed in oceanic floor topography terminates the Mid-Pacific, Magellan, and Marshall seamounts (Fig. 3). The palinspastic reconstruction of the sinistral strike-slip fault restores integrity of the Mid-Pacific Seamounts, while the Magellan and Marshall–Gilbert seamounts line up as a NW-trending belt that marks the initial position of the deep dextral Magellan–Gilbert Strike-Slip Fault (Fig. 3, inset). The Line Islands extend to the southeast as an echelon of the Tuamotu–Gambier Islands and make up a common volcanic belt above the dextral Line–Gambier Strike-Slip Fault. The Magellan–Gilbert and Line–Gambier faults extend from the Darwin Rise to the Polynesian Rise and make up the Equatorial Strike-Slip Fault Zone (Fig. 3, inset). The echelon arrangement of rises indicates their genetic relation to this fault zone.

Thus, we can make the following conclusions: (1) Strike-slip dislocations of various ranks in the oceanic lithosphere, systematically coordinated and expressed as plicative (folds) and disjunctive (strike-slip faults and transtensional duplexes) structures, played a crucial role in the formation of not only particular volcanic edifices and large volcanic fields, but also linear volcanic belts extending over thousands of kilometers; and (2) the entire assemblage of strike-slip dislocations at various hierarchical levels developed under conditions of meridional compression of the oceanic lithosphere.

The tectonomagmatic structural features superimposed on the abyssal plates, including the present-day volcanic edifices above the SPITA, were formed over a period of no less than 120 Ma. The meridional compression of the lithosphere that lasted for such a long period requires explanation. Tangential stresses related to the earth's rotation may be a possible cause. The role of this factor in global tectonics was discussed in many fundamental works published mainly before the domination of the paradigm of tectonics of lithospheric plates. In these publications, a significant role is ascribed to the permanent (although very small) stresses of meridional compression related to the centrifugal forces. These stresses act under conditions of both nonuniform and uniform rotation of the earth. The lithosphere is likened to a Maxwell body that reacts as a brittle material to fast loading and as a viscous matter to slow loading. It is suggested that the meridional compressive (insignificant, but permanently acting) stresses lead to viscous deformation of the lithosphere at the first stage and the brittle deformation at the next stage. In our case, the linear belts of brachyform folding give way to the strike-slip faulting. The northwestern strike of dextral strike-slip faults in the Equatorial Strike-Slip Fault Zone attracts attention. In terms of orientation and kinematic characteristics, this zone completely fits the system of the marginal continental strike-slip fault zones (Fig. 4). These zones, in turn, correspond to the diagonal systems of planetary fracturing that are probably related to rotational stresses.

The Polynesian and Darwin rises are situated (Fig. 4) within the belt of so-called critical parallels (20°–50° N and S) that correspond to the region of maximal tangential displacements of subcrustal masses under conditions of nonuniform rotation of the earth that actively affect tectonics of the lithosphere. Following the concept of A. von Humboldt, many researchers ascribe the formation of latitudinal foldbelts in the Northern and Southern hemispheres to these critical parallels. The Darwin and Polynesian arches probably reflect the peculiar folding of the oceanic lithosphere. However, these arches can be produced by frontal stacking of the lithosphere that slowly moved toward the equator under the influence of centrifugal forces. Upon convergence near the equator, the northern and southern stresses relaxed after the formation of the Equatorial Strike-Slip Fault Zone oriented at an angle of 45° to the counter compression of the lithosphere in the North and South Pacific (Fig. 4).

The permanently acting rotational forces and associated deformations of the lithosphere were accompanied by processes related to the earth's endogenic energy. This idea is reflected in the works of researchers who focused their attention on tectonics of lithospheric plates and mantle plumes. The total effect of all diverse (contemporaneous or consecutive) forces gave rise to phenomena that generally do not obey the laws of linearity. This conclusion follows from the concept of nonlinear geodynamics successfully developed by Pushcharovsky [2, 3]. It would be more reasonable to search for the causes of tectogenesis and magmatism on the basis of all available hypotheses rather than one hypothesis.

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