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The Southern Uralian-Mugodzhary mountain chain as a northernmost impact area of the India-Eurasia collision

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Introduction. The South Urals and Mougodzhary ranges are southernmost segments of the Uralian intraplate orogen crossing the Eurasian lithospheric plate. Due to such a position, The South Uralian- Mougodzhary mountain chain is a key region for analysis of the problem of impact of the Late Alpine collision onto the intraplate orogenesis. And the problem is much easier to solve due to a wide distribution of deformed Cenozoic rocks. The inadequately studied horizontal component of recent block movements of the South Uralian-Mugodzhary range was determined by the following methodics: (1) a definition of morphostructural pattern of the recent relief, (2) field study of morphology and kinematics of macrotectonic-scale structures formed by the Upper Mesozoic and Cenozoic rocks, and (3) mass measurement of slickensides and other mesotectonic-scale structures in these rocks.

A relief and morphotectonic structure. The South Uralian segment in its central part is occupied by ancient gentle arch, probably of Oligocene-Early Miocene age, with its dividing crest, the Uraltau ridge, up to 1 km high , playing a role of a main watershed. An axis of the arch is displaced eastward from the topographic axis. The eastern slope is combined with a sharp escarp. Besides, eastern slopes of the all ridges are predominantly steeper than the western ones. So, the South Urals is strongly asymmetrical in a vertical section and, since it has emerged from horizontal compression (and some proofs will be given below), one can suppose that the compression has arised from westward underthrust of the recent Central Kazakhstan block situated in the east.

The Uraltau arch is complicated by side pressure ridges uplifted now much higher than the main watershed, up to 1,6 km. Transverse rivers, originating in slopes of

the Uraltau, dissect these side ridges and have an antecedent character. Hence, these side uplifted blocks are very young and have been developing simultaneously with the drainage system, i.e. since Pliocene-Quaternary. The river terraces experience splitting and elevation in places where the rivers transect big ridges. That is why some authors consider neotectonic structure to be a system of linear basement folds [Eliseev, 1950; Rozhdestvensky, 1974; Zinyakhina, Rozhdestvensky, 1991]. The main characteristic feature is a system of linear Late Mesozoic-Cenozoic troughs where the sedimentary cover reaches 300-400 m. They all, as a rule, are confined to soft Paleozoic rocks and weakness zones: the Kungurian evaporites and ophiolites of the Middle Paleozoic.

The Mougodzhary segment (megaanticline) is arranged en echelon to the South Urals and has directly opposite transverse asymmetry: its western flank is steeper and combined with a reverse fault. Both are evidence for the presence of a shear between the South Urals and Mougodzhary. Besides, if the latter was also formed under compression, the underthrust, unlike the South Urals, must be directed here from the west but not east.

The neotectonic stress/deformation field. The Late Mesozoic-Cenozoic cover is deformed, and that allows us to determine the stress regime. At the vicinity of the West Mugodzhary Paleozoic fault rejuvenated in the recent epoch, the cover strata are tilted in form of a steep flexures and folds. In the north, drilling data suggest thrust component of the fault. Another band of the strongly deformed Cenozoic rocks is confined to an axial part of the Cis-Uralian foredeep. All the mapped compression structures, both thrusts and folds, have submeridional or slightly diagonal orientation suggesting a sublattitudinal compression. According to the interpretation of satellite photographs and digital elevation maps, a trace of the above West Mougodzhary reverse fault is repeatedly displaced by oblique strike-slips, dextral ones of north-eastearn orientation and sinistral ones of north-western orientation. It is obvious that this set of conjugated strike-slips was formed under the sublatitudinal compression.

The sublatitudinal compression associated with submeridional extension is established by mass mesotectonic measurement of slickensides and veins in the Jurassic-Cenozoic rocks. At last, sublatitudinal compression of whole Urals is confirmed by direct measurement of current stresses in mines [Aleinikov et al., 1988; Lyovin, Fomin, 2001].

Strike-slip tectonics and block kinematics. The extended strike-slip faults are characteristic for both South Urals and Mougodzhary however they differ in arrangement and kinematics.

In *the South Urals*, dextral strike-slips of north-eastern up to submeridional strike prevail. It is interesting to note in this connection that the recent dextral strike-slips are predominant in the neighbour part of the Central Asia. Linear structures of the

South Uralian segment constitute an arc bending westward and framed in flanks by passing strip-slips. All these features, along with the anomalous steepness of eastern flank, evidence for underthrust and block movement directed from east to west.

In *the Mougodzhary*, in complete contrast to the South Urals, sinistral strike-slips prevail concentrated in the north. In adjacent part of the Alpine-Himalayas collisional belt, sinistral strip-slips are widespread in the eastern Caucasus and western Alborz. Intraplate sinistral strike-slips are numerous in the Volga region. The Mougodzhary arc is convex eastward and accompanied by passing sinistral and dextral strike-slips in flanks. All this makes us consider the recent deformation of Mougodzhary to occur under eastward movement and underthrust of the block situated in the west of Mougodzhary, i.e. recent Peri-Caspian block.

In the first approximation, strike-slip structure and kinematics of the whole region may be presented as a combination of two large-scale strike-slip-related forced virgations: of a dextral and sinistral kinematics in the north and in the south respectively.

Links of the Uralian intraplate deformation with the India-Eurasia collision. Based on these facts, it may be concluded that the recent deformation of the South Uralian-Mougodzhary mountain chain occured at almost cross to it sublattitudinal compression and/or longitudinal (submeridional) extension. The compression was concentrated in the Jurassic-Cenozoic troughs playing a role of the weakness zones during the Alpine orogeny. In contrary, the alpine stresses relaxed into extension where they affected the rigid metamorfic rocks of the Uraltau unit. Such a selectivity of compressional/extensional deformation depending on rheology of rocks, along with all above structural features, can be explained by external position of sources of stresses, which, probably, were caused by intraplate collision of the East European craton with frontal blocks of pressure zones of the Arabian and Indian indenters.

From the west, the Peri-Caspian block of the Peri-Arabian collisional area moved northeastward, being restricted by sinistral strike-slips of north-eastern strike. From the east, the Central Kazakhstan block of the Peri-Indian collisional area moved northwestward, being restricted by dextral strike-slips of north-western strike. Besides, the Central Kazakhstan block met thick crust of the Volga-Kama anteclise. All this would be quite suffiicient for emergence of the compression and anomalous recent uplift of the Southern Urals.

In plunges of the lobe collision area where blocks of unequal crust thickness did approach, transverse compression of the Urals resulted in an intraplate underthrust of blocks with thinner crust. Such are the West Mugodzhary zone where the suboceanic crust of the Peri-Caspian syneclise underthrusts beneath the Uralian thick crust and the Loz'va zone where the thinner crust of the West Siberian young plate underthrusts

beneath the Eastern European craton.

General conclusions. (1) Recent deformation of the South Uralian-Mougodzhary mountain chain was formed at approximately transverse (i.e. sublatitudinal) compression and associated longitudinal (submeridional) extension. (2) This transverse compression was realized in gentle folding of the basement as an arch complicated by mega-scale folds, in crumpling the cover beds of intramountain and foredeep basins, as well as in formation of strike-slip faults and lateral extrusion of a rock material. In all these attributes, the recent structure of the South Uralian-Mougodzhary mountain chain does not differ essentially from those of Tien-Shan, Altai and other renewed mountains of a collisional origin. (3) The compression of the recent South Uralian-Mougodzhary orogen was caused by intraplate underthrust and/or collision of platform blocks: Central Kazakhstan and Peri-Caspian ones belonging to zones of dynamic impact of the Indian and Arabian indenters accordingly. As these blocks did not move strictly towards each other, but with some offset, the sinistral shear had been arised between South Urals and Mougodzhary.

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