ISSN 0145-8752, Moscow University Geology Bulletin, 2018, Vol. 73, No. 3, pp. 238–246. © Allerton Press, Inc., 2018.
Original Russian Text © Al.V. Tevelev, I.A. Prudnikov, Ark.V. Tevelev, A.O. Khotylev, E.A. Volodina, 2018, published in Vestnik Moskovskogo Universiteta, Seriya 4: Geologiya, 2018, No. 2, pp. 23–32.

A Kinematic Model of the Formation of the Sim Trough of the Uralian Foredeep

Al. V. Tevelev[a,] *, I. A. Prudnikov[a,] **, Ark. V. Tevelev[a,] *, A. O. Khotylev[a,] ****, and E. A. Volodina[a,] *******

[a] *Department of Geology, Moscow State University, Moscow, 119991 Russia*
**e-mail: atevelev@rambler.ru*
***e-mail: prydnikov@gmail.com*
****e-mail: arctevelev@rambler.ru*
*****e-mail: akhotylev@gmail.com*
******e-mail: ekaterina.volodina2015@yandex.ru*

Received October 27, 2017

Abstract—The structural features and mechanism of the formation of the Sim trough within the Uralian Foredeep, as well as the development of the entire Karatau–Suleiman block, are considered. This wedge-shaped block was subject to lateral extrusion to the north along conjugated strike-slip fault zones under a general latitudinal compression. This factor determined the local meridional compression and latitudinal extension of the block. In the central part of the block, the latitudinal extension was compensated by gradual subsidence, which resulted in the formation of the Sim trough.

Keywords: Urals, foreland basin, structural assemblages, fold, strike-slip fault, transpression

DOI: 10.3103/S0145875218030110

INTRODUCTION

The Uralian Foredeep borders the Ural Fold Belt from the west along its entire length and is traditionally divided into a series of extended local depressions that are filled with flysch and molasses complexes from the Moscovian Stage of the Middle Carboniferous to Permian inclusive (Fig. 1a).

The Sim trough occupies a specific position in the structure of the southern part of the Uralian Foredeep (Fig. 1b); it is located between the large structural elements of the Foredeep: the Yuryuzan–Sylva and Belaya depressions, being separated from the main field of the Upper Paleozoic formations by the Riphean Karatau block. The Sim trough is filled with thin carbonate and thin flyschoid strata, the total thickness of which, according to various estimates, ranges from 1200 to 2300 m (Fig. 2).

The Upper Paleozoic section in the trough compared to the same sections in the major depressions of the Uralian Foredeep is characterized first by significantly lower thickness, and secondly, by the much lower degree of dislocation of rocks. The Sim trough has irregular outlines that are not characteristic for such structures. The eastern wing is a west-dipping gentle monocline; the southern wing of the trough is a flat-dipping centroclinal. In the north the trough is bounded by a monocline complicated by latitudinal discontinuities. The western wing of the trough is the most complicated structurally; it is divided into three narrow lobes by sublatitudinal uplifts.

There are many ideas on the structure and history of the formation of the Sim trough, which were recently examined in great detail by A.Yu. Kisin (2008). However, most of them are connected with the structural and geodynamic interpretation of the Karatau block, which is usually of much more interest for researchers than the Sim trough itself. Without going into detail, we distinguish three main points of view on the formation of the Karatau block. The first point of view (in time of appearance, as well) was proposed by M.M. Tetyaev and N.S. Shatsky, who believed that the Karatau block was formed due to vertical movements and considered it as a transverse ridge of the Riphean rocks within the Uralian Foredeep. Among the major followers of the overthrust origin of the Karatau block are M.A. Kamaletdinov (1974) and Yu.V. Kazantsev (1984) who believe that the Karatau block was thrusted to the area of the Uralian Foredeep as well as the large allochthons of the Western Ural fold-thrust zone. Recently, Kisin (2008) developed ideas about the general crustal folding as a mechanism of the formation of the Karatau uplift and, accordingly, the structure of the Sim Trough. As the volume of this article does not allow us to analyze the existing points of view in detail, we refer readers to the above-mentioned work (Kisin, 2008).

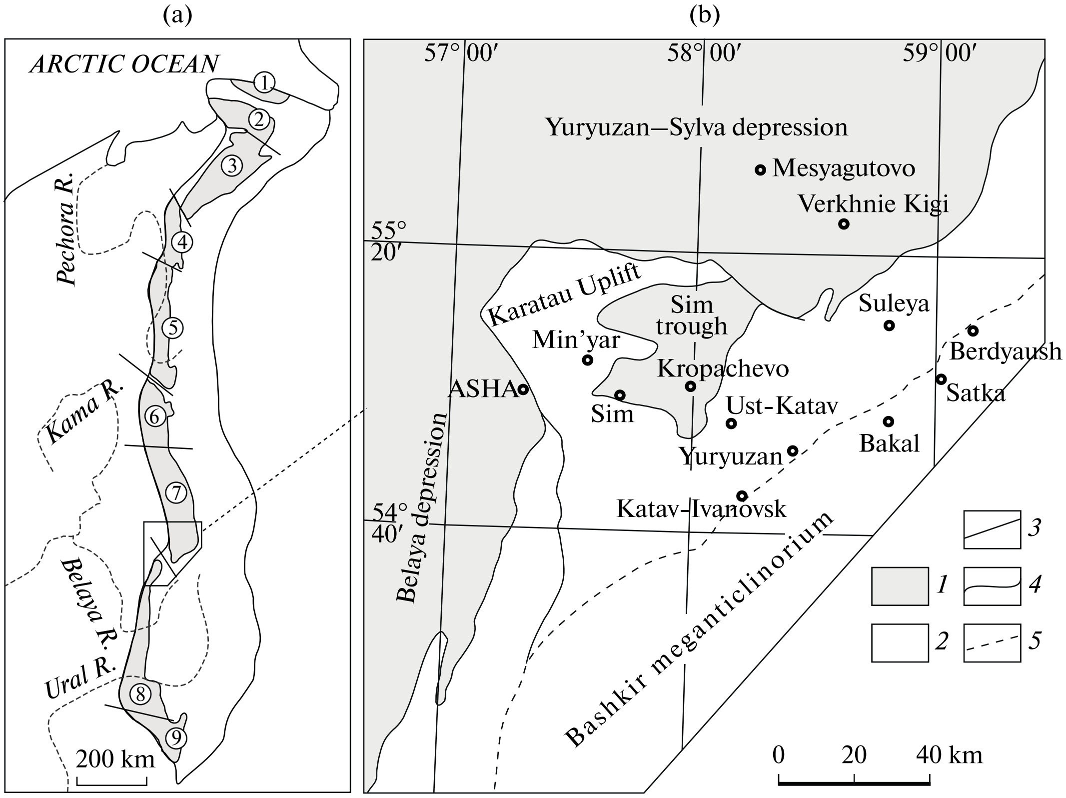

Fig. 1. The location scheme of structural elements of the Uralian Foredeep: (a) main depressions, according to (Misens, 1997) with amendments: (1) Kara, (2) Korotaikha, (3) Kosiyu–Rogovskaya, (4) Bolshaya Synya, (5) Upper Pechora, (6) Solikamsk, (7) Yuryuzan–Sylva, (8) Belaya, (9) Aktobe; (b) location scheme of the Sim Trough: (*1*) Late Paleozoic complexes of the Uralian Foredeep; (*2*) mainly Riphean complexes of the Bashkir meganticlinorium; (*3*) ruptures; (*4*) stratigraphic boundaries; (*5*) the proposed western boundary of the Timanides within the Bashkir meganticlinorium

In general, the Sim trough is located in the middle of the large Riphean Karatau–Suleiman block (Fig. 3A), which includes a series of sublatitudinal uplifts (anticlines Karatau, Vorob'inye Mts., Azhigardak and Berezovye Mts.) in the west, and Suleiman anticline in the east. This block has the shape of a blunt wedge that narrows to the south. It is bounded by the Asha sinistral strike-slip fault in the west, by the Pervomaiskaya dextral transpression zone in the east, and by the frontal Karatau thrust fault in the north.

KINEMATICS OF THE CONSTRAINTS OF THE KARATAU–SULEIMAN BLOCK

The kinematics and structure of the zones that bounds the Karatau–Suleiman block vary considerably.

The Asha sinistral strike-slip fault has an amplitude of at least 10 km; in the eastern wing is compensated by a series of overthrust and thrust faults, similar to the horsetail structure. Riphean formations are exposed in the hanging wings of the overthrust and thrust faults forming asymmetrical anticlines; in the wings, Paleozoic rocks form asymmetrical synclines. Further to the south, the Asha sinistral strike-slip fault has a meridional strike and is transformed into a dip-separation thrust with a series of small plates thrusting to the west. The southwestern wing of the Asha strike-slip fault, which is represented already by the Permian sequences, forms the steep wing of the box syncline and extends predominantly parallel to the shift, dipping both to the southwest and southeast.

The frontal Karatau thrust has the form of an irregular arc bending to the north. The allochthon is composed of Riphean rocks, whereas the autochthon is composed of Permian sequences, which are often folded in a series of inverted folds of northwestern and northern vergency. The sublatitudinal anticlines of the Vorob'inye Mts., the Azhigardak and Berezovye Mts., which are composed of Riphean sedimentary rocks, have a structure similar to that of the Karatau anticline. The only difference is that they are constrained by overthrust faults of the northern vergency, which are likely to become more flat-dipping with depth. Thus, the structure and kinematics of the Asha strike-slip fault correspond completely to the classical model of the formation of horsetail structures (Fig. 3a).

The dextral Pervomaiskaya transpression zone separates the Suleiman anticline from the main field of development of the Riphean complexes of the Bashkir meganticlinorium. The Pervomaiskaya zone consists of a bundle of northeastern dextral strike-slip faults that diverge to the northeast. In the southwest the zone is squeezed to the suture (to one fault zone). A series of small overthrusts (plates) composed of carbonate–terrigenous rocks varying in the age from the lower Devonian to the Frasnian Stage inclusive was punched out from the transpression zone to the northwest and overthrusted over the bituminous Famennian limestones (Fig. 3B). The morphology and kinematics of the Pervomaiskaya transpression zone correspond to the classical model of the formation of structures of this type (Fig. 3B). The zone is parallel to the western boundary of deformations of the Timanide Foreland basin, which extends within the Bashkir meganticlinorium (Puchkov, 2010). This boundary, most likely corresponds to the Katav–Yuryuzan zone of major dextral strike-slip faults: Katav-Ivanovsk, Suleya, and Yuryuzan.

KINEMATICS OF THE KATAV–YURYUZAN ZONE OF DEXTRAL STRIKE-SLIP FAULTS

The folded structure of the Riphean complexes emphasizes in many respects dextral displacements throughout this zone. The numerous Z-shaped overturns of the layers and the real dextral displacement of the markers are mapped. Therefore, our special attention was focused on the study of structural parageneses and kinematics of faults in the Katav–Yuryuzan zone within several reference sites (Fig. 4).

The Quarry site is located near the entrance to a large active quarry north of the town of Katav-Ivanovsk, in the underside of the Yuryuzan fault. The thin-layered calcareous siltstones of the Katavian Formation have been discovered here. They form a flexural fold (the closing wing has the following dip and strike: the dip azimuth (Dip Az. 140°) and the dip angle (∠40°) with nearly horizontal parallel wings. The structural paragenesis is represented by numerous slip planes, locally developed cleavage, fine corrugation, and other mesostructural elements.

Slip planes in limestones occupy a large area (several dozen square meters) and form series, penetrating the limestone stratum by several meters. Under a very distinct striation, whose orientation (Dip Az. 120∠69) is similar to that of the slip planes themselves (Dip Az. 125∠73), there are distinct scarps along ruptures, usually filled with banded calcite veins (Fig. 5a). All studied slip planes record overthrusts. Series of conjugated planes form the SF-texture associated with shear deformations.

The cleavage (strike azimuth 30∠90) is developed locally on the adjacent wings of the opposing flexures. It is expressed by a series of frequent parallel subvertical fractures, which are accompanied by fine corrugation of thin-layered siltstones (Fig. 5b; inset). Morphologically, this cleavage resembles crenulation cleavage, or wavy cleavage. Cleavage zones have uneven edges; microlitons of several centimeters in size are nearly completely wedged out. The axial surfaces of small folds are vertical, i.e., parallel to the cleavage. The

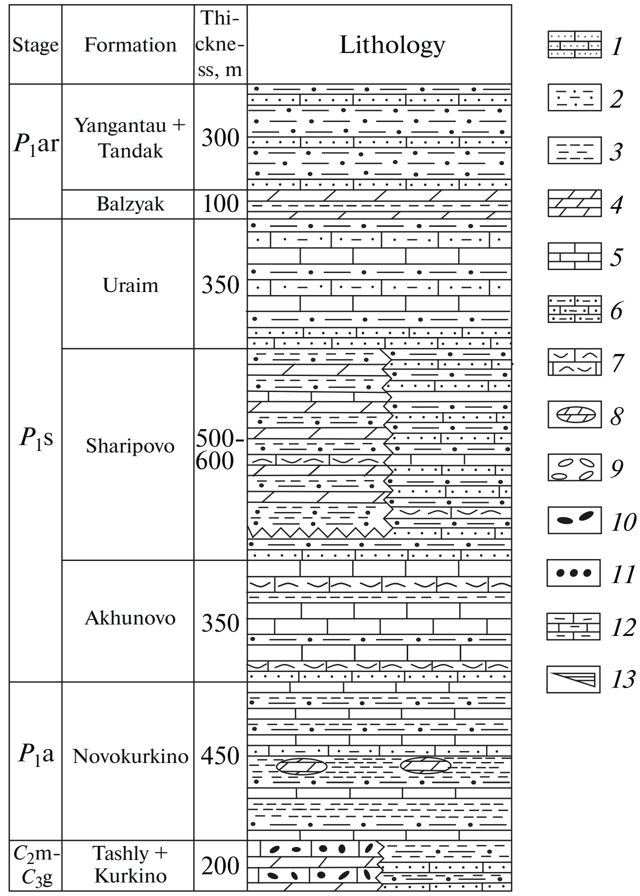

Fig. 2. The stratigraphy of the Sim Trough: (*1*) sandstones; (*2*) siltstones; (*3*) mudstones; (*4*) marl; (*5*) limestones; (*6*) calcareous sandstones; (*7*) detrital limestones; (*8*) marl concretions; (*9*) conglomerates; (*10*) chert concretions; (*11*) gravel; (*12*) clayey limestones; (*13*) olistostrome.

crenulation cleavage is cut at an angle by rare shears of the overthrust kinematics, which are approximately parallel to the slip planes. The ruptures, which are confined to the small cleavage bends, are filled with small calcite veins.

In addition to cleavage in siltstones, there is a coarse system of latitudinal vertical cracks. They divide rocks into blocks of 1–2 m thick, almost across a thin cleavage. Most likely, this is a superimposed latitudinal coarse cleavage, which will be discussed below.

There are rare tectonic breccias in this outcrop. The steeply dipping linear zone of tectonic breccias up to 15 cm thick and of several meters long extends in meridional direction (Dip Az. 270 ∠75). Rock fragments are represented by cherry-colored and green siltstones. They have angular, flat, and isometric outlines (Fig. 5c). The flatted fragments are oriented conformably to the entire breccia zone. Cement in breccia is carbonate (calcite and siderite). The proportion of rock fragments is approximately 50%; they vary from

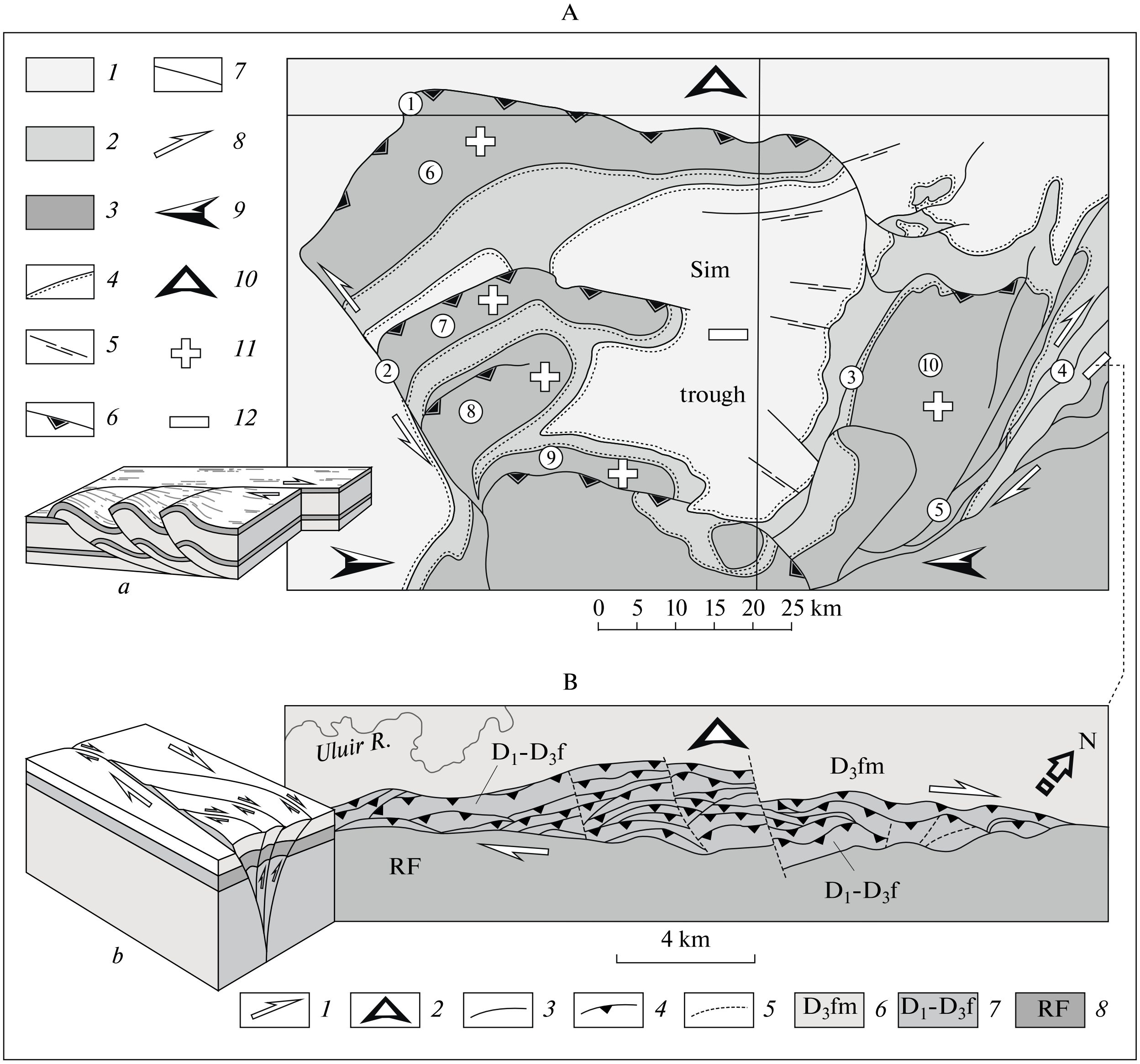

Fig. 3. Structural–kinematic schemes: (A) Karatau–Suleiman block: (*1*) complexes of the Moscovian Stage (Permian); (*2*) Devonian complexes of the Bashkirian Stage; (*3*) Precambrian complexes; (*4*) unconformable boundaries between complexes; (*5*) cleavage; (*6*) thrusts and faults; (*7*) other faults; (*8*) displacement direction along oblique-slip faults; (*9*) direction of general compression; (*10*) displacement direction of the entire Karatau–Suleiman block; (*11*, *12*) the direction of vertical movements of individual blocks (*11*, up, *12*, down), the numbers in the scheme: (1) Karatau thrust; (2) Asha sinistral oblique-sip fault; (3) Katav dextral overthrust fault; (4) Pervomaiskaya zone of dextral transpression; (5) Lakly dextral overthrust fault; (6–10) anticlines: (6) Karatau, (7) Vorob'inye gory, (8) Azhigardak, (9) Vorob'inye gory, (10) Suleiman. (B) Ai section of the Pervomaiskaya transpression zone (based on geological survey data, conducted in 1977 by F.A. Piskunov et al. (with amendments): (*1*) the displacement direction along the general oblique-slip fault, (*2*) the verergencyof the series of thrusts, (*3*) the general oblique-slip fault, (*4*) thrusts of northwestern vergency, (*5*) other faults, (*6*) Famennian limestone of the autochthon, (*7*) Lower Devonian–Frasnian carbonate–terrigenous complexes of the allochthons, (*8*) Riphean complexes. Block diagrams, according to (Twiss and Moores, 2000) with amendments: (*a*) model of formation of "horse tail" structures, (*b*) model of thrust formation in the transpression zone.

0.5 to 4.5 cm and are distributed irregularly in the groundmass.

The studied mesostructural elements allow us to reconstruct the stress paleofields at the time of formation within the framework of the Coulomb-Anderson model (Fig. 5d). A unified structural paragenesis comprises the closing wing of the flexure (1); vertical cleavage (2); the SF-texture, that is, a series of sliding plates of overthrust kinematics (3); shears that cut the cleavage at an angle, small corrugation folds with vertical axial surfaces (4); zones of tectonic breccias (5), which are usually formed as a result of brittle shear deformations, although at smaller angles to the direction of compression. This paragenesis corresponds to

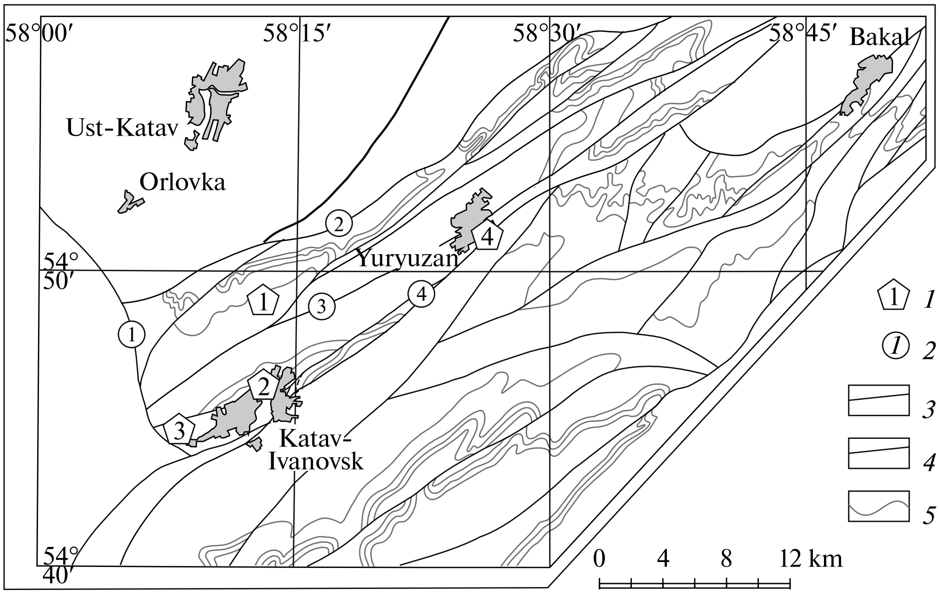

Fig. 4. The location scheme of the reference sites: (*1*) numbers of sites, (*2*) numbers of faults, (*3*) major faults, (*4*) secondary faults, (*5*) mark horizons. The numbers in the diagram are: (1) Quarry, (2) Katav-Ivanovsk, (3) Bashles, (4) Yuryuzan; faults (numbers in circles): (1) Orlovka, (2) Suleya, (3) Yuryuzan, (4) Katav-Ivanovsk.

the NE–SE compression (azimuth 300°) and the NE–SW extension (azimuth 30°). This situation determines the kinematics of the Yuryuzan fault as a steep overthrust.

It is possible that the meridional zones of tectonic breccias are of another structural paragenesis. It is possible that they constitute a unified paragenesis with a coarse latitudinal cleavage (6), which is associated with meridional compression.

The Bashles site is situated in an abandoned quarry northwest of the Bashles village, in the recumbent wing of the Katav-Ivanovsk fault. Rocks of the Katav Formation are also exposed in a quarry. They are predominantly gently dipping and complicated by small slightly oblique flexures (Fig. 5H), whose parallel wings dip to the south (Dip Az. 170–180∠10–15) and the closing ones to the southeast (Dip Az. 165∠55).

Massive limestones in places are broken by a submeridional to northwestern steep cleavage (Fig. 5f) and thin-layered calcareous siltstones are widespread crenulation cleavage. In microlitons of crenulation cleavage, small crest-like and keel-like folds are found. The folds are up to 1.5 cm in amplitude and up to 3–4 cm along the wavelength. As a rule, the crests and keels in the folds are tightened into cleavage zones and the rounded hinges are located in microlitons (Fig. 5e). Microlitons are almost everywhere displaced relative to each other in cleavage zones; the displacement amplitudes are from millimeters up to several centimeters. The crenulation cleavage is predominantly orthogonally laminated, while on the closing wings the flexure sits obliquely. The general position of the cleavage zones is as follows: Dip Az. 135 ∠70 that correspond to the orientation of the Katav-Ivanovsk fault. Within the sites with crenulation cleavage are distinct compression patterns: small wedge-shaped blocks sandwiched between microlitons are squeezed upward.

In some sites the zones comprise thin bands of bleached rocks (up to 3–4 cm), either extended as beds or lenticular. At times, these zones of bleaching are cut by short transverse lenticular calcite veins (Fig. 5i) 3–6 cm long and up to 0.5 cm thick (Dip Az. 325∠90) developed along the ruptures (Fig. 5i, an inset). During the development of such fractures, boudinage structures can be developed under compression conditions across a layer and extension conditions along one. Slip planes are rare within the Bashles site.

The only distinct SE-dipping slip plane was discovered at the bottom of a quarry; the orientation of the slip plane and the striation coincide (Dip Az. 140∠30). Based on rare small scarps, it became possible to establish the thrust kinematics of the fault with which the slip plane is associated. In some places thinly laminated siltstones are locally deformed that is resulted in the formation of mesostructural kink-bands (Fig. 5g). The layers in the kink-band are steeply dipping to the northwest (Dip Az. 330∠65–85), while the kink-band is steeply dipping to the southeast (Dip Az. 150∠65–70). Such structures are usually interpreted as a compression pattern directed at an acute angle to the layering (an inset in Fig. 5g).

The set of the studied mesostructures allows us to distinguish two parageneses and reconstruct the position of the paleostress axes within the framework of the Coulomb–Anderson model (Fig. 5j). The first paragenesis of

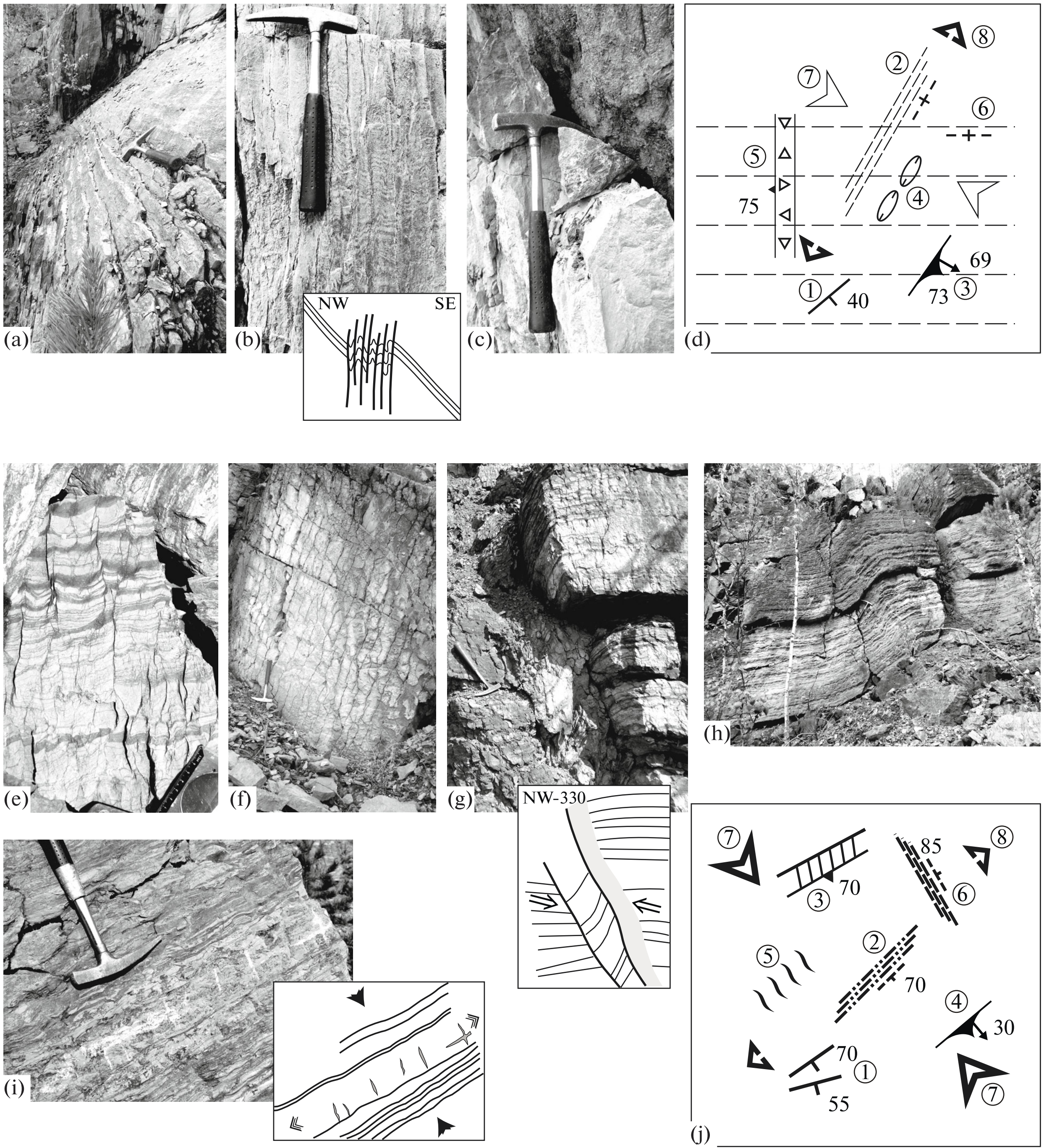

Fig. 5. The mesostructures and structural schemes of the reference sites Quarry (a–d) and Bashles (e–j). See explanation in the text.

compression (7) to extension (8) includes small flexures with steep joining wings (1), thin crenulation cleavage (2), close kink-band (3), the thrust slip planes (4), a series of ruptures (5). The structural elements listed enter the compression paragenesis, the main axis of which is gently dipping to the southeast; the extension axis is horizontally oriented to the northeast. This situation determines the kinematics of the Katav–Ivanovsk fault as a steep overthrust.

The second paragenesis is represented only by a steep coarse cleavage of the northwest strike (6). Most likely, it is connected with the western boundary of the Orlov fault, which bounds the Yuryuzan syncline from the west.

The Katav-Ivanovsk site is located within the Katav-Ivanovsk town area to the north of the water pond, in the underside of the fault, bounded the Katav–Ivanovsk fault from the north. Here, a vertical wall is opened in a quarry: a section of a large (in the whole wall), slightly inclined latitudinal anticline with a rounded lock (Fig. 6c). The southern wing is gently dipping in general (Dip Az. 175∠20–35), becoming steeper at the bottom (up to 50°–55°). The northern wing is also gently dipping (Dip Az. 350∠20), but further to the north there is a small flexure. The joining wing is more gently dipping (∠10°), but to the north layers have a steeper dip: at an angle of 60°–65°, and near the hinge of the adjacent syncline of up to 90°.

Further to the north is the southern wing of a similar fold. This means that, in general, the folds are keel-like. The hinge of the fold is very gently dipping to the east (Dip. Az 90 ∠7–10).

The anticline is composed of brownish-red to red limestones and calcareous siltstones with undulating thin layering of the Upper Riphean Katavian formation. This is most clearly visible on the weathered surface due to the different strengths of rocks. It is underlain by thin microlayers of a darker reddish-brown substance. The thickness of such micro-layers varies from fractions of a millimeter to 2–3 mm. They are irregular in thickness and can periodically branch out and converge again.

Within the outcrop one can observe crenulation cleavage (170 Dip Az∠75), similar to that described in the Bashles site (Fig. 6a). It roughly corresponds to the position of the axial surface of the fold, which has a weak northern vergency. In massive rocks, a thin cleavage that overlies the layering at a steep angle is also manifested. This cleavage also cuts the small sublayered slip planes formed during the formation of a fold due to interlayer slip. Rare S-shaped veins of pink calcite, in places slightly ptygmatitic, which are of the same origin also occur (Fig. 6d; an inset).

Along with the evident compression structures within the exposure zone are left-handed lenticular calcite veins developed along detachment cracks, which are constrained by extended thin veins that correspond to the general shears. They record the dextral strike-slip fault (Fig. 6b; an inset).

The set of the studied mesostructures makes it possible to distinguish the structural assemblage and to reconstruct the position of the paleostress axes (Fig. 6f). The first (main) structural paragenesis of submeridional compression (6 in Fig. 6): the sublatitudinal extension (7) includes the inclined folds of the northern vergency (1, 2), layered sliding planes (3), crenulation cleavage (4), calcite S-veins. The second structural paragenesis (the sublatitudinal dextral strike-slip fault) includes the bands of lens-shaped left-to-right calcite veins or the Riedel T-structures (5), bounded by parallel veins (according to Riedel Y-cleavages). A similar situation determines the kinematics of the fault, which feathers the Katav–Ivanovsk as a dextral overthrust fault.

The Yuruzan site is located at the bridge across the Yuryuzan River in the Yuryuzan town area, directly in the *Katav–Ivanovsk fault zone*. The section the Upper Riphean Avzyan Formation of argillaceous and carbonaceous–argillaceous shales with the boudinaged interbeds of black dolomites was opened by a road cut. The layers form a flat submeridional anticline: the western wing (Dip Az. 285° ∠30) and the eastern wing is gently dipping, while the direction and dip angle are irregular. In general, rocks dip in the eastern direction (Dip Az. from 40° to 120°). In some places, rocks are folded into small size folds with an amplitude of up to 15 cm and a wavelength of 20–40 cm. The folds are practically symmetrical. At times, shales contain fragments of dolomites several centimeters in diameter.

The slip planes have a running surface. They are predominantly gently dipping (Dip Az. 125∠45 for the slip plane, Dip Az. 115°∠42 for hatching), but sometimes steeply in the same direction (Dip Az. 120°∠70 for the slip plane + hatching) and characterized by fault kinematics with a small shear component (Fig. 6f).

Competent layers of dolomites are almost universally boudinaged within the outcrop. As usual, boudins have an irregularly rounded shape (Fig. 6g), sometimes the layer is gradually narrowing and disintegrates into several angular pieces. Some boudins are entirely made up of large stromatolite structures. Flattened boudins often include a series of transverse calcite veins, either lenticular or thin parallel, sometimes flexuous (Fig. 6l). The ruptures in boudins have a latitudinal strike and a steep dip (Dip Az. 90∠90).

Some horizons of shales are transformed into tectonites with a clearly manifested lenticular-banded structure, close to SF-tectonites (Fig. 6i). In benches of the more competent layers, a coarse cleavage, dipping to the southwest (Dip Az. 235∠60) is distinctly manifested. The microlitons vary in thickness from 3 to 15 cm. Clay shales are cut by a series of vertical uneven cracks, which are accompanied by corrugation resembling a wavy cleavage. The fractures, as well as the axial surfaces of folds, extend in the meridional direction; the hinges are horizontal or slightly inclined to the north. The amplitude of the folds is 0.5–1.5 cm, while the thickness of microlitons is 0.7–4.0 cm.

In places, shales are corrugated, forming Z-shaped structures (drag folds) oriented along the dip of beds (Fig. 6k). Such structures can be treated as slipping folds; however, in this case they are most likely still related to drag folds.

In the northeastern part of the block of chaotically dislocated rocks, a series of mesostructures, which indicate a gently dipping fault zone (Fig. 6j), was discovered. This block is underlain by intensely schistose dolomites (4 in the inset, Fig. 6j), which are cut by an inclined fault (5). Numerous ptygmatitic veins of pink calcite occur in shales (6). The chaotic horizon is composed of blocks of massive dolomites (probably boudins of broken strata (1)), blocks of thinly layered dolomites turned across the horizon (2) immersed in

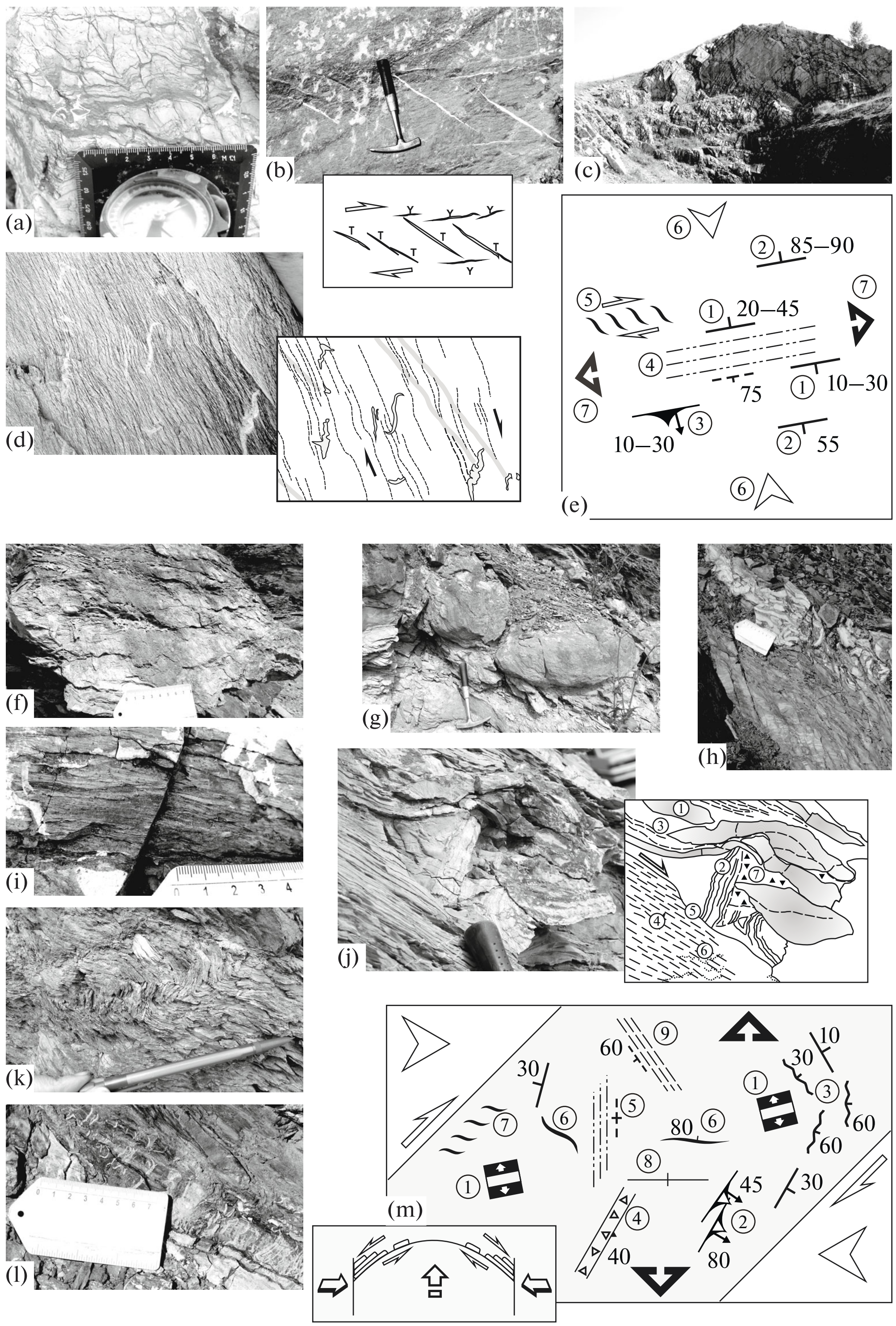

Fig. 6. The mesostructures and structural schemes of the reference sites of Katav-Ivanovsk (a–e) and Bashles (f–m). See explanation in the text.

an intensively fractured matrix (3), transformed in places into a tectonic breccia (7).

Tectonic breccias often fill the pressure shadows around boudins. In addition, a lenticular body of tectonic breccias 12 cm in thickness (Dip Az. 120∠40) covers the zone of steep low-amplitude faults, steeply falling to the southeast (Dip Az. 110∠55–60). The thickness of wedge-shaped microlitons is 0.5–3.0 cm (Fig. 6h).

The set of studied mesostructures allows us to distinguish two parageneses and reconstruct the position of the paleostress axes (Fig. 6m). The direction of compression is determined by the orientation of the schistocity and SF-tectonites, faults, axial surfaces of ptygmatitic veins, the direction of the pulling apart of boudins, and the surfaces of the thrust-type slip planes. The direction of compression is determined by arrangements of boudins, the orientation of the cleavage and the axial surfaces of folds. The rather complicated pattern obtained can not be interpreted within the framework of the Coulomb-Anderson model. In fact, the object is located within the Katav-Ivanovsk fault zone, which is a narrow zone of dextral transpression.

The general paragenesis of the dextral transpression includes *extension structures* (Riedel's T-structures): ruptures (8 in Fig. 6m), steep sublatitudinal calcite and siderite–calcite veins (6), including left-handed veins (7); the boudinage structures (1); Z-structure; chaotic horizons of gently sloping faults (2); *compression structures* (S-structure), which are meridional wavy cleavage (5); *cleavage structure*s (Y, R and P synthetic cleavages by Riedel), schistosity and SF-tectonites (3), and tectonic breccias (4). A coarse cleavage of the northwest strike (9) was developed substantially later or locally manifested in the overall structure of the anticline. Since this fold was formed as a result of punching-out in the transpression zone, the slip planes on the fold wings are of the fault-type. This assumption, at first glance, appears to be poorly grounded under conditions of compression (an inset in Fig. 6m).

Thus, it has been established that in the general setting of dextral transpression, shear strains were concentrated directly within narrow zones of large overthrust faults (Suleya, Yuryuzan, and Katav-Ivanovsk), and compression–extension deformations are manifested almost predominantly in the wings of these discontinuities (in separating blocks).

CONCLUSIONS

The regularities that were revealed make it possible, in general, to estimate the kinematics of the formation of the Sim trough and the large fault zones in its frame (Fig. 3A). The Sim trough is a gentle depression formed on a large structurally complex Karatau–Suleiman uplift. The mechanism of its formation is as follows. Under the conditions of the Ural sublatitudinal compression, the entire Karatau–Suleiman block was squeezed due to the wedge-shaped morphology not only upward, but laterally: to the north along the adjacent oblique-slip fault zones. It is probable that the Pervomaiskaya zone of the dextral transpression, parallel to the Katav–Yuryuzan dextral strike-slip fault zone, formed under conditions of simple shear dominated. The Asha sinistral strike-slip fault, in fact, is a cleavage, formed under conditions of simple shear and complicated by positive horsetail structures.

At this, the distribution of stress fields within the Karatau–Suleiman block is different. The northward displacement of the block determined the local setting of meridional compression, which was realized in the formation of large sublatitudinal anticlines in the western frame of the depression, and later, elements of latitudinal cleavage within the trough itself. In general, the Suleiman anticline follows the strike of the Bashkir meganticlinorium, but when it is displaced northward away from the positive structures of the Asha strike-slip fault. Due to this, the extension within the block was in the sublatitudinal direction. As a consequence, in the central part of the Karatau–Suleiman block, the latitudinal extension was compensated by gradual subsidence, which led to the formation of the Sim trough.

The peculiarities of the distribution of stress fields within the Katav–Yuryuzan overthrust fault zone are of special interest. Within the zone of a specific discontinuity, tangential stresses are highly prominent, which are identified based on the structural parageneses characteristic of the transpression zones. At a distance from the faults in both wings tangential stresses are not manifested. The existing structural parageneses are associated only with normal stresses. As usual, near the fault zones, normal stresses also predominate. However, locally pronounced tangent stresses are also noted.

REFERENCES

Kamaletdinov, M.A., *Pokrovnye struktury Urala* (Nappe Structures of the Urals), Moscow: Nauka, 1974.

Kazantsev, Yu.V., *Strukturnaya geologiya Predural'skogo progiba* (Structural Geology of the Uralian Foredeep), Moscow: Nauka, 1984.

Kisin, A.Yu., Structural position of the Karatau tectonic block, *Litosfera*, 2008, no. 4, pp. 35–47.

Mizens, G.A., The formation stages of the Uralian Foredeep, *Geotektonika*, 1997, no. 5, pp. 33–46.

Puchkov, V.N., *Geologiya Urala i Priural'ya (aktual'nye voprosy stratigrafii, tektoniki, geodinamiki i metallogenii)* (Geology of the Urals and Uralian Region (Actual Problems of Stratigraphy, Tectonics, Geodynamics, and Metallogeny)), Ufa: DizainPoligrafServis, 2010.

Shatskii, N.S., *Ocherki tektoniki Volgo-Ural'skoi neftenosnoi oblasti i ikh klassifikatsiya. Izbrannye trudy* (Essays on Tectonics of the Volga–Urals Oil-Bearing Region and Its Classification. Selective Works), Moscow: Nauka, 1964, vol. 2.

Tetyaev, M.M., *Geotektonika SSSR* (Geotectonics of the USSR), Moscow–Leningrad: GONTI, 1938.

Twiss, R.J. and Moores, E.M., *Structural Geology. 6th ed.*, New York: W.H. Freeman and Company, 2000.

Translated by D. Voroschuk