Tverdokhlebov, V. P. 1971. On Early Triassic proluvial deposits of the Pre-Urals, and times of folding and mountain-building processes in the Southern Urals. Izvestiya Akademii Nauk S.S.S.R., Seriya Geologiskaya, 1971 (4), 42-50.

Coarse-grained deposits, referred before in the Orenburg Pre-Urals to the Giryal Svita[1], and in Bashkiria to the Nakaz Svita, are distributed only in the eastern zone of the Pre-Uralian Depression, where they form an almost continuous strip from the Giryal Mountains in the south to the Nakaz Mountains in the north.

The development of these deposits is interpreted differently by different researchers. P. E. Offman referred them to the Nakaz Svita of the Late Permian, which N. M. Kochetkova (1964) referred to lower parts of the Tatarian. G. V. Vakhrushev (1945) included these deposits, however, in the Zirgansk Svita, assigned, in his opinion, to the Lower Triassic. A. V. Khabakov (Khabakov et al., 1933) rightly assigned the sandstone-conglomerate deposits of the Nakaz Mountains, Tyulgan, and Kozii Mountains to the Giryal Svita, allocating them on the right bend of the River Ural to the southern end of the Giryal Mountains. However, the age of these formations was wrongly interpreted by him as Ufimian. P. I. Klimov (1936), and then B. N. Krasilnikov (1953), also tentatively correlated the Giryal and Nakaz Svitas with the Buzuluk Svita of the Orenburg Pre-Urals, and this was later also accepted by the majority of investigators. However, even the assignment of these same formations to the Triassic remained unproved.

Analysis of facies and cyclicities, and also new finds of organic remains, allowed the author to begin confidently to assign these deposits to the middle and upper sub-svitas of the Blyumental Svita (Tverdokhlebov, 1967) (the Blyumental Svita belongs to the Vetluga Series in its whole thickness).

Studies of faunal composition show that deposits of middle and upper Blyumental sub-svitas in the eastern zone of the Depression present the main forms of proluvium[2]. The wide development of proluvial formations at that time was linked to sharp reinforcements of uplift by folding in the Urals and, as a consequence, increasing outflow of coarse-grained material on to the Pre-Ural Depression. The intensity of the drop of this Depression usually readily assisted 'remains' from the geological records of proluvial facies which used to lie above the base of erosion.

To proluvium we refer the deposits included in the vast and abundant alluvial fans which are situated along all eastern zones of the Pre-Ural Depression. The main units are boulder-pebble conglomerates, sandstones and types of complexes of granulometric composition,

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[1] [Translator's note] The Russian term Svita is not translated, since there is no direct equivalent in Western terminology. 'Svita' is often interpreted as equivalent to 'Formation', but that is an over-simplification. Russian geologists use the term 'Svita' in a local sense, and a geographic term is usually used, but there is less formality in application than for formations and members. It is not always clear whether a Svita is defined lithostratigraphically or biostratigraphically, or perhaps both. Type sections need not be defined, the Svita need not represent a particular mappable packet of rocks, and boundaries may be defined locally by the appearance, or disappearance, of particular fossils. Hence, 'Svita' may lie somewhere between 'Formation' and 'Zone'.

[2] [Translator's note] Proluvium is a term widely used by Russian sedimentologists to mean material washed down from the mountains by seasonal streams.

representing a sandstone-siltstone-mudstone mixture with variable proportions of the different components. The structure of these 'superficial deltas',

with a thickness similar to classic alluvial fans, was described by V. I. Eliseev (1963, 1964) and E. V. Shantser (1966) in Upper Pleistocene deposits of the Fergana and Alakulsky Depressions.

In these are clearly distinguished all members of these single facial parageneses, divided into two groups of facies - inner or proximal, and outer or distal. In the proximal group are stream facies of strong and weak currents and covering facies. The distal group includes fan facies and facies of standing water.

1. Boulder and boulder-pebble conglomerates, unbedded or non-horizontally bedded - deposits of strong currents of sediment-laden streams in alluvial fans.

Conglomerates of similar type form fan deposit bodies, they amalgamate at their own bases; at the summit they are partially eroded in subsequent epochs. The sizes and petrographic compositions of clasts in different alluvial fans are different. The coarsest fans, Giryal and Nakaz, are found in the far south and in the north of the studied territory.

At the edge of the Giryal alluvial fan, the maximum size of boulders (up to 0.5 m), and the greatest abundance of boulders, are seen in the proximal part of the dense fan near the village of Verkhne-Ozernii. In fractured boulders, metamoprhic fragments predominate (48%), then follow limestones (36%), volcanic (10%) and terrigenous (4%) fragments, and vein quartz (2%).

Among metamorphic clast types, the key role is taken by quartzite, differentiated into micaceous and graphitic varieties, and quartzite with volcanic, detrital terrigenous, and carbonate components. Apart from these, among metamorphic clasts are seen quartz-sericite, quartz-chloritoid, and different crystalline schists, migmatites, mylonite granites, cataclasites, porphyroids, and porphyrites. All this complex of clasts in the basal deposits have wide distribution in the Central Urals [their presumed source area].

Among carbonate clasts in the boulder fraction are encountered organic-clastic limestones, as well as organic differences in pelitomorph and cryptocrystalline structures, and coarse-crystalline marble-like limestones and marbles, but two final differences stand out. In limestones and marbles, abundant faunal remains are encountered. Their age is different, from Devonian to Lower Permian.

Among igneous clast types may be distinguished: gabbros, gabbro-diabases, diabases, amygdaloidal diabases, sillites, variolites, albitophyres, andesites, andesite porphyrites, quartz porphyries, felsites, tuffs of alkaline type and vent type of small intrusions. As the clasts become smaller, and as their size and petrographic composition become more uniform, the concentration of the components most stable to degeneration increases.

By comparison of the actual composition of conglomerates of the Giryal alluvial fan with rocks which made the western side of the Urals, and its central part, it becomes obvious that the 'maternal' components were volcanic, metamorphic, and sedimentary materials, with

sources from the Central Urals and, only in part, the western zone. This is entirely supported by the presence in boulder-pebble materials of a large proportion of marble-like limestones and marbles of Carboniferous and Devonian age. As for limestones, the types of components in western zones of the Urals contain exceedingly weak traces of metamorphism, and marbles are not encountered.

To the north of the Giryal alluvial fan is observed a rapid reduction, and then the disappearance, of clasts of volcanic composition and marbles, and a reduction in the

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proportion of pebbles. Still further to the north, in the region of the village of Dubovskii, boulders again make their appearance. Their composition is similar to Precambrian formations of the western limits of the Central Urals.

Further to the north is a coarse alluvial fan situated near the village of Novochebenkov (the region between the rivers Yamana and Tashla). In basic sections here, boulder-coarse pebble conglomerates diminish, and their petrographic composition, in certain

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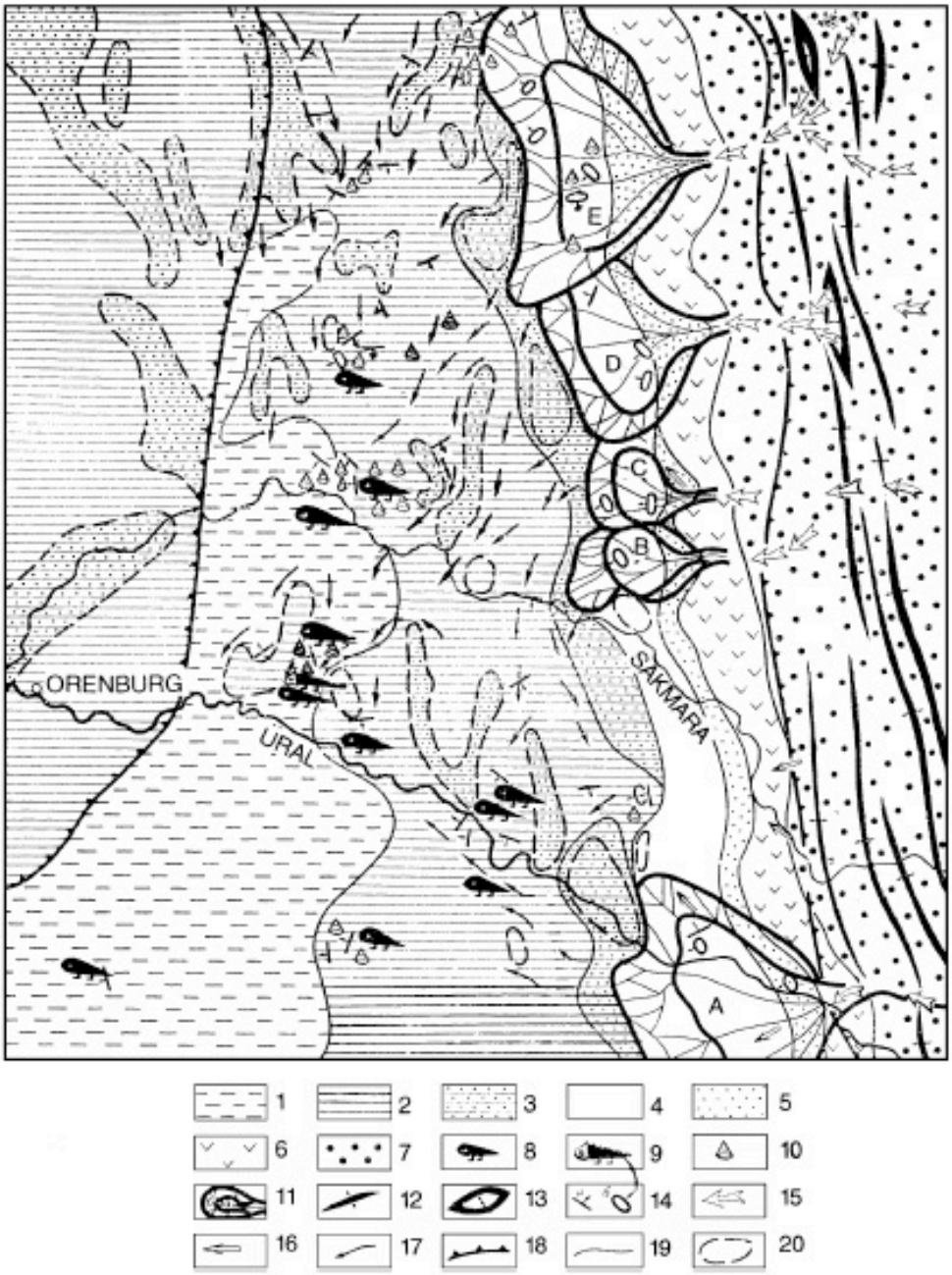
ratios, descends to the composition of pebbles in the Dubovskii alluvial fan. Here, clasts of metamorphic composition are also present in large quantities, similar to Precambrian formations of the Central Urals, but Devonian and Carboniferous limestones predominate in southern zones of the Urals; but the coarsest boulders and pebbles occur in them.

Further to the north, along the Tyulgan and Nakaz mountain chains, a number of alluvial fans may be traced by outwashed formations. The coarsest of these, in the whole area under study, are exhibited by the Nakaz alluvial fan. In its main part, thick layers (up to 100 m) of boulder-pebble conglomerates are deposited, but the lower two-thirds of the layer are composed of boulders whose size reaches 0.5-0.7 m. From bottom to top of the section, the size of the clasts reduces; upper parts of conglomerate beds already show medium pebble materials with abundant small pebbles, gravels with rare large pebbles and small boulders.

Such clear general sorting in 100 m-thick beds of conglomerate gives essential evidence that these are deposits produced by strong stream flows.

Boulder materials of the basal bed of the Nakaz alluvial fan are composed of up to 90% metamorphic clasts, similar in composition to boulders in the Giryal fan, with typically 8% of volcanic clasts, and 2% of marble-like limestones. In the coarse pebble fraction, the proportion of volcanic clasts reaches 16%, and limestones reach 32%.

Very characteristic of coarse pebble-boulder conglomerates, in all the main enumerated alluvial fans, are cemented masses of extraordinary clay content. Except for these, they contain an important admixture of sandstone-siltstone material. As a rule, basal beds of conglomerate, and occasionally those higher up, are distinguished more by weak cementation, than are conglomerate beds with dense sandstone-carbonate cements in higher parts of the section. Many studies of these crumbly congolomerates interpret them as reworked (diluvial) formations. We link these, by their appearance, to deposits of turbidity currents.



[Figure] Palaeogeomorphological map of the Orenburg and Bashkir Pre-Urals. Middle Blyumental (Middle Induan) time. 1, sediments of lacustrine-alluvial plains; 2, sediments of alluvial plains; 3, sediments of alluvial plains, periodically exposed to denudation; 4, sediments of proluvial plains; 5, low folded hills; 6, medium folded hills; 7, high folded hills; 8, amphibians; 9, reptiles; 10, phyllopods; 11, alluvial fans (a, proximal part; b, distal part); 12, sediments of coarse anticlinal folds and related ridge sediments; 13, coarse synclinal structures and related mountain-edge depressions; 14, directions of flow (a, based on dominant slopes of cross beds; b, based on orientations of oblique pebbles); 15, main orientation of clastic material; 16, secondary orientation of erosion; 17, conjectured orientations of river flow; 18, boundaries of the Pre-Ural Depression; 19, boundaries of palaeogeomorphological zones; 20, boundaries of areas of uplifted blocks. Symbols on the map indicate the alluvial fans: A, Giryal; b, Novokulchumov; B, Dubovskii; G, Novochebenkov; D, Nakaz.

Bedding in stream conglomerates is either completely undifferentiated, or weakly expressed and close to horizontal. In its origin, the great muddiness of streams is necessarily close to a turbidity current. The deposits, according to L. N. Botvinkina (1965), are characteristic only of the continental slope, i.e., indicate conditions of great marine depths. It seems to us that there is a single mechanism of sedimentation in sediment-laden flows which is very similar to typical turbidity currents. "Specific turbidity currents are composed of very great amounts of suspended sediment. Therefore, such currents might have great density and become intermixed by the law of the viscosity of liquids. This creates conditions in which exceedingly coarse particles may be carried in suspension, and these begin to fall out as the speed of the current reduces, sorted by size and weight" (L. N. Botvinkina, 1965, p. 185). Also further: "Characteristic features of deposits of turbidity currents are horizontal bedding together with a significant amount of coarse-grained sediment (particularly in the lower parts of beds)... A second characteristic feature of these is graded bedding of sedimentary material in each bed, from coarser below to finer above" (loc. cit.).

Higher in the sections of fans, alternating sandstone and sandstone-mudstone-siltstone deposits of covering facies and stream conglomerates are encountered. The proportion of boulder-pebble conglomerate clearly reduces higher in sections, but it is noticeable that the proportion of clay clasts to cement reduces, which testifies to a reduction in

muddiness and in the active force of the stream, and which relates to its transport ability. V. I. Eliseev (1964, p. 136) explained the similar appearance of Upper Pleistocene deposits of the Alkulsk and Fergana depressions in the following manner: "Analysis of possible changes in muddiness of streams through time may indicate the following explanation. Deposits of lower portions of conglomerate alluvial fans require the the action of glacial water through time from mature glaciers in the Djungarsk Alatay. However, upper portions probably formed at a time when the area affected by freezing conditions noticeably reduced, which led to a reduction in the muddiness of streams." The possibility of links between the Lower Triassic molasse formations of the Pre-Urals and glaciers will be discussed below.

General rules in the construction of alluvial fans - such as decreasing proportions of clastic material in each succeeding higher bed of conglomerate, increase in the degree of sorting, and decrease in the content of mudstone-siltstone material in the matrix - are often enough broken in sections of beds or lenses of conglomerates. They are characterised by either (1) some increase in clasts and significant increase in the mudstone-siltstone admixture in the cement, or (2) sharp increase in sections of boulders and pebbles, and increase in "washed out" cemented masses, indicated by the absence of genetic links to renewed muddiness of streams.

The first fact attests to the protracted existence of alluvial fans and to multiple repetitions of re-supply by mudflows. The place of operation of these streams, notwithstanding their multiple recharging, remains very constant, which is defined by the geological position in the development of alluvial fans at the border among uplifted mountain building and regions of depression adjacent to them. Secondly, coarse pebble-boulder conglomerates with sand-gravel-carbonate cement, without admixture of siltstone-mudstone material, are deposited usually in the upper parts of vertical sections of alluvial fans. In its slope, at some distance from the top, which cuts through lenses, they form small stream conglomerates, cover sandstones, and mudstone-siltstone deposits. Notwithstanding enough significant thickness (seen to 4.5 m), the extent of such lenses is not greater. It is very probable that these

formations represent river deposits, and had the same sources of supply as those mudflows; but formed at periods of subdued snow melting. Similar pebbles were described by V. I. Eliseev (1964, p. 137) in the Alakulsk depression; they are "...well washed, more rounded, and coarser than lower-lying ones. They correspond to the final phase in the formation of alluvial fans, when streams almost no longer deposited material freshly arrived from the mountains, but mainly reworked pebbles from earlier deposits... As proof of this are clearly expressed raised terraces, developed in proximal parts of alluvial fans." Hence, one begins to understand the appearance of small extended lens shapes (trough forms) of coarse-pebble and boulder conglomerates, facies which are different from more fine-grained proluvial deposits of upper parts of sections of alluvial fans. Similar features are observed in the range of the Nakaz alluvial fan on the upstream River Tugustemir, on the River Kupla, and on the stream Klyuch, near the village Tashla.

2. Sandstones of variable grain size, with strongly marked cross-bedding - deposits of weak streams of alluvial fans.

Sandstones of this type have textural signs of river-bed alluvium, very similar to normal, but they are distinguished by especially weak sorting. Only the coarsest clastic material - coarse gravel and pebbles - gives novel concentrations in bedded units and separate cross-bedded series. Cross bedding of the sandstones is characterised by

great changes in the range of thickness, in the angles with which they cut each other, and in the angles of slope of cross bedding within units. Also, beds of similar sandstones show extremely variable thicknesses, frequently giving a lens-like construction.

All of these features indicate deposits of sandstone produced in shallow streams that were poured out on the surface of alluvial fans, and that were broken into separate currents with markedly different forces and directions of flow.

3. Fine-grained mudstones and sandstone-siltstone-mudstone mixtures - cover deposits of alluvial fans.

These formations are distributed in a restricted manner. In proximal parts of the fan, they are encountered extremely rarely - they are well known in upper parts of the Klyuch stream and the River Kupla; somewhat more completely developed deposits of the peripheral facies group occur at the village Tugustemir. V. I. Eliseev (1963) characterised similar formations as the deposits of pools in deepening channels of streams after the waters had abated.

The existence of similar pools was possible only in periods without active sediment-laden streams, but these intervals were rather prolonged, which is indicated by finds in such deposits of conchostracans which had successfully colonised the pools. Thicknesses of sandstone-siltstone-mudstone deposits are usually not great - from 0.3 to 2 m. Burrows in such ephemeral deposits give clear evidence of the constructive nature of sedimentation in the period of active life of the alluvial fan. To a great extent, this is a result of the colossal overloading of streams, which drop most of their material in the distal part of the alluvial fan, and this is why such a deposit is not capable of eroding a bed.

4. Clays, loams and sandy loams with interbeds of dolomite - deposits of stagnant-water facies of alluvial fans.

Deposits of this type develop weakly in peripheral areas. They are observed only in the Nakaz alluvial fan, deposited on the left-hand side of the River Yaman-Yushatyr.

Here, among sandstones and conglomerates, are observed beds (thickness up to 2.5 m) of strongly muddy and sandy siltstones and silty mudstones. Bedding is frequently undifferentiated, and in places the so-called usual spotted texture is apparently the result of a disproportionate amount of turbid (possibly also organic) substances. In separate interbeds, soil textures are observed - a type of unbedded crumpling, with traces of mixing and creep, with abundant remains of roots of plants and feeding burrows, with dispersed carbonate concretions. Among the silty mudstones interbedded dolomites are encountered. Deposits of stagnant-water facies of the Nakaz alluvial fan are similar in principal features, however, to the deposits of such facies in the Fergana depression.

The protracted and variable intensities of mountain-building processes in the Urals, and the associated long duration of the alluvial fans, caused the very complex structure of the latter, and features which are greatly different from classic alluvial fans, as described in the geological literature on the basis of younger deposits.

For the majority of Early Triassic alluvial fans of the Pre-Urals, the pattern of interplay of times and extents of streams and fan facies, and their abundance with respect to each other, significantly hinders their division.

Despite this, so-called classic alluvial fans are characteristic typically of arid regions, but the studied territories in the Early Triassic were not entirely dried up, and they

possessed only a few characters of aridity.

If in arid regions streams or rivers, forming alluvial fans, dry up in a relatively short distance from the pre-mountains, then here they are continued considerably further - a change to proluvial deposits of alluvial plains is observed in the peripheral fan - by narrowly confined streams both of fan facies of alluvial fans and of channel alluvial deposits. It is not practical to study clear erosion of them in the tributary stage. And the deposits of alluvial fans themselves that are conserved in the annals of geology, seem themselves to be only fragments, having been spared from subsequent reworking thanks to the intensively lowered Pre-Ural depression and significant for continuation also the amplitude of the uplift of the Urals - the principal source of clasts and water volume.

Palaeogeographic conditions in the areas under study during Vetlugian (or Blyumental) time are presented next.

At the end of the Tatarian stage, depression of the Pre-Ural zone in the regions of the Orenburg and Bashkir Pre-Urals produced enormous low-lying plains, on which large intracontinental basins developed. In early Blyumental times, tectonic activity in the Urals caused by huge rising territories, which generated a general reduction in basic erosion, drainage of intracontinental basins, and intensive development of erosional processes. At

these times, the foundations of ramified fluvial networks were produced by changes in the alluvial regime of the basin. But in large parts of the territory, bottom-erosive phases predominated, and accumulation took place only in central parts of the Pre-Ural depression.

Middle Blyumental time was characterised by a dramatic enlargement of the area of sedimentation, extending to the boundaries of the Pre-Ural depression, and enveloping a vast expanse of the south-eastern European parts of the USSR.

Clastic material was received essentially from the Urals, which represented at this time a high-mountain chain.

The location of deposits of the high mountains are also at times entirely confidently restored to their contemporary situation by a coarse anticlinal fold on the western slope of the Urals, in such a way that subsequent tectonic movements did not change it in essential features.

Axial parts of the high mountains of Middle Blyumental times completely coincided with anticlinal folding. In a similar coincidence, V. E. Khain (1954, p. 53) pointed out: "In regions of young and intensive enough upheavals, folding movements in part successfully overcome the action of denudation and accumulation; these movements are expressed to a significant extent in the relief - uplifts correspond to elevations or even mountains, and depressions to valleys". S. S. Schultz (1948) also notes a similar regularity by analysis of the neotectonics of Tyan-Shanya. In eastern parts of the region under study, in Middle Blyumental times, a mountain chain formed, composed from at least two principal branches, divided by intermontane depressions.

The immense thickness (up to 100 m) of the basal strata of boulder conglomerates with rhythmic sorting, deposits from streams, close to turbidity currents, attest that every one of these deposits (as indicated above) was an avalanche from an alluvial fan. For the feasibility of such grandiose 'mature' avalanches, an indispensible preliminary was the accumulation of a colossal amount of sediment-laden water and boulder material in intermontane valleys - immense natural collections. The overflowing of such natural

reservoirs calls for a break-through of western branches of the mountain chain - an original natural dam - and the overthrow from the Urals to the plain of the water-sediment mass, of coarse clastic type, the deposits of thick alluvial fans. Deposits of alluvial fans of narrow composition, proluvial plain accumulations stretched in the mentioned directions, situated to the west of the mountain chains.

It is very important to resolve the question about the sources of the clastic materials, their means of transport, and about the nature of streams with suspended sediment.

The composition of boulders and coarse pebbles indicates also that they came mostly from regions lying far from the boundaries of the western slope of the Urals. This is confirmed also by the presence of clasts of marble with Devonian and Carboniferous faunas (in the western slope of the Urals, types of this composition are not metamorphosed) and complex volcanics (spilites, variolites, amygdaloidal diabases, etc.), not characteristic of the western slope of the Urals.

The presence of coarse boulders (up to 0.7 m) of easily destroyed types (mainly marble), whose origins show that they were transported enormously long distances, shows that they were not carried for most of their journey in fluid streams. In our opinion, this appearance may only be explained by the assumption that, for a large part of the distance, these clasts were transported by glaciers. This is indicated by the great muddiness of Middle Blyumental rivers, fed by glacial waters, and the egg-like shape of the boulders.

Glaciers probably existed in the Early Triassic, as pointed out by A. N. Mazarovich not long ago; however, he concluded this only from general geological processes, and did not base his idea on the composition of deposits or on texture analysis. Even more, the Giryal facies deposits, studies of which permit decipherment of the physico-geological conditions of the Urals, were viewed by him as consisting of the Upper Permian, and Lower Triassic deposits of this region were considered to have been destroyed.

It seems to us that at the beginning of Middle Blyumental times, there are indications that central parts of the Urals attained such heights that the whole area was covered by glaciers, notwithstanding the hot climate of this latitude, dominant in the bordering plains.

Frozen conditions extended, in all probability, not only over the central Urals, but partly also to their western slopes. Glaciers of multiple tongues descended from the central Urals to the side of the western slopes. At the boundaries of the territories under study they surmounted only eastwards, most of all the tall mountain chains. Primary unloading of glaciers descended in intermontane valleys, divided eastern and western mountain chains. Here, colossal volumes of the water-sediment mixture and clastic material gathered, carried away by glaciers from the region of erosion in the central Urals, and it is possible, also the eastern slopes; formations provided the main material for 'avalanche discards'. Later, during periods of maximum melting of the glaciers, along the opened-up routes, overflow suspension streams descended to the boundaries of the proluvial accumulation plains.

Analysis of the facies composition of the rocks, and their variation during the course of the Triassic period, showed that for the extent of the whole Early Triassic epoch, folding and mountain-building processes developed in the southern Urals uninterrupted, but in varying intensity ('horse-race-like'). This is clearly reflected in the rhythmicity of sedimentary processes on the boundaries of the Pre-Ural depression. Beginning in Early Blyumental times, these processes then developed maximally in Middle Blyumental time, when the major tectonic events probably took place. As is well known, many studies of these processes are linked to the Middle Triassic epoch. The protracted and universal Middle Triassic interval was presented as the sole

evidence for this. At the present time, there is proof of widespread Middle Triassic deposits in the Pre-Urals (Ochev et al. 1964; Tverdokhlebov 1967) and their mechanism of accumulation in tranquil tectonic conditions.

It is established that almost simultaneously to the folding processes, in all probability, under the influence of these processes, intensive elevation of the ground into domes began in the Pre-Ural Depression. Clearly, there are close links between the forms of alluvial fans and such structures (the circumstance of which is exactly determined in the contemporary situation of diapirs and changes of facies compositions of Early Triassic deposits). It looks as

if proluvial deposits of the Nakaz alluvial fan flow from north to south, round the raised district (Yaman-Yushatyr diapir); in the Matveev uplift there was restricted sliding to the south of the Novo-Cherbenka alluvial fan; the Novokulchumov diapir caused strong stretching from east to west of the Tuyumbetsk alluvial fan, and restricted its development in a southern direction.

To summarise what has been said, it should be noted that a detailed stratigraphy of the Triassic deposits, and a restoration of the palaeogeographic conditions of the Triassic period in the territories of the Pre-Ural Depression and adjacent regions, also has a great significance for clarification of the history of the geological development of the Urals.

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