Permo-Triassic Rocks of Orenburg Oblast

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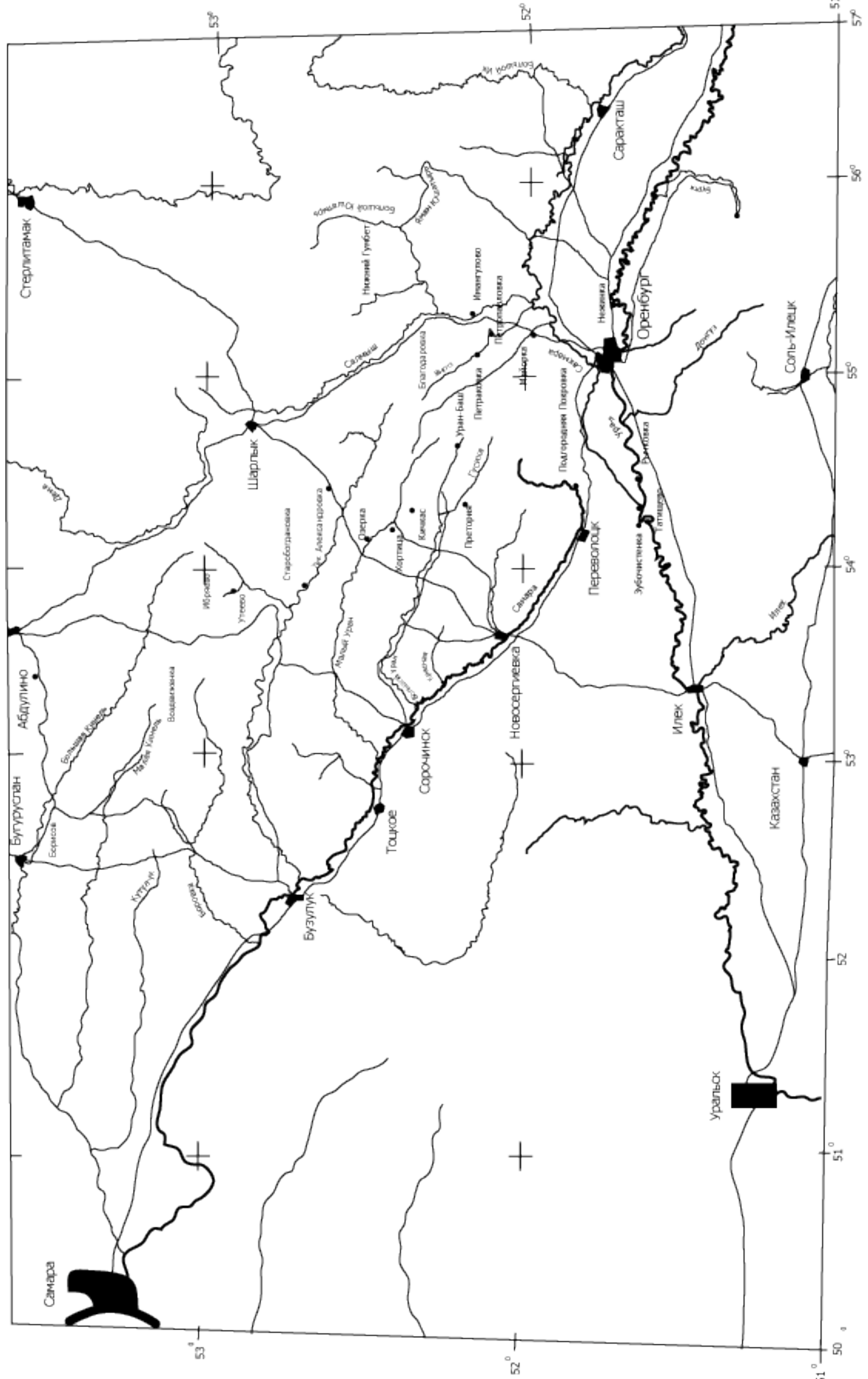
Palaeontologists from Bristol had visited Moscow in 1993, 1994, and 1995, and we had been part of a large field trip to the Orenburg region in the south Urals in 1995 (Benton 2003). After a break, the time was right for renewed work, and we obtained funding from the National Geographic Society to pay the costs of a 4-week expedition in July 2004. The Royal Society also provided funding for exchange visits between the two countries over a 2-year period.

The expedition was led by Valentin Tverdokhlebov, who had fifty years of experience mapping the Permo-Triassic red beds of the Orenburg area. Other Russian collaborators were Misha Surkov, our palaeontological collaborator and translator, as well as two of his students, Edvard Mamzurkin and Alexander ("Sasha") Butyrin. The western team consisted of Mike Benton, professor of vertebrate palaeontology at the University of Bristol, Donald Benton, then 14, Richard Twitchett, then a postdoctoral researcher in Tokyo, and now at the University of Plymouth, Andy Newell, a former graduate student in Bristol and now a geologist with the British Geological Survey, and Cindy Looy, a Dutch palaeobotanist and palynologist who had worked with Twitchett on the PTB in Greenland.

The first fieldwork took place in the Orenburg region as a Russian-British expedition under a research project studying global climate change at the late Palaeozoic – Mesozoic boundary. The project is centred at the Research Institute of Geology of SSU and supported by grants from the Ministry of Education of the Russian Federation (02-9.0-25), the Russian Foundation for Basic Research (04-05-64695) and National Geographic (7469-03). This report is written based on personal observations during fieldwork, with photographs from a database provided by all members of the expedition. We are very grateful to VP Tverdokhlebova and MV Surkov, for advice about the nature of geological processes. The Internet version of the report was prepared jointly by E. Mamzurina and MV Surkov. All rock samples collected during the fieldwork were transferred to the Museum, Department of Geoecology.


Самара
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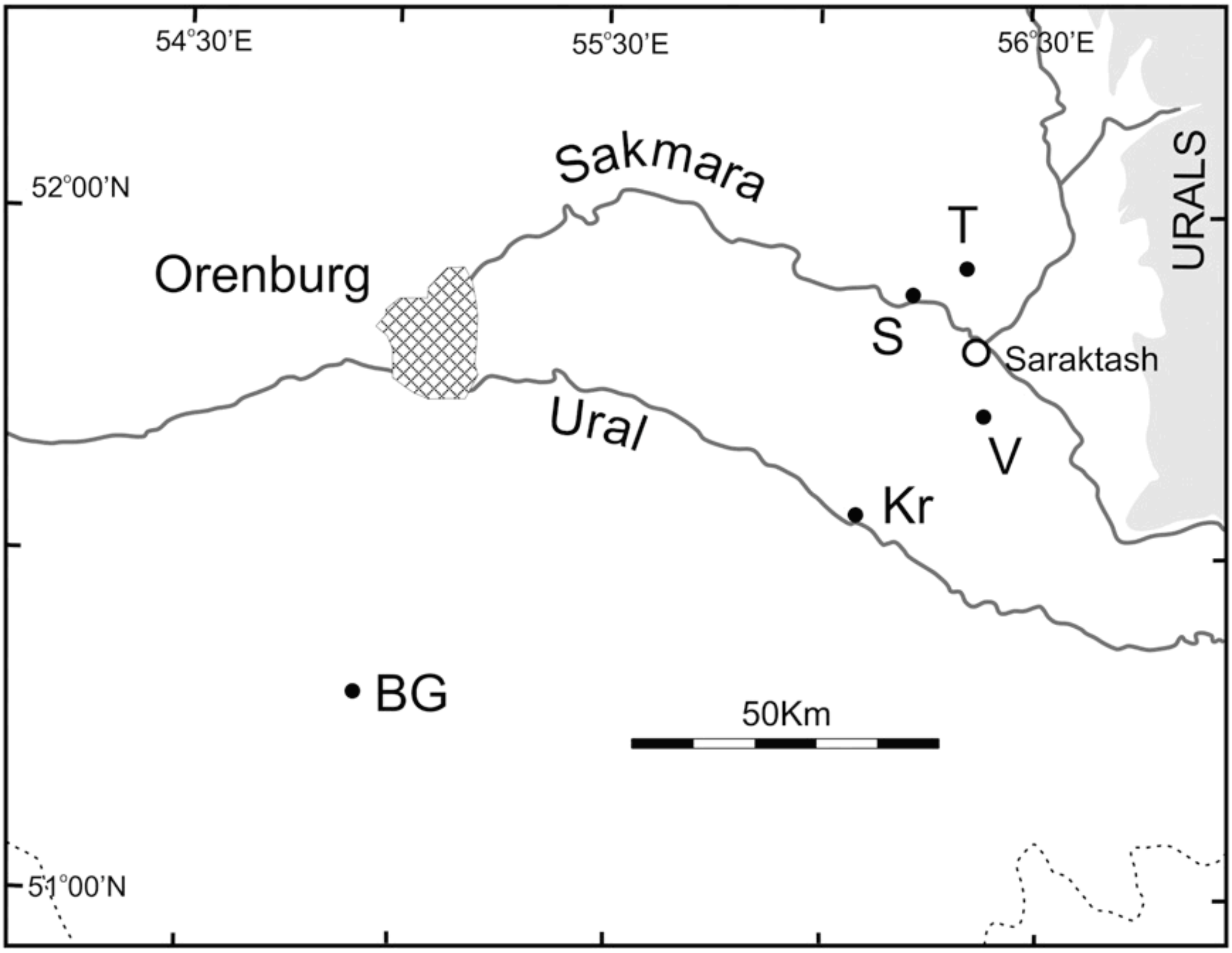
Саракташ
Соль-Илецк
Илек
Уральск
Казахстан

Map of study area



Outline location map of the Orenburg study area. Individual section localities are BG, Boyevaya Gora, Kr, Krasnogor, S, Sambullak, T, Tuyembetka, and V, Vozdvizhenka. Also shown are the Ural and Sakmara rivers and the border with Kazakhstan in the extreme south (light dashed line).

Route 1, Sambulak Hill.

The outcrop is located on the right bank of the River Sakmara, 500m north of the river, on the steep picturesque escarpment of Sambulak Hill. The outcrop can be divided into two parts: the lower part represents the alternation of ochre clay interbedded with secondary calcareous material in illuvial paleosols, referred to as caliche (Tverdokhlebov, 2001) and the upper part comprises 10m+ ofLower Triassic conglomerates - the remains of giant ancient alluvial fans from the Ural Mountains.

The sequence was studied from the base upwards. Permian strata are, as noted above, alternations of ochre clay with silty material and intercalations of caliche, which is in part paleosol and corresponds to the so-called horizon "B" of modern soils. In this section, layers of conglomerate sometimes occur (Sample 15). Each cycle begins with thinly bedded deposits of “proluvia” (outwash deposits), clay and silt, alternating with leached and redeposited horizons of Caliche . It should be noted that about 90% of each cycle accumulated instantaneously, while the formation of interlayed Caliche, up to 1m thick, requires up to 100000 years, since the processes of soil formation are always continuous.

Various types of caliche were recorded through the section:

1 Caliche-like nodule (sample number 11),
2 Immature Caliche (sample number 5),
3 Three thin Caliche layers (sample number 13),
4 Massive Caliche layers (sample number 8).

It is interesting to note that different kinds of Caliche form in certain different paleogeographical conditions according to the period of its formation. The concretionary stage is first,, when Caliche as such, in a discrete interbed has not yet formed, comprising instead separate clumps. After this initial stage, the Caliche bed will appear quite thin (a few cm to few tens of cm) and often enriched with material from the parent rock; in this case, ochre clay. Finally, following a long hiatus in sedimentation, and with the presence of a sufficiently mature soil, a more massive and thick bed (up to 1-2m) can grow, which will continue to develop until the arrival of further sedimentation. One horizon of Caliche was sampled at different levels, to illustrate its development, as an example of a single horizon (samples 17, 18, 19). In some interbeds, Caliche occurs together with a greenish mineral, malachite (sample 3). The formation of malachite in this case is obviously connected with an organic process - once entering the water stream, boulders or soil pellets, rich in organic material, undergo a process of sedimentation on their surfaces whereby oxygen is absorbed by microorganisms, creating a reducing environment and a geochemical barrier (sample 7), which in some cases contributes to the deposition of malachite. Remnants of petrified wood (sample 1) and evaporitic intercalations of limestone (sample 9). were also collected. It is interesting that moving upward in the section, Caliche seams become thicker and more obvious, whereas at the base of the outcropping section, Caliche beds are no thicker than 10-20cm. 10m below the PT boundary they attain thicknesses of 50cm to 100cm.

Permian strata are clearly overlain by Lower Triassic conglomerates, and the underlying clays are preserved intact. Such preservation of the underlying clay surface is due to the fact that this territory was a place of aggrading alluvial fan deposition, which occurred without disturbing the underlying surface.

At the outcrop, mud cracks and soil horizons, enriched with plant roots are preserved. In the clay beneath the conglomerates, calcareous streaks – Caliche, are seen. These show a texture indicative of compression under the weight of the overlying alluvial sediments, clearly visible in the thin (2-5mm) silty-clay layers.

Early Triassic conglomerates of 5m thickness, protrude as blocks which are separated from the rest of the sediment by obvious vertical cracks. The Conglomerate contains pebbles up to 20cm across, with composition referrable to a wide range of igneous rocks. These deposits were part of a huge alluvial fan originating in the mountains of the ancient Urals. In the thicker conglomerate beds, fine cementing material (Sample 8) is found, which suggests that the energy periodically decreased, and accordingly, the particulate material transported by the flow is finer.

Route 2. Verkhneozernaya-g.Giryal-Tatar Saraktash - bank of the River Sakmara near its confluence with the Great Ica.

Verkhneozernaya

The outcrop is located about 3.4 km south-east of the village of Verkhneozernaya. Here on the banks of the river Sakmara, fossil alluvial fan deposits are exposed, which are represented by conglomerates. The photo clearly shows that the boulders and pebbles are cemented into a single complex.

Pebbles in the conglomerate are not sorted, and their size can reach several tens of centimetres (sample 21), which is characteristic of strata formed as a result of avalanche sedimentation. The composition of pebbles in these conglomerates is of metamorphic and extrusive and intrusive igneous rocks, with some metamorphosed limestones containing a Middle Devonian fauna. The estimated thickness of these strata in the alluvial mid-fan structures reaches 800m, while in the region of Verkhneozernaya, the total thickness of alluvial sediments reaches about 200m. Formation of such a sequence would take about the same time as that required for a normal alluvial cycle, but because of avalanche sedimentation, it could have formed in as little as a few days. Several centuries may have elapsed between such sedimentation cycles.

In arid conditions, almost all such sedimentation is of an avalanche nature; the alluvial plain is sparsely vegetated, thus enhancing the effect of a catastrophic flood. An apparent sharp increase in the catastrophic nature of sedimentation in the Early Triassic is probably partly due to a contemporary decline in vegetation due to global climate change, which strengthened destructive energy of flows.

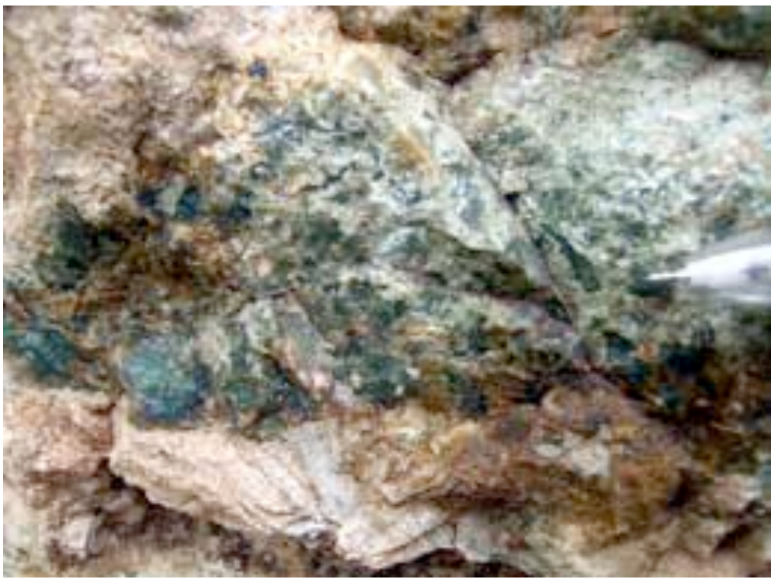
The uniqueness of outcrops in the area of Verkhneozernaya lies in the fact that highest piedmont facies, is not usually preserved in the geological record. Here, due to diapirism and its related subsidence, caused by the intensification of orogenic processes of the Urals, contributed to the conservation of this sequence.

Giryal

The outcrop is located 2km west of the village of Alabaytal, 20km west of measured palaeo-current orientations, which generated the above apron. Here, the Kopansky Conglomerates are exposed. These deposits are part of the same alluvial fan seen at Verkhneozernaya, but here are more distal. The photo clearly demonstrates reduced clast size and better sorting, compared with the conglomerates from Verkhneozernaya village. This difference in degree of sorting and size of pebbles is a shining example of reduced energy in the palaeo-current from its source towards the periphery. Previous measurement of the orientation of flat pebbles indicates that the palaeo-current was flowing to the west-south-west. Examples of such fans are also found in Quaternary sediments of the foothills of the Tien Shan Mountains.

Tatar Saraktash

A outcrop of a thick Caliche bed is located 500m south-east of Tatar Saraktash. Here can be seen simple caliche as well as different grades of calichified-calcrete rock-and siliceous-silcrete build-ups. An initial examination showed a 1-2m m intercalation, which is separated into blocks. This bed can be divided into two parts - the upper part is mainly white when freshly broken, the lower part is pink and incorporates fragments of country rock. At first glance, it is clear that this Caliche, unlike that seen at Sambulak, is much harder and different in its formation (sample 23). The calichification processes are inextricably linked with silcrete formation. Alkaline reaction of calcium carbonate solutions promotes the dissolution and migration of silica, released during the evaporation of solutions, in the form of opal and microcrystalline quartz, which encrusts void spaces. In these voids, the transition from calcrete to silcrete can be seen. Layers of caliche clusters or shapeless silicified spots result in an opaline rock, with individual pores and cavities filled with microcrystalline quartz and amethyst (Tverdokhlebov, 2001). The photo clearly shows bluish opal grains (sample 22).



River Sakmara Bank near the confluence with Great Ica river

This outcrop is located on the right bank of the River.Sakmara, 2km east of Tatar Saraktash, some 1 km to the east of the previous exposure. Even at such a short distance, instead of a single Caliche bed, several streaks of varying thickness are evident, and it is interesting that even within one exposure a thick layer becomes significantly thinner. This indicates that thick Caliche layers have a relatively small lateral extent, being of mainly local significance. Caliche may develop in different rocks, as shown by the presence of small siliceous nodules coated by Caliche. In Caliche, imprints of plant roots are seen, which once again proves the inextricable link between Caliche and soil, with organic material.

Route 3. Tuembetka

This viewpoint is 1km NW of the Tuembetka landmark. Here, Caliche interbedded with Kopansky Conglomerate crops out. This Caliche was not formed in paleosols, but in conglomerates, and is therefore not considered pure, but well mixed (Sample 25). The upper part consists of thick Triassic sediments, of which 120m is preserved here in a synclinal trough. The next observation point is located in the same area at elevations above 400m, 600m north of trigonometric point 386.8 m. Here, on top of another escarpment is a stunning view, clearly illustrating the impact of salt diapirism on the relief of the surrounding terrain, where the difference in the hardness of the deformed sediment layers create escarpments 400m west of Tuembetka viewpoint. It is clear why these mountains are also called "goat hills", because of their cuesta origin. The base of these Goat Hills" is composed of Permian rocks, the top of the same Triassic siltstone and conglomerates (samples 27, 28), which is confirmed by sampling. The photo shows alternating light Caliche (up to 30cm thick) with Vyatka rocks - the standard situation for this area.

Route 4. Quarry at Chuloshnikov village

The quarry is located 4.5 km NW of Chuloshnikov village. Late Permian conglomerates with lenses of sandstone (sample 29) are exposed in the sides of the old workings. Pebbles in the conglomerates are well rounded, up to 5cm in diameter, and of stable siliceous rock. The Conglomerate stratum is located about 20 m below the Permo/Triassic boundary. In the thicker conglomerates, fossilized tree trunks, part-replaced by malachite (sample 31) were seen, of which large quantities were caught in talus.

However, the main discovery was in a lens within the conglomerates near the top of the Vyatka siltstone, 20m below the P-T contact,. This find consisted of two large vertebrae of *Dinocephalia*. They stood out from the surrounding rock quite clearly. Numerous pieces, probably of the same vertebrae, were seen and sampled from the talus.

Because the vertebrae are of great palaeontological interest, it was decided to retrieve and send them to the Saratov State University laboratory. But their removal from the thick conglomerates was not an easy task due to their fragility. Therefore, the extraction took place carefully by removing them in a plaster jacket together with the matrix in which they sat.

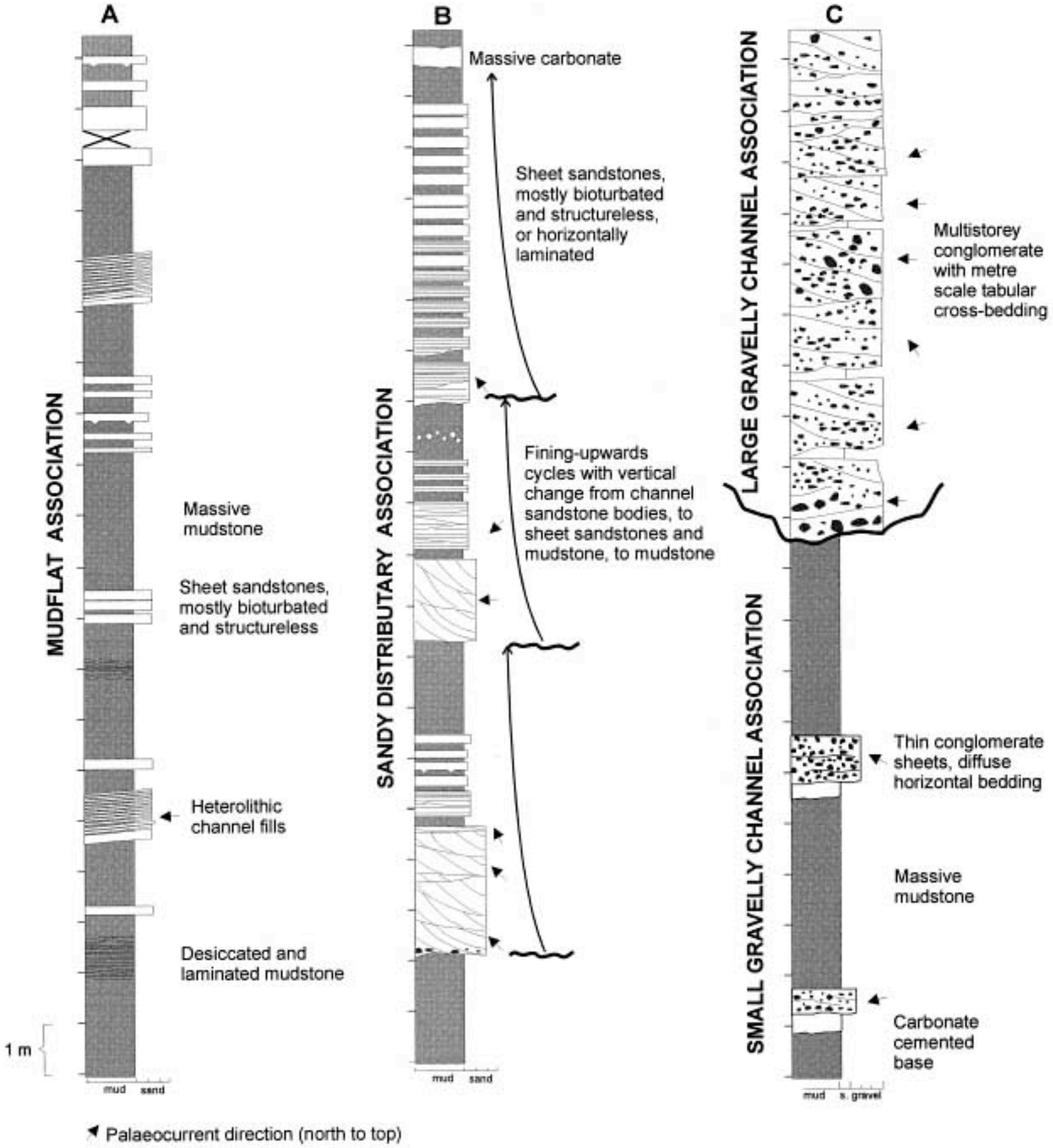
Route 5. Vyazovka Ravine

This ravine, located 500m east of the village of Vyazovka was studied. The outcrop lies in the sides of a long (about 5 km in extent) gully. Clearly visible in one of the walls are cross sections of channels, small palaeocurrent directions, evident in the overlying sand lenses extending down through several phases of previously accumulated sediments. In downcutting sandstones, the remains of freshwater fauna and flora were found. Red clay contains persistent thin beds (about 1-2cm) of fine-grained calcareous siltstone, of very pale, almost white colour (possible ash horizons). On top of this unit is a fine, tabular-bedded clay from the bottom of the same bed - clay in the form of layers, each 5-6cm thick, typically of lacustrine origin. Some 1-1.5 m higher, a lens of slightly calcareous sandstone is interbedded with Caliche nodules (samples 34, 38).

The uppermost part of the Vyazovka exposure, was observed along the route of the River Gryaznushka channel. Here, conglomerates laterally correlative with conglomerates at Chuloshnikov (sample number 36) are seen in the lower part of the section. 10-15m higher, is the P-T boundary. A sample of Caliche was collected 1.5-2m below the P-T boundary (sample 37).

Andy Newell, on the 1995 expedition, in Vyazovka Ravine, pointing to a fine bentonitic clay band, at the top of a fining-upward sedimentary cycle

Cindy Looy in the Vyazovka Ravine, at the foot of several fining- upward sedimentary cycles, running from coarse sands at the base to paleosols at the top.

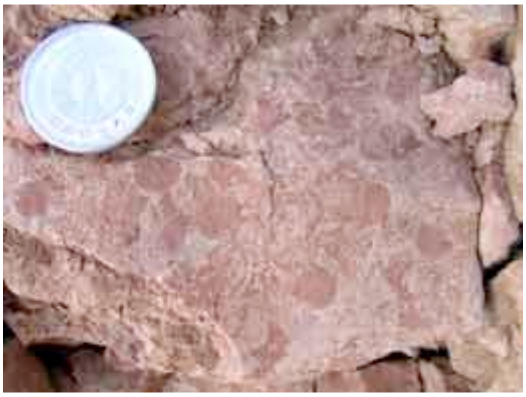


Vyazovka Ravine section
Sedimentological logs showing typical example of facies and facies stacking patterns within:
(A) the mudflat association (Kulchumovo),
(B) the sandy distributary association (Vyazovka), and
(C) the small and large gravelly-channel associations (Kulchumovo).
From Newell et al. (1999).

Route 6. Karolki Ravine.

On the slopes of the ravine, located at 700m SW of Karolki village, sedimentary incision into the P-T boundary, which occurred before main Triassic sedimentation, is well exposed. The incised complex comprises interbedded clays, sandstones and conglomerates, and a large part of the section is composed of a sand - silt - clay mix in which the proportion of any one component does not exceed 50% in these mixed sediments of alluvial plain genesis. For flat-lying alluvium, it is not unusual to see cross-bedding, often as multi-sedimented sets, in which the earlier sandstone or siltstone beds are cut off by the later formation. Good exposure enables observation of the variety of different textures. The rocks are quite commonly interbedded with carbonate-rich material which was clearly invasive, and show desiccation mud cracks. Build-ups close to paleosols may be encountered showing signs of surface weathering, as well as results of caliche-forming processes, where relics of the primary rocks remain as darker spots. In sandstones, ripple current layering was observed. The influence of organic material on the characteristics of sedimentation was also noted. Gray rocks - one of the signs of an abundant organic matter content. Such grey layers may result from the existence of small areas of wetland.

Caliche with traces of plant roots.



Ssandstone with feeding traces
or burrows of arthropods.

Early Triassic grit, with fragment of a small amphibian’s mandible.

Giant footprints were located in the Korolki Ravine, at a locality called Boyevaya Gora, 14 km NNW of Sol-Iletsk, on the Asiatic side of the Ural River, and close to the border between Russia and Kazakhstan. The ravine cuts through a fine section of the Permian to Triassic transition (PTB). In the Korolki Ravine, the Kulchomovskaya Svita (latest Permian) lies below the ledge, and the Kopanskaya Svita (basalmost Triassic) above. Members of the 2004 expedition (left to right), Mikhail Surkov, Michael Benton and Valentin Tverdokhlebov inspect the sandstone lying right at the PTB.

Careful logging by the Russian and British geologists showed that the footprints occurred in the Vyatskian zone, some 50 m below the PTB. The footprints were emplaced in a reddish-brown mudstone deposited from suspension beneath shallow ponded water in a floodplain environment. The footprints were subsequently cast by the base of the overlying fine-grained sandstone, which was deposited from a sheet flood event.

In more detail, approximately 124 m of mudstones, siltstones, sandstones and conglomerates are exposed in this section. The local PTB is located 94 m above the base of the measured section, at an abrupt facies change from red mudstones with well developed caliche to trough cross-bedded pebbly sandstones and conglomerates. These latter beds have yielded Early Triassic *Tupilakosaurus* remains, a left angular of *Wetlugasaurus samarensis* (?), and limb and dermal bones of indeterminate Temnospondyli. The mudstones a few metres beneath the boundary contain the Vyatkian ostracods *Volganella magna*, *V.* ex. gr. *laevigata*, *Wjatkellina fragilina*, *Gerdalia* sp., *Suchonellina inornata* var. *macra*, *S. inornata* var. *magna*, *S. parallela*, *S. parallela* var. *typica*, *S. futschiki* and *Suchonella typica*. The youngest Permian vertebrate remains are found 22 m beneath the PTB, and comprise tetrapods (*Scutosaurus* sp., Karpinskiosauridae gen. indet., *Chroniosuchus paradoxus*, Theriodontia fam. indet.) and fishes (*Isadia aristoviensis*, *Toyemia blumentalis*, *Mutovinia stella*, *Saurichthys* sp., *Gnathoriza* sp.).

The sedimentary succession at the track locality is dominated by red mudstones and sandstones. The mudstones are generally massive and often contain root traces and weakly developed palaeosols with calcrete nodules. The associated sandstones are generally less than 0.5 m thick, have sharp erosive bases, and are cross-bedded or ripple cross-laminated with bioturbated tops. The red colouration of the mudstone and the presence of rootlets and palaeosol horizons with calcrete probably indicate a continental setting with a semi-arid to subhumid climate. The mudstones were probably deposited from suspension in shallow ephemeral lakes (Tverdokhlebov et al. 2005) and on floodplains adjacent to broad, shallow river channels, represented by thin, erosive-based sandstones. Cross-bedding indicates that the flow direction was towards the west. Recession of the flood water allowed plant colonization of the muds and longer subaerial exposure led to the development of palaeosol horizons with calcrete nodules. Overall, the range of facies is similar to that described by Newell et al. (1999) from Vyatkian deposits 75 km to the north-east, and they suggested that the overall depositional system was a fluvial 'terminal fan' characterized by a network of shallow channels ending in a mud-dominated flood basin.

Unique find of Late Permian tetrapod track near Sol-Iletsk

During this expedition a unique find of Permian fossil tetrapod tracks was made at the Boyevaya Gora, 14km NW of Sol-Iletsk.

During the fieldwork, a fragment of dense bluish Upper Permian sandstone was noticed with strange bumps similar to the negative prints of large vertebrates. This observation, made by one of our English colleagues - Richard Twitchett, caused increased attention to be paid to the sandstone layer from which the said block fell. It was decided to strip and extract sandstone blocks to inspect more closely the bottom surface of the sandstone.

Recovered fragments were on average 0.5 - 1.5m in diameter and very heavy. During excavation, similar, rounded bulges were detected on many blocks. The base of the sandstone preserved all these irregularities, as casts from the underlying bed of clay. But with only a few blocks visible, it was impossible to say with confidence whether the irregularities are animal tracks or are simply the result of flowing water, as the sandy material accumulated on a soft clay surface. That these bulges resemble the footprints of animals, could have been the result of clay compaction.

Therefore, the next and most time-consuming step was the reconstruction of the lower surface of the part of the sandstone bed, which was extracted in the form of separate fragments.

So, at the end of the day we had exposed the basal surface of the sandstone, literally littered with negative imprints (about 10) among which several areas of tracks were identifiable. Unfortunately, the prints obtained were rather vague, so it was decided to extend the work the following day.
The next day, we removed 4 more clearly defined deep negative footprints, representing a fragment of the trackway.
In the clay, positive prints of the last four tracks also remained fairly clear. Two negative imprints were ascribed to rear feet, two to fore feet; one of the prints examined even showed claw marks

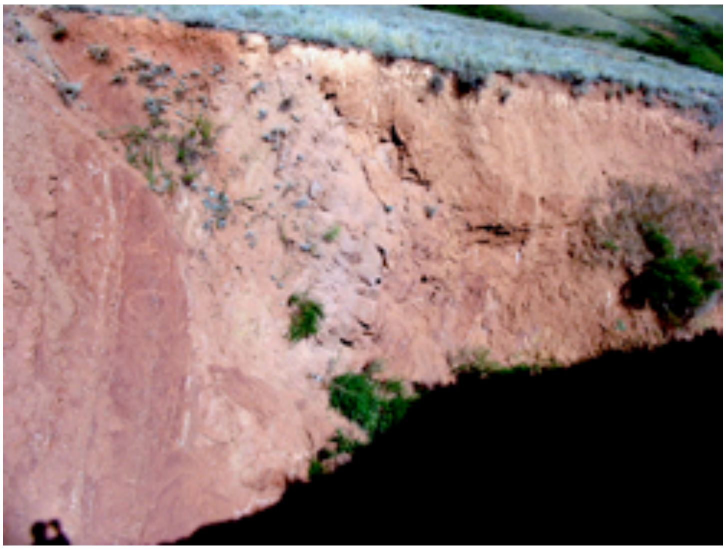
(right impression). The prints suggest that they were left by large four-legged animals the size of a bull, because the depth of individual prints was up to 10 cm. Orientation, length, width and depth of all negative prints was measured. The sandstone blocks with the four last prints was removed for future research in Saratov, as was a sample of clay from the trace, for ostracods. A sandstone sample with the imprint of three fingers was collected for the museum of the Department of Environmental Geoscience, Geological Faculty, N G Chernyshevsky University, Saratov State.

The discovery is the largest and most numerous of all Upper Permian trackways hitherto detected in European Russia

Route 7. Bayevaya Mountain.

Bayevaya Mountain is located 1.3km to the east of the village of Myertvy Soli. At this locality, a clearly visible depression has formed on top of the salt diapir. In the central part of the depression are two lakes, one of which is overgrown. Surrounding the depression, is a circular escarpment.

Near Bayevaya Mountain, the salt tectonics have tilted the strata close to vertical. 100m SE of the lake, in the sides of a ravine, there is a so-called tectonic breccia, resulting from local diapirism.



Nezarosshee lake is situated 300m from the top of Bayevaya Mountain, 1,2 km SE of Myertvy Soli.
The lake's outline is not circular, and its depth, in the centre exceeds 25m (according to measurements by VP Tverdokhlebova). Fresh water is present at the surface, but, increasing salinity with depth cannot be ruled out.
The coastal part of the lake floor and its banks are composed of blue gypsum.

Route 8. Kamennaya Yaruga Ravine

Kamennaya Yaruga Ravine is located 4km east of the village of Fedorovka. On the right bank, sediments of Kopansky (grey-coloured sediment) and Staritskaya (thick, red-coloured) units of the Lower Triassic are exposed. The grey-coloured rocks originated in a type of dry delta, while the red sequence has an alluvial origin. Dry delta deposits are underlain by eolian strata. These comprise actual aeolian and reworked aeolian outwash

deposits, recognised recently by the usual signs of typically rounded and sorted aeolian grains but with alluvial cross-bedding. Apart from fine-grained sands, the eolian strata include more coarse-grained sand; the larger grain size contributing to the presence of increased permeability zones, which promote the formation of calcite overgrowths. These layers indicate increased wind strength during deposition.

Gray organic-rich dry delta sediments are not surprising because such a deltaic region at a river mouth would receive much organic debris. In the dry delta sequence, rocks of different grain size are found; from sand up to lenses of conglomerates. The grey sediments are often cross-bedded.

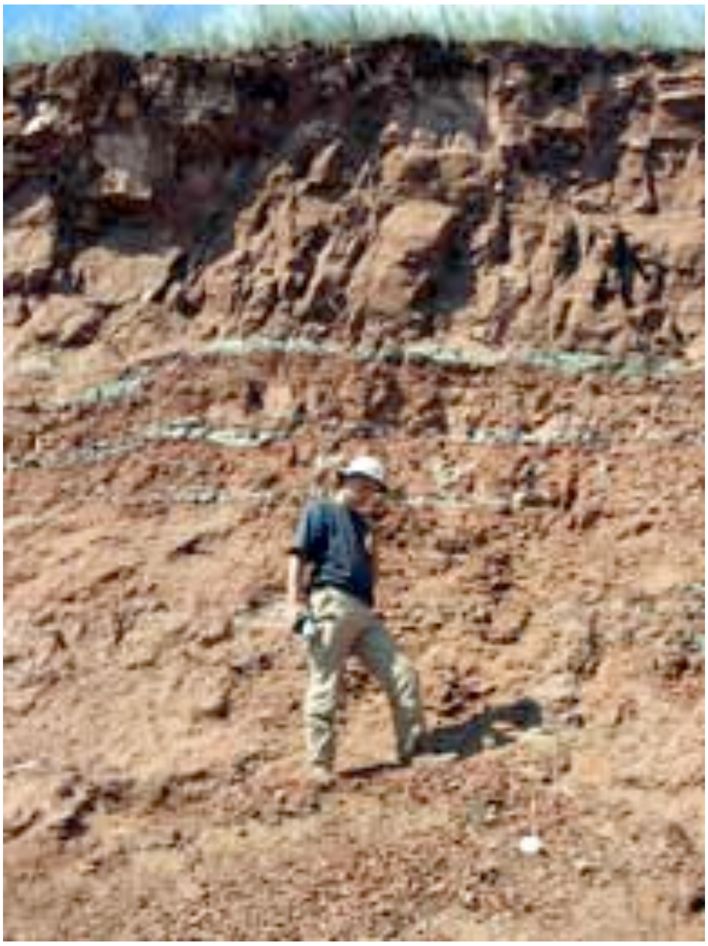
The alluvial deposits are heterogeneous, with distinct light layers of sandstone and clay. The consistent dip of the cross-bedding suggests that the surface slope at this point roughly coincides with the direction of current flow that deposited these sands. It happens that the dip reveals the transverse and not the longitudinal palaeo-flow section, The oblique view is not visible in this series.

Fragments of fossil amphibian and reptile bones were found in the dry delta conglomerates, which confirms the richness of organic material of these deposits.

Route 9. River Tok Estuary. Quarry on the Buzuluk – Grachevka road

The outcrop is located on the right bank of the river Tok. 400m downstream from its confluence with the River Samara, The P-T boundary is exposed. Below the boundary, red-silty clay with interbedded pale siltstones occur, which owe their light coloration to the leaching of oxidized iron, which imparts the red colour to the Permo-Triassic continental deposits. The Permian and Triassic boundary lies above a basal ochre sandstone at the top of the section.
50 m upstream on the same side, modern conglomerates have locally accumulated in the stream. In the conglomerates, a fragment of bone was found; probably Lower Triassic as the upstream deposits are of this age.

The Buzuluk-Grachevka road



The quarry is located 1 km to the east of Buzuluk village, the length of which is about 3km. Stratigraphically, these deposits correspond to the level of the dry delta, investigated in the Kamenaya Yaruga ravine. In the Triassic, this area was in an interdistributary location. From the base up, most of the section consists of ochre siltstones with bluish streaks, enriched by organic matter. The upper part consists of red sandstone.

The layers near the base of the outcrop represent a seasonal cycle. Sediment accumulated in the rainy season, the clay component then desiccated (mud cracks) again to be buried by the next cycle. Cracks in the surface sediment may have existed for weeks or years, becoming less well-defined the longer the crack existed unburied. Sandstones, lying on the silts are an example of an ancient sabkha. Sandstones, like the siltstones have an origin related to the alluvial plains. No Caliche exists in these deposits, as this forms in a humid climate. The strata described above same were deposited in highly arid climate, and with generally reducing soils, which explains the lack of Caliche.

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Route 10. Elshanka village

This outcrop is located 2km west of Elshanka village. Here, aeolian deposits, which overlie clays, are unique in local thickness; as they represent 15m high buried dunes. At the bottom of the dune there are layers of grit, analogous to those at Yaruga, and cross-bedded sandstones. Within the grits, layers of sand can be seen, demonstrating that these deposits result from water-reworked aeolian deposits. That is, it suggests that the sedimentation of aeolian deposits was briefly interrupted during which period fluvial sediments were formed. In the body of the dune, thin layers of carbonate flour exist in the zones of higher permeability, ie, large grain size. The increase in grain size was due to increased wind strength, but strong winds also contributed to the formation of lenses and cross-bedding. The top layer of the sand-dune is covered by weathered aeolian deposits.

In the interbedded weathered material above the dune, a breccia occurs; containing probable infilled fossil animal burrows, which originated from a single horizon.

Above are cross-bedded carbonate cemented conglomerates – of the dry delta sediment type. Jurassic deposits cover a yellow-stained Triassic surface with slight disconformity. Jurassic rocks are full of ferruginous concretions, which have made the more permeable Triassic rocks in contact with them yellow in colour.
A few kilometers from the ancient dunes, at the level of aeolian deposition, palaeo-sabkha composed of silty-clay deposits was seen. Being at the same stratigraphical level, this is a classic example of facies transition.

Route11. Tupikovka

This outcrop is located in the sides of an ~E-W gully, extending for about 2km. The ravine itself lies 500m NW of Tupikovka village. The lower part of the outcrop is an alternation of red conglomerates and sands. In the conglomerates the fossil remains of vertebrates were found. Above, are cross-bedded grey conglomerate, sand and sandstone, which overlap the red-alluvial cross-bedded conglomerates and sandstone interbeds. Upper alluvial sediments are an 8 m thick sabkha deposit which, again overlie alluvial deposits.