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Murchison's first sighting of the Permian, at Vyazniki in 1841

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ABSTRACT

Roderick Impey Murchison named the Permian Period in 1841 based on his work on Lower Permian marine sediments around the city of Perm', on the west flank of the Ural Mountains. However, he had observed post-Carboniferous red beds earlier, around the town of Vyazniki, west of Moscow, lying above the classic Carboniferous limestones of the Moscow Basin. Murchison's notebooks and papers show that he and colleagues equivocated about the exact age of these red beds, whether latest Permian or early Triassic, but he always favoured the former view. So, his initial observation of the Vyazniki redbeds provided a marker for the top of the Permian and base of the Triassic in the European Russian platform.

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1. Introduction

Roderick Impey Murchison (1792–1871; [Fig. 1](#)) famously named the Permian Period in 1841, based on his fieldwork in Russia ([Thackray, 1978](#); [Benton, 2003](#)). This was the last remaining gap in the standard time scale that Murchison and others had been establishing through the 1830s, a range of time called then informally the 'lower New Red Sandstone', and lying between the Carboniferous and Triassic (= 'upper New Red Sandstone'), which had been named respectively in 1822 and 1834. The general assumption is that Murchison was first able to provide a formal name for the 'lower New Red Sandstone' after having seen fossiliferous marine Lower Permian rocks around the city of Perm', on the flanks of the Ural Mountains, and these observations clearly gave him the evidence he needed to mark the base of the period, where it overlay the Carboniferous. However, less well known perhaps is the fact that he and colleagues had seen Upper Permian red beds at Vyazniki, on the road from Moscow to Perm'. Close reading of Murchison's notebooks, his published writings from the 1840s, and a recent visit to the original locations, have now shown that he understood he had begun his studies on the Permian rather earlier than expected. The Vyazniki red beds, he surmised, might mark a rock unit immediately before the Triassic, a view that concurs remarkably with current opinion.

Permo-Triassic continental red beds cover 1.4 million square kilometres of European Russia and provide an important record of changes to terrestrial environments and ecosystems before, during and after the end-Permian mass extinction ([Newell et al., 1999, 2010](#); [Tverdokhlebov et al., 2003, 2005](#); [Benton et al., 2004](#); [Sennikov and Golubev, 2006](#)). This was unknown in Murchison's day, and he was surprised when he left the grey-coloured Carboniferous limestones, and passed stratigraphically upwards into red sandstones and mudstones on the road between Vladimir and Vyazniki.

2. Murchison's 1841 visit to Vyazniki

2.1. The field notebooks

Murchison visited Vyazniki on May 19th, 1841, and he recorded the first evidence of continental Permian, indeed of any Permian, here. Murchison noted variegated clays and sands at Tolmachevo ([Fig. 2](#)), now a noted viewpoint over the Klyaz'ma River, but he did not reproduce his field notes for some time, clearly uncertain of the significance of what he had seen (see below). This was Murchison's second visit to Russia, undertaken with the aim of documenting the geology of European Russia and the Urals, but also to attempt to fill the gap between the well-defined Carboniferous and Triassic rocks of Western Europe ([Benton, 2003](#); [Collie and Diemer, 2004](#)).

Murchison had visited Russia in 1840, and saw the geology of the west and the Moscow Basin. In 1841, Murchison began his trip in St Petersburg, and then, accompanied by three colleagues ([Fig. 3](#)), Edouard de Verneuil (1805–1873), the French palaeontol-

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Fig. 1. Portrait of Roderick Impey Murchison (1792–1871) drawn at about the time he explored Russia.

ogist, Alexander von Keyserling (1815–1891), the German–Russian mining expert, and a young Russian mineralogist, second lieutenant Nikolai Koksharov (1818–1893), headed for Moscow. Verneuil (Daubrée, 1875; Gaudant, 2008; Santonja, 2008) had learnt his palaeontology from Jean-Baptiste Elie de Beaumont, and he travelled widely over Europe and especially in the Crimea, in the 1830s. He made a special study of the fossils of the Devonian of the

Bas-Boulonnais in France, and then travelled with Murchison and Sedgwick through the Rhenish provinces and Belgium in 1839. He was the obvious choice for Murchison who required a palaeontologist with wide experience of lower Palaeozoic fossils. Keyserling (Rogers, 1973) had been born in Kurland (part of Latvia), of a landed German family, hence his title 'Graf' (= Count), and was educated in Berlin before he took a position in the Russian civil service. He was a personal friend of Tsar Nicholas I, and is remembered for his work in geology as well as in botany and agriculture. Koksharov (Koksharov, 1890; Shafranovsky, 1964) had graduated from the Institute of the Corps of Mining Engineers in St Petersburg in 1840. The Institute had been placed under the command of the Ministry of Defence during military reforms of the Emperor Nicholas I, so all graduating students, as well as the teaching staff, held military ranks. Koksharov later became director of the Institute of Mines, and made significant contributions to mineralogy.

The three noble geologists of independent means—Murchison, de Verneuil, and von Keyserling—and their young protégée, the 22-year-old Koksharov, nicknamed 'Kok' by Murchison, investigated the Carboniferous limestones and sands south of Moscow in early May 1841, returned to Moscow to watch the Imperial military parades, and then headed east from Moscow on the road to Nizhny Novgorod. They proceeded together to the old monastery city of Vladimir, and then Verneuil and Keyserling took a southerly route to Kazan', and Murchison and Koksharov continued on the main road east.

Details of the trip and Murchison's observations are gleaned from two sources. He wrote a series of field notebooks through his life, and his 13 Russian notebooks are preserved in the Geological Society of London Archives (LDGSL 839). These were written in the field largely in pencil, and they were then worked over by Murchison at some later time when he scored out some sections, and added numerous small annotations using ink. The revised versions of the notebooks were then carefully copied by an amanuensis, who had a more legible hand than Murchison's, and the rewritten narrative was presumably intended for publication. This redrafted autobiographical journal is in nine well-bound volumes (LDGSL 841), provided with a fine title page inscribed 'Wanderings in Russia from 1840 to 1845 inclusive by Roderick I. Murchison', and it was transcribed and published, with maps and explanatory annotations, by Collie and Diemer (2004).

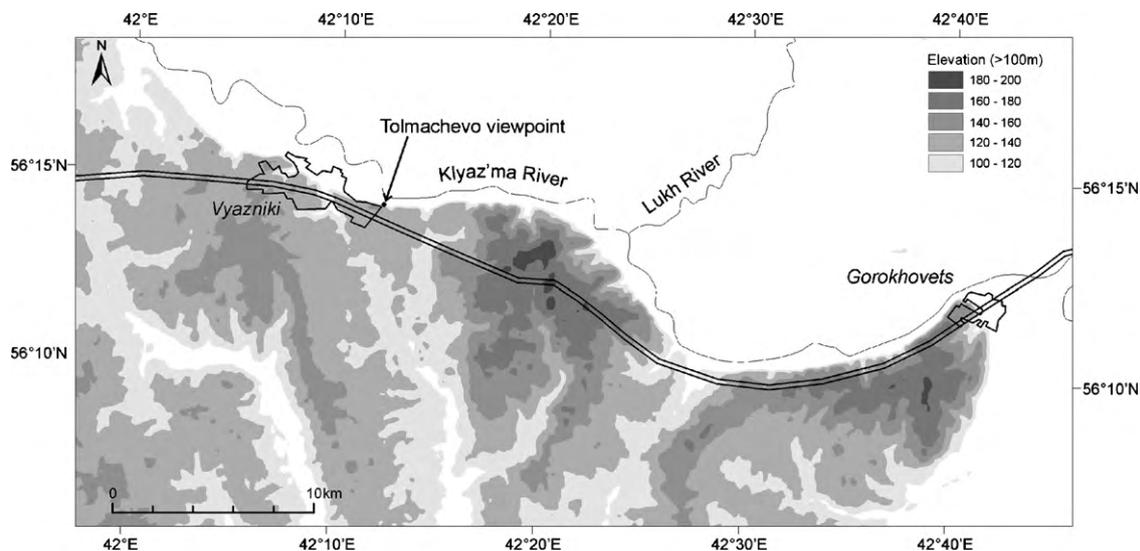


Fig. 2. Location map of Vyazniki and Gorokhovets, showing the main road from Moscow (far to the west) to Nizhny Novgorod (to the east). The Tolmachevo viewpoint, where Murchison and Verneuil first saw Permian redbeds, is indicated.



Fig. 3. Portraits of Murchison's three companions on the 1841 expedition, Edouard de Verneuil (1805–1873), the French palaeontologist (A), Alexander von Keyserling (1815–1891), the German–Russian mining expert (B), and Nikolai Koksharov (1818–1893), the Russian mineralogist (C). Verneuil is pictured about 1850, but the other two considerably later in their lives. All images are in the public domain, and the portrait of Koksharov is from Münster (1865–1869), courtesy of Irena Malakhova.

The field notebooks show that the party left Moscow early in the morning on May 17th (29th),¹ and reached the Vladimir/Vyazniki area 36 h later, so, late on May 18th (30th). After staying overnight in a private mansion just before Vyazniki, Murchison and Koksharov spent a day in the town, before crossing the River Oka on May 19th (31st), on the eastern side of which they spent the night, and then proceeded on their way to Nizhny Novgorod on the Volga, and thence to Kazan' to the south.

Murchison describes the monastic and church splendours of Vladimir, and the road east to Vyazniki that he traversed with many side trips to look at the Carboniferous limestones along the banks of the Klyaz'ma River (Collie and Diemer, 2004, pp. 181–183). In the travelogue, Murchison (LDGSL 841, p. 283; Collie and Diemer, 2004, p. 184) wrote:

Viasniki is a pretty small town, with a very good (Russian) *gastinitza* or inn, the Nijny Gorodskaya. The town is at the base of red alluvial and diluvial hills, on a flat, from which the river has receded. Blocks of greenstone, quartz rock, etc., are tolerably abundant, and granite is scarce. The northern drift cover is very thin on the high ground between Viasniki and Goroghoretz [= Gorokhovets], and is often of a light grey whitish colour, but every here and there the red marl and sand, either regenerated, or in place, appears near the surface.

Further consideration of the red rocks is omitted, presumably because he was unsure at the time what he had found: the geologists had traversed huge amounts of undoubted Carboniferous sediments from Moscow to Vladimir, and somewhere between Vladimir and Vyazniki there had been a transition from Carboniferous to 'red marl and sand'—Murchison was not then clear in his mind whether these

red beds represented the base of the New Red Sandstone or not. His views may be tracked in his hitherto unpublished field notebooks, and through the series of publications that followed the expedition.

In the relevant notebook (LDGSL 839, N86, pp. 60–71), Murchison had headed page 60 'The Geology of Vladimir' in pencil in the field, presumably meaning to present an outline of the geology of the region. Later, he added some phrases in ink that convert the heading into a short sentence that was later copied out: 'The geology of Vladimir and Viasniki I pass over and refer to my big book.' The remainder of page 60, and pages 61–64, of the field notebook are scored through and were not copied into the autobiographical journal, and that account moves straight to notebook p. 65, where Murchison describes Viasniki as a 'pretty small town' (above).

The omitted text is as follows:

The Geology of Vladimir [and Viasniki I pass over and refer to my big book.] and rocks on the Clasma between Vladimir and Kovrof (Pallas² loose).

The Carbonif. Limestone is seen for the last time eastwards occupying a plateau on the r. bank of the Neretta³ at a height of at least 200 feet above the Clasma. The little river Neretta runs between the limestone ridge and the village of Velikova.⁴ The

² Peter Simon Pallas (1741–1811), German-born naturalist, geographer, and traveller, professor of natural history (academician) of the Imperial Academy of Sciences and Arts in St Petersburg since 1767, who explored remoter parts of European Russia and Siberia in an expedition from 1768 to 1774, at the behest of Empress Catherine I, and wrote many books, including *Travels through the southern provinces of the Russian Empire* (Leipzig, 1799–1801; English translation, 1802 and 1812), which was perhaps in Murchison's travelling collection, and might have been falling to bits by this point.

³ Murchison wrote out Russian place names as he heard them, and using the German-style orthography of the day. This has been replaced by a more English-based transliteration (Benton, 2000). Place names in this section of text are (with modern transliteration): Clasma, Clasma, Klasma (Klyaz'ma); Kovrof, Kovrof (Kovrov); Neretta (not marked on Google maps); Nijny Gorodskaya, Nijny Novgorod (Nizhny Novgorod); Okka (Oka); Velikova (Velikovo; 2 km south of Melekhova, where there are large limestone quarries today); Viasniki (Vyazniki).

⁴ In the field notebooks, Murchison notes with grave accents the emphasized syllable in Russian words and place names—these are not reproduced in the redrafted travelogue, nor in Collie and Diemer (2004).

¹ The two versions of dates were commonplace in Russia in the nineteenth century. The Russian Orthodox Church, as well as many other people, retained the old Julian calendar (and the Orthodox church still holds key ceremonies 13 days later than elsewhere). In the 19th century, there were 12 days' difference between the old Julian dates (named after Julius Caesar, who introduced the scheme in 45 BC) and the newer Gregorian dates (named after Pope Gregory XIII in 1582 whose advisers proposed to accommodate leap years to bring the business and lunar calendars back into line).

line of quarries presents a milk white face (very refreshing to a poor devil of a geologist who has seen nothing like a rock for many hundred versts⁵) of piles of stone at intervals passing through the scented fir wood.

The limestone contains beds which are as thick as Moscow rock when exposed—others yellow and others greenish grey. They are generally cleaved [?cleared] by pits—the sand and clay being dug away (drift and alluvium) and a roof of strong- [61] bedded stone left whilst they quarry a depth of 6 or more feet, supporting the roof by posts. When the crest becomes dangerous, they abandon the pit and open another contiguous. By going under these roofs I wanted to believe in a general slight inclination to the E.N.E. by which the limestone is carried under the red Deposits of the great basin.

There are few or no beds of flint or chert associated with this limestone which on the whole appeared to me to have a Superior Member. It is void of any interleaved red deposits or any thing carbonaceous and on this eastern Edge the rock resumes [?rejoices] therefore its old Archangel characters.⁶ In it we found our old friend

Euomphalus pentangulatus -

Spirifer -

Stromboides -

and another level or two - *Encrinites* and some [62] unknown shells including a winged bivalve. Fossils however are not so plentiful as in the Inferior? strata.

No Producti were found.

By catechising at the natives, workmen, noblemen and others we could not discover that any rock was in situ in the Klasma beyond a verst or two about Kovrov where the white limestone is very feebly seen and evidently declines or slopes away.

The contour of the country gives this idea also—The calcareous plateau probably extends by the new chaussée⁷ of Pavlovsk⁸ and the new stretches towards Viasniki in the East &c. but I am not of opinion that the Clasma is the boundary as marked by Helmersen⁹ in his new map; for the red regenerated materials are so abundant.

The view from the r. bank of the Clasma is precisely similar to that of the r. banks of [63] the Okka and of the Volga near Nijny and on both these streams we know that the terrain is the same on both banks though the left bank has been subjected to mighty denudation and the latter presents steep acclination. If nothing but the superficial detritus were seen it might be supposed that this had been accumulated on a hard rock like the limestone on the one bank while the softer materials on the other side had been denuded. But this is flatly contradicted by the fine vertical section of the soft sandstone and green and white marl of which the r. bank is composed.

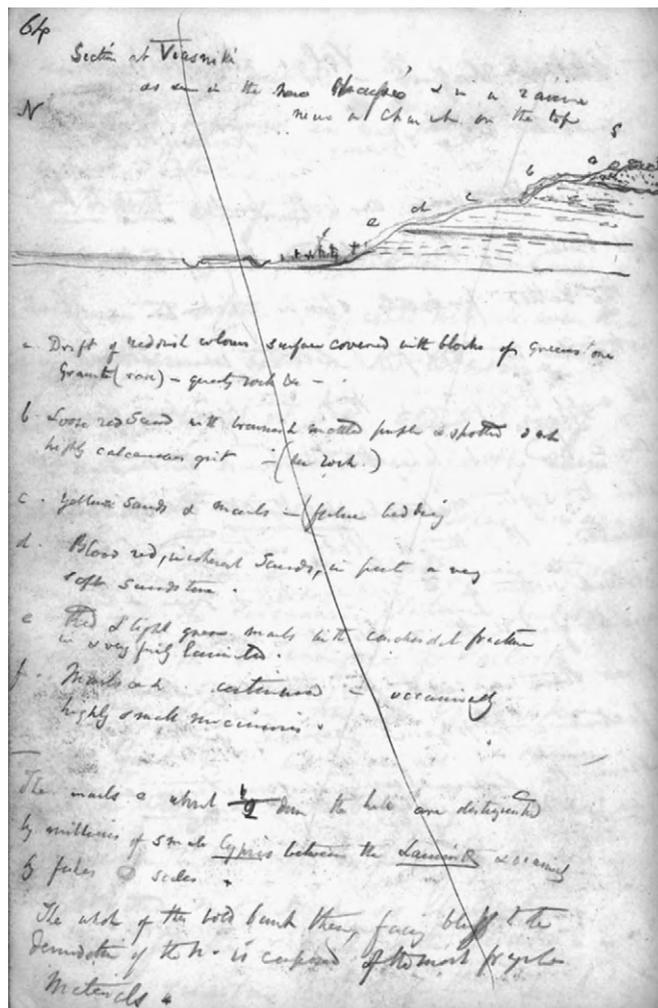


Fig. 4. The first identification of Permian rocks. Page 64 from Murchison's notebook for May 19th, 1841 (LDGSL 839, N86), showing his pencil sketch of the log through the ravine at Tolmachevo, at the eastern end of Vyazniki, on the south (right) bank of the Klyaz'ma flood plain.

How then [to] account for the singular feature in the physical geography of these tracts, since the dissimilarity of functions is alien to it? (see next page) [64]

Section at Viasniki [Fig. 4], as seen in the new chaussée and in a ravine near a church on the top. [The section is marked 'N' to the left, and 'S' to the right.]

- Drift of reddish colour surface covered with blocks of greenstone Granite (rare)—quartz rock &c.
- Loose red sand with brownish mottled purple and spotted dark highly calcareous grit—(red rock)
- Yellowish sands and marls—(false bedding)
- Blood red, incoherent sands, in fact a very soft sandstone.
- Red and light green marls with conchoidal fracture, and very finely laminated.
- Marls &c continued—occasionally highly small inclusions[?]. The marls and which [way] down the hill are distinguished by millions of small Cypris between the Laminæ and occasionally by fishes scales.

The whole of this bold bank there, facing bluff to the denudation of the hill is composed of the most fragile materials.

Murchison evidently visited the Tolmachevo section (56°14.321N; 42°11.968E; Sennikov and Golubev, 2006, locality 9; Fig. 5), a ravine some 50 m long that lies 200 m west of the public

⁵ A versta is an old Russian measure of distance, commonly used, and representing 3500 feet (1.067 km).

⁶ A reference to Arkhangel'sk, commonly called in English then Archangel, a maritime city in the north of European Russia where Murchison had observed abundant Carboniferous limestones in 1840 and 1841.

⁷ Chaussée is French for highway, and the word became part of the Russian language as шоссе (Shosse).

⁸ Pavlovsk = Pavlovskoye, which lies 15 km SSE of Kovrov, on the modern M-7 highway from Vladimir to Vyazniki, presumably then under construction.

⁹ Gregor (Grigory Petrovich) Helmersen (1803–1885), frequently mis-spelled Helmersen by Murchison and many others. He was born near Dorpat (now Tartu, Estonia), and his father was an officer of the Russian Army. The family moved to St Petersburg when Gregor was a child, and he worked in Russia through his whole life, so he was a Russian, although with a German surname. He was a stratigrapher, structural geologist and geomorphologist, who became director of the Mining Institute of St Petersburg, and author of books on the geology of Russia. At the time of Murchison's 1841 expedition, Helmersen had just published his *Reise nach dem Ural und der Kirgisiensteppe, in den Jahren 1833 und 1835. Erste Abtheilung* (Kaiserliche Akademie der Wissenschaften, St Petersburg, 1841), and Murchison was complaining about the geological map that accompanied this volume.



Fig. 5. The present view eastwards from the Tolmachevo viewpoint (Maxim G. Minikh [left] and AGS [right] ponder the view). This is now a tourist spot, identified by local geologists as the point at which Murchison made his discovery of the Permian redbeds.

viewpoint, and descends from a cluster of cottages to the shore. There is a well-worn footpath down the ravine, and sections used to be very clear, but it is now partly overgrown. Our field observations correspond to the sketch log in Murchison's notebook N86 (Fig. 4). He shows a hint of a church at the top of the section, but Tolmachevo church lies further west, and a cluster of buildings in the distance at the foot of the cliff, which might just be the eastern end of Tolmachevo (now incorporated into Vyazniki).

In the deleted text reproduced above, Murchison clearly convinces himself that the limestones around Kovrov and Velikova are Carboniferous in age, both by lithology and fossils. He is puzzled by the apparent disappearance of the Carboniferous limestone as he heads east, and believes he can detect a very slight ENE dip, so indicating that the red beds to the east, beginning at Vyazniki, overlie the Carboniferous. He also has difficulty explaining why the cliff of red marls and sandstones at Vyazniki is so high on the right-hand (southern) side of the River Klyaz'ma, but that the plains to the north are much lower, and apparently devoid of outcrop. In the labelled drawing of the Tolmachevo section (Fig. 4), Murchison distinguishes an upper layer (a) of Drift, and indicates that beds b-f beneath are presumed bedrock.

Murchison and Verneuil met their colleagues in Kazan', after passing down the Volga, and the combined party continued their exploration of the western flanks of the Ural Mountains, reaching Perm' on June 14th or 15th. After 2 days in the town, the party split again, and Murchison saw gypsum-bearing white limestones, which he assigned to the lower part of the New Red Sandstone, and, on later days, other marine beds of the Lower Permian. The party continued their excursion, criss-crossing the Ural Mountains, exploring the Permian and Triassic redbeds around Orenburg to the south, and then swinging far west to examine the Donetsk coal field, and they finally returned through Moscow to St Petersburg, from where Murchison left on 24th October on a steamer to Hamburg and then to London.

2.2. Murchison's publications on the Russian Permian

Murchison (1841) established the Permian System in a short paper, one of several summary documents and maps he and his team prepared during October, in Moscow and St Petersburg, before they returned home. The Permian is founded primarily on the rocks he saw after visiting Vyazniki, east of the Volga: marine beds around Kazan' and Perm itself, and Orenburg in the south: limestones with shells, gypsum, salt, and copper-bearing sandstones, lithologies that he had seen in the Zechstein of Germany

and Magnesian Limestone of England. He argued that the marine molluscs were reminiscent of the Carboniferous and plant remains from the copper-bearing sandstones were Triassic in aspect.

Of the Vyazniki beds, Murchison (1841, p. 419) wrote 'The overlying red deposits which occupy a great basin in the governments of Vologda and Nijni Novgorod, have not as yet been found to contain any organic remains except minute *Cyprides* and badly preserved *Modiolae*; but when we take into consideration their thickness, geological position, and mineral characters, we are disposed to think that they may at some future day be identified with a portion of the "Trias" of German geologists.' The Vyazniki red beds were then uppermost Permian or Lower Triassic, according to Murchison's first impressions.

In their first substantial account, presented to the Geological Society of London in April 1842, Murchison and Verneuil (1842) provide further detail, giving lists of the marine fossils from the Kazan', Vyatka, Perm', and Orenburg regions, many regarded as intermediate in character between Carboniferous and Triassic forms, as well as the Zechstein flora and a first mention of reptile bones. This great basin of Permian rocks lay over Carboniferous seen to the west and east. In describing the overlying red sandstones and marls, Murchison and Verneuil (1842, p. 727) wrote: 'At only Viasniki on the Kliasma could the authors detect any traces of fossils, and these are minute *Cypridae*, associated with apparently flattened *Cyclades*?¹⁰ which are imbedded in blood-red marl. The thick cover of detritus which is spread over a very large area, obscures the junction of these red deposits with the eastern edges of the Carboniferous limestone of the Moscow and northern regions.' Murchison and Verneuil leave the question of the age of the deposits open.

This, and numerous other short reports presented in 1842 and 1843, were a prelude to Murchison's planned *magnum opus*, his *Geology of Russia*, published eventually in 1845 (Murchison et al., 1845). Here, the authors use words similar to those in their 1842 paper to describe the Vyazniki deposits, suggesting, as Collie and Diemer (2004, p. 183) note, that this part of the text was little changed since its first reading to the Geological Society in 1842. They described the discovery of the key fossils at Vyazniki (Murchison et al., 1845, p. 182):

At Vyasniki on the Kliasma and in the ravines to the east of the town, there is a clear section of marls, sometimes slightly micaceous and sandy, with other beds of light red and green colours, very finely laminated, overlaid by blood-red, incoherent sands passing into sandstones, yellowish sands and marls, and variegated, highly calcareous grit. In the light red, variegated marls towards the middle of the cliff, and in a ravine to the north of the high road, we detected a profusion of microscopic crustaceans resembling *Cytherinae*, associated with a small flattened bivalve shell, having the general form of *Cyclas*, and these, as before said, are the only organic remains with the exception of a very small (fish?) bone observed near Nijni and now unfortunately lost, which we have been able to detect in these widely spread red strata of such very persistent lithological characters.

Then follows a brief review of the Permian east of the Volga, and the authors still leave it open whether the red marls and sandstones of Vyazniki and Nizhny Novgorod are Permian or Triassic in age, but they conclude: 'On the whole, however, we confess we are disposed to view these variegated sands and marls like those of Orenbourg as a part of the Permian system.' Further, in the definitive map (Murchison et al., 1845, pl. 6), the Vyazniki 'Marls with *Cytherinae*' are placed clearly at the top of the Permian, lying above the 'Concretionary Limest.' of Nizhny Novgorod, and these above a

¹⁰ Note that Collie and Diemer (2004, p. 183) mistakenly identify '*Cyclades*' as 'plant fragments', but the term is used by Murchison as a plural version of *Cyclas*, a well-known genus of bivalve.

mixed succession of marls, limestones, sands, and other sediments from east of the Volga. The Vyazniki beds lie below Triassic gypsum, marls, and limestones of Mount Bogdo and other locations. Murchison and Verneuil (1845) strengthened their view that the Vyazniki beds were Permian, and not Triassic, because the fossils, they argued, were more like Carboniferous than Triassic assemblages. The text in Murchison et al. (1845) concerning Vyazniki was likely printed in 1842 or 1843 (Thackray, 1978) and, although Murchison managed to insert revised sheets in certain places, there were inevitable mismatches between text and map.

3. After Murchison

The Russian geologist N.M. Sibirtsev (1896) restudied the Tolmachevo section as part of his geological mapping for the Geological Committee of Russia, and he identified the age of the rocks as Upper Permian. He reported fossil plants, invertebrates, and some bones. Further collecting in the 1950s extended the faunal lists, especially of vertebrates, and these have been identified as possibly terminal Permian in age (Strok et al., 1984; Sennikov and Golubev, 2006; Newell et al., 2010), possibly younger than any of the other Russian Permian vertebrate faunas.

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References

- Benton, M.J., 2000. Conventions in Russian and Mongolian palaeontological literature. In: Benton, M.J., Shishkin, M.A., Unwin, D.M., Kurochkin, E.N. (Eds.), *The age of dinosaurs in Russia and Mongolia*. Cambridge University Press, Cambridge, pp. xvi–xxxix.
- Benton, M.J., 2003. *When Life Nearly Died: the Greatest Mass Extinction of all Time*. Thames and Hudson, London, 336 pp.
- Benton, M.J., Tverdokhlebov, V.P., Surkov, M.V., 2004. Ecosystem remodelling among vertebrates at the Permo-Triassic boundary in Russia. *Nature* 432, 97–100.
- Collie, M., Diemer, J., 2004. Murchison's Wanderings in Russia. British Geological Survey, Nottingham, 474 pp.
- Daubrée, M., 1875. Notice nécrologique sur Edouard de Verneuil. *Annales des Mines, 7ème Série* 4, 318–320.
- Gaudant, J., 2008. *Géologues et Paléontologues: de la Passion à la Profession*. Éditions Presses de l'École des Mines, Paris, pp. 105–134.
- Koksharov, N.I., 1890. *Vospominaniya ('Reminiscences')*. Russkaya Starina (April–June), 1–20 (in Russian).
- Münster, A., 1865–1869. *Portretnaya Gallereya Russkikh Deyateley*. Tom 2. [Portrait Gallery of Russian Figures. 2 vols.] A. Münster Publishing House, St. Petersburg.
- Murchison, R.I., 1841. First sketch of some of the principal results of a second geological survey of Russia, in a letter to M. Fischer. *Philosophical Magazine and Journal of Science, Series 3* 19, 417–422.
- Murchison, R.I., de Verneuil, E., 1842. A second geological survey of Russia in Europe. *Proceedings of the Geological Society of London* 3, 717–730.
- Murchison, R.I., de Verneuil, E., 1845. On the Permian System as developed in Russia and other Parts of Europe. *Quarterly Journal of the Geological Society of London* 1, 81–87.
- Murchison, R.I., de Verneuil, E., von Keyserling, A., 1845. *The Geology of Russia in Europe and the Ural Mountains*. 2 vols. Volume 1, John Murray, London. Volume 2, Bertrand, Paris.
- Newell, A.J., Tverdokhlebov, V.P., Benton, M.J., 1999. Interplay of tectonics and climate on a transverse fluvial system, Upper Permian, southern Uralian foreland basin. *Sedimentary Geology* 127, 11–29.
- Newell, A.J., Sennikov, A.G., Benton, M.J., Molostovskaya, I.I., Golubev, V.K., Minikh, A.V., Minikh, M.G., 2010. Disruption of playa-lacustrine depositional systems at the Permo-Triassic boundary: evidence from Vyazniki and Gorokhovets on the Russian Platform. *Journal of the Geological Society*, 167, in press, doi:10.1144/0016-76492009-103.
- Rogers, J.A., 1973. The reception of Darwin's *Origin of Species* by Russian scientists. *Isis* 64, 484–503.
- Santonja, J.T., 2008. La influencia de Edouard de Verneuil en el desarrollo de la investigación de la geología española de su época. *Trabajos de Geología* 28, 15–24.
- Sennikov, A.G., Golubev, V.K., 2006. Vyazniki biotic assemblage of the terminal Permian. *Paleontological Journal* 40, S475–S481.
- Shafiranovsky, I.I., 1964. *Nikolai Ivanovich Koksharov*. Nauka, Moscow-Leningrad, 216 pp.
- Sibirtsev, N.M., 1896. General geological map of Russia. Sheet 72. Vladimir, Nizhny Novgorod, Murom. Geological investigations in the Oka-Klyaz'ma basin. *Trudy Geologicheskogo Komiteta* 15 (2), 1–283 (in Russian).
- Strok, N.I., Gorbatkina, T.I., Lozovskiy, V.R., 1984. Upper Permian and Lower Triassic Deposits of the Moscow Syncline. Nedra, Moscow, 140 pp. (in Russian).
- Thackray, J.C., 1978. R.I. Murchison's Geology of Russia (1845). *Journal of the Society for the Bibliography of Natural History* 8, 421–433.
- Tverdokhlebov, V.P., Tverdokhlebova, G.I., Surkov, M.V., Benton, M.J., 2003. Tetrapod localities from the Triassic of the SE of European Russia. *Earth-Science Reviews* 60, 1–66.
- Tverdokhlebov, V.P., Tverdokhlebova, G.I., Minikh, A.I., Surkov, M.V., Benton, M.J., 2005. Upper Permian vertebrates and their sedimentological context in the South Urals, Russia. *Earth-Science Reviews* 69, 27–77.