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Murchison's assessment of the Donetz coal basin

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Abstract. In 1840 and 1841, Roderick Murchison, together with Edouard de Verneuil and Alexander von Keyserling, undertook two field campaigns to examine the geology of Russia in Europe and the Ural Mountains. The 1840 campaign followed a route that took them as far north as Archangel before returning through Moscow to Saint Petersburg. After the successful 1840 campaign, the Russian government sanctioned a second campaign in 1841 that took the team as far east as the Ural Mountains during which they examined the stratigraphy en route as well as copper, gold, platinum and diamond mines. The team visited the Donetz coal basin during their return journey, having been requested by the Russian government to assess the quality and quantity of the coal deposits in that region. At that time, the Czar and his ministers were debating whether to industrialize Russia, including the construction of railroads, and assessing the coal resources in the Donetz region was an important element in that debate. Murchison and his team spent several weeks in the Donetz region examining the stratigraphy and visiting coal mines. The results of their investigation appear in Chapter 6 of *The Geology of Russia* (Murchison *et al.*, 1845, pp. 89–123) accompanied by cross-sections in Plate 1 and a geologic map in Plate 6. Further records of their fieldwork are found in his field notebooks, journal account, and letters written to his wife Charlotte. The team found that the active surface and shallow mines in the Donetz coal basin would soon be exhausted, but that there was promise for finding additional economic coal buried at depth beneath younger deposits, particularly if steam engines were introduced to assist with exploratory borings and mine dewatering. Murchison's recommendations were supported by his up-to-date knowledge of Paleozoic stratigraphy and coal mining technology. Those recommendations contributed to the development of an important source of coal which had ramifications for the development of Russian industry in the nineteenth century. The energy resources reported on by Murchison continue to play a role in international conflict as evidenced by the war in Ukraine that is currently under way.

Keywords: Roderick Murchison – Donetz coal basin – *The Geology of Russia* (1845) – Ukraine

Introduction

In the late summer of 1841, Roderick Murchison spent several weeks investigating the coal fields of the Donetz region in what was then southern Russia. He had been commissioned by Czar Nicholas and by the Czar's finance minister, Count Georg von Cancrine, to investigate the extent and quality of the coal deposits in the Donetz coal basin (Collie and Diemer, 2004). He was also asked to suggest improvements in coal mining practices that could be applied in order to increase the production of coal. The Russian government at the time was exploring the bene-

fits of expanding the railway system as well as establishing steam-powered manufacturing facilities so that coal was a necessary source of energy to enable those transitions (Riasanovsky, 1984). At that time the Donetz coal basin was the most productive source of coal in Russia and was therefore of strategic importance.

Why did the Czar choose Murchison to undertake this task? First, Murchison was widely perceived as an authority on geological matters, including coal-bearing rocks (Geikie, 1875; Collie and Diemer, 2004). Second, he was known to Baron Brunow, the Russian Ambassador to Brit-

ain, who recommended Murchison to high-ranking ministers of the Czar including Sergey Uvarof, Minister of Education, and Count Georg Cancrine, Minister for Finance (Collie and Diemer, 2004; Benton and Sennikov, 2021). Murchison's growing reputation as an authority on geological matters was widely known; he had joined the Geological Society of London in 1825 at the age of 32 (Geikie, 1875). He quickly rose in prominence and was first elected President in 1831 (Herries Davies, 2007). It was during his second term as President, from 1841 to 1843, that Murchison visited the Donetz coal basin.

Murchison's research method

Murchison's impressive scientific output was possible given his abundant energy, ambition and networking skills (Bailey, 1952; Rudwick, 1985; Secord, 1986; Stafford, 1989; Oldroyd, 1990; Diemer, 2008;). Murchison was also a master at logistics and synthesis, and he developed a fieldwork methodology that enabled him to make rapid progress when mapping large areas (Diemer, 2022). This paper provides an example of his fieldwork methodology as he applied it in Russia. That methodology first of all relied on detailed preparations. He typically assembled as much information as he could about a region he planned to visit. This included gathering together publications and maps and corresponding in advance with scientists who were familiar with the region (Bailey, 1952).

Once on the ground, Murchison invariably sought out local experts to ask their advice (Collie and Diemer, 1995; Diemer, 2017, 2018). He made a habit of visiting local museums to inspect the fossil collections and, where possible, acquired any geologic maps that covered those areas. Another practice Murchison engaged in was to travel with at least one other geologist. This permitted the exchange of ideas in the field and the verification of observations by another expert. In undertaking fieldwork in Russia, Murchison relied heavily on Edouard de Verneuil, an

accomplished paleontologist, to identify the Paleozoic fossil material while in the field. Later, upon returning to Paris, De Verneuil was largely responsible for describing and illustrating the fossil evidence that was published in Volume 2 of *The Geology of Russia* (1845). Murchison also relied on his younger colleague, the naturalist Alexander von Keyserling, to undertake independent surveys of remote locations such as the Petchora River basin on the west flank of the northernmost Urals, and Mount Bogdo in the Khirgis steppe. In both cases, Keyserling's remit was to retrieve fossil material which could then be examined by specialists in order to determine the age of the strata at those remote sites. Upon return from the field, Murchison promptly announced his findings, both at scientific meetings and in print.

The Russian campaigns, 1840 and 1841

An excellent example of his fieldwork methodology in action was the work he did that resulted in the mammoth book entitled *The Geology of Russia in Europe and the Ural Mountains*. The book is a handsome, well-illustrated, two volume set published in 1845 by John Murray of London and Bertrand of Paris. Murchison wrote Volume 1 on the geology of Russia, and his collaborator, Edouard de Verneuil, prepared Volume 2 on the paleontology of the regions that they visited.

Volume 1 of *The Geology of Russia* is illustrated by a pair of maps, one of which is shown here (Fig. 1), five copper engraved plates with cross-sections, as well as a dozen lithographs, and 83 wood-cuts (Thackray 1978; Diemer and Diemer, 2021). The map shown here, Plate 6 of *The Geology of Russia*, is accompanied by a generalized stratigraphic section on the right margin, and a cross section along the base of the map extending from Saint Petersburg on the north to the Sea of Azof on the south.

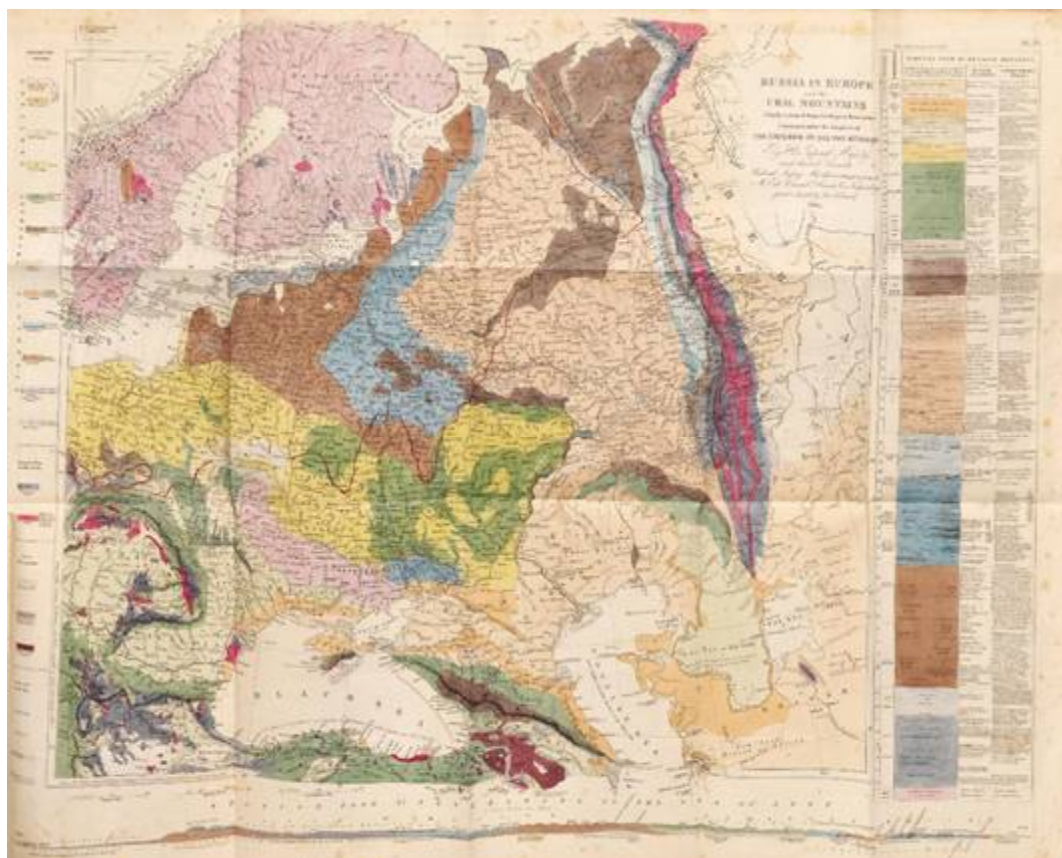


Fig. 1. Plate 6 from The Geology of Russia (1845)



Fig. 2. Travel routes for Murchison and his team in 1840 in northern Russia. Underlying geology modified from Plate 6 of The Geology of Russia (1845)

The maps and sections of Volume 1 were the product of observations made during two extensive field campaigns in Russia. Shown here is the route that Murchison and his team took during the 1840 campaign where they started in Saint Petersburg and traveled north to Archangel before turning southward to Usting and Nishni Novgorod (Fig. 2). Their route then took them to Moscow on their way back to Saint Petersburg. During that expedition they mapped crystalline basement rocks unconformably overlain by the Silurian and Devonian Systems. They also mapped the Carboniferous System overlain by red sedimentary rocks that would later be assigned to the Permian System (Murchison, 1841; Benton *et al.*, 2010; Benton and Sennikov, 2021).

The more southerly route taken in 1841, as well as the route taken in 1840, is shown on Fig. 3. The 1841 route began in Berlin where Murchison conferred with Alexander von Humboldt about the geology of Russia. Murchison and members of his team then traveled to Saint Petersburg and continued through Moscow, Kazan and Perm before criss-crossing the Ural Mountains several times. The team then traveled back through Orenberg, Samara, Sarepta and Novo Tcherkassk before arriving in the Donetz coal basin. Note the modern-day outline of the country of Ukraine and its border with Russia and Belarus. Note also that the Donetz coal basin is in eastern Ukraine and is the location of much fighting today.

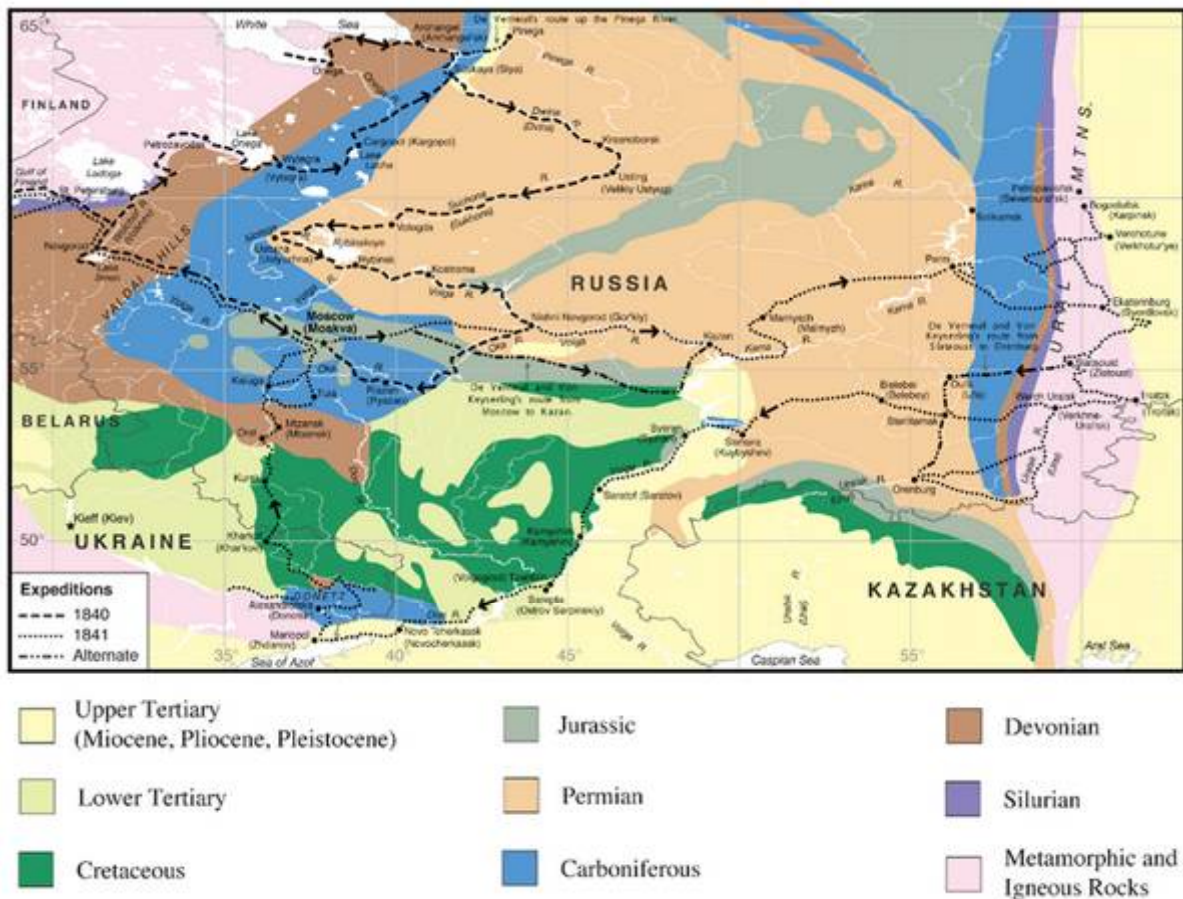


Fig. 3. Travel routes taken by Murchison and his team in Russia in 1840 and 1841. Underlying geology modified from Plate 6 of *The Geology of Russia* (1845).



Fig. 4. Travel routes (dotted lines with direction of travel indicated by arrows) taken by Murchison in the Donetz coal basin in 1841. Underlying geology modified from Plate 6 of *The Geology of Russia* (1845).



Fig. 5. Geologic map of Donetz coal basin, close up from Plate 6 of *The Geology of Russia* (1845). The units shown on the map, and their colors are as follows: a (pink) Azoic gneisses, b (red) younger granites, 3 (blue) Carboniferous, 4 (orange) Permian, 7 (green) Cretaceous, 8 (yellow) Eocene, 9 (pale green) Miocene, 10 (dark tan) Pliocene, and 10' (light tan) Pleistocene.

The Donetz coal basin

A closer view of the Donetz region appears in the next map (Fig. 4). The southeastern corner of this map is labeled as part of Russia. The political boundary can be seen as a gray line situated a short distance to the west and north of Taganrog. The remainder of the map, including the Donetz coal basin, is in Ukraine.

Murchison and his colleagues traveled extensively within the Donetz coal basin, visiting active coal mines, in an effort to assess the quality and extent of the coal deposits. The sites they visited enabled Murchison to map the extent of the Carboniferous system shown in blue in Fig. 4. Upon arriving in the Donetz region, they first traveled northward up the Kalmiuss River valley, and then turned to the east to inspect coal mines that occur in the eastern part of the Donetz coal basin. From there, they traveled westward, as far

as Petropavlosk before returning to Bachmuth, where they then turned northward toward Moscow at the end of their field season. This extensive inspection led to the detailed geology for the Donetz coal basin which was incorporated into Plate 6 as shown in Fig. 5.

This close up view of the Donetz coal basin from Plate 6 of *The Geology of Russia* (1845) shows the locations of various coal mines as black dots, as well as cross-sections as black lines. The cross sections in Plate 1 of *The Geology of Russia* (1845) illustrate the attitude and extent of the coal deposits. Murchison and his team spent several weeks on a close inspection of the Donetz coal basin. Whereas they were not the first to examine the geology of the Donetz coal basin, they were the first to apply the recently developed Paleozoic system nomenclature to those deposits.



Fig. 6. Ivanitski's geologic map of the Donetz coal basin and vicinity. From the British Geological Survey, Keyworth, GSM 1/126 (31).

Previous work in the Donetz coal basin

Shown here is a geologic map of the Donetz region made by Captain Ivanitski (Fig. 6). The shoreline of the Sea of Azof is indicated by a blue band at the base of the map. The blue areas in the central part of the map delineate the occurrence of coal bearing deposits. Murchison was provided with a copy of Ivanitski's map by General Tcheffkine, the Director of Mines and Public Works, when he passed through Saint Petersburg earlier in the summer. This copy of the map is today in the archives of the British Geological Survey and has Murchison's handwritten annotations.

Passages from *The Geology of Russia* reproduced in Fig. 7 identify the sources of information provided by the Russian authorities. It is clear that Murchison benefited from access to that material when he was investigating the Donetz coal basin. He pointed out that the previous workers had said "*that owing to the convolutions of the strata and the want of fixed mineral characters, no regular order could be established.*" He

went on to say "*To geologists, therefore, who like ourselves were thrown into a new field, in which the succession of the beds was perfectly unknown to us, nothing could be more satisfactory than to find, in one of the first sections which we made, a key to the whole order of this country and by which we established the most ancient strata occupy the southern zone of this carboniferous region*" (Murchison *et al.*, 1845, vol. 1, p. 93). Thus, led to the Kalmiuss River section by reference to the maps and sections of Captain Ivanitski and others, Murchison and his team were able to establish that rocks of the Devonian System rested unconformably on crystalline rocks and were dipping and ascending stratigraphically in a northerly direction, as will be shown in subsequent figures. This discovery was an important conceptual breakthrough that permitted the correlation of the coal-bearing rocks of the Donetz region with the Carboniferous System of western Europe. This new overview built on the data-rich observations of Ivanitski to firmly establish the stratigraphic position of the coal-bearing rocks of the region.

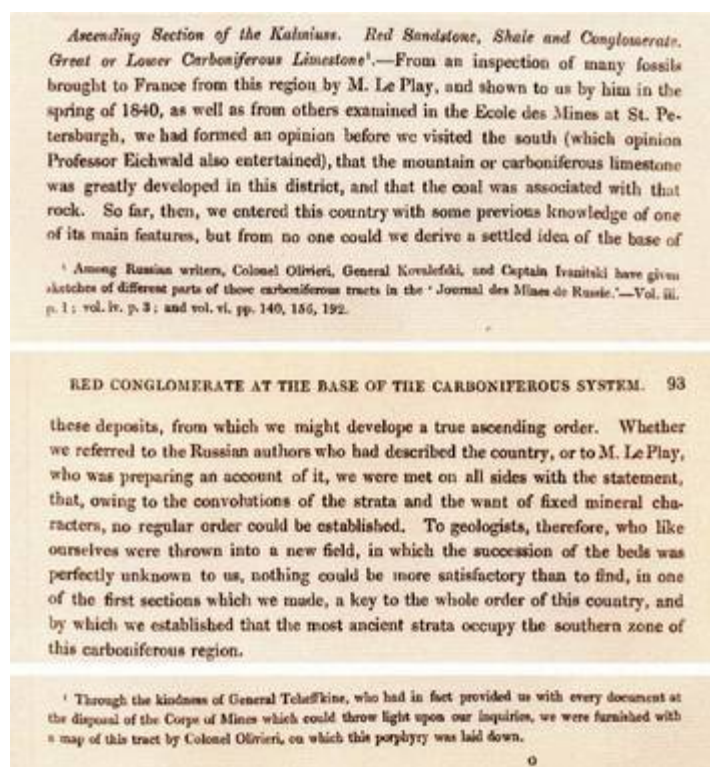


Fig. 7. Sources of information provided by the Russian authorities to Murchison reproduced from *The Geology of Russia*, 1845, pp. 92–93.

Plate 1 of *The Geology of Russia* (1845) documents the attitude and stratigraphic positions of the coal seams at 9 locations throughout the Donetz coal basin (Fig. 8). 'Figure 1' in the upper right portion of Plate 1 is the key Kalmiuss River cross section (Fig. 9) with granites and porphyries at the base which are overlain by a red conglomeratic sandstone which Murchison assigned to the Old Red Sandstone. Recognition of the Old Red Sandstone enabled Murchison to assign the base of the Carboniferous to the southern end of

the Kalmiuss River cross-section. The section includes crystalline igneous rocks (pink and red) at the base which are unconformably overlain by northward dipping stratified sedimentary rocks (brown, blue and gray). The brown strata, labeled as Old Red Sandstone are overlain by tilted and folded Carboniferous strata (gray and blue). The coal seams within the Carboniferous strata are shown as black lines on the section (Fig. 9) and the locations of coal mines are represented by black dots on the map (Fig. 5).

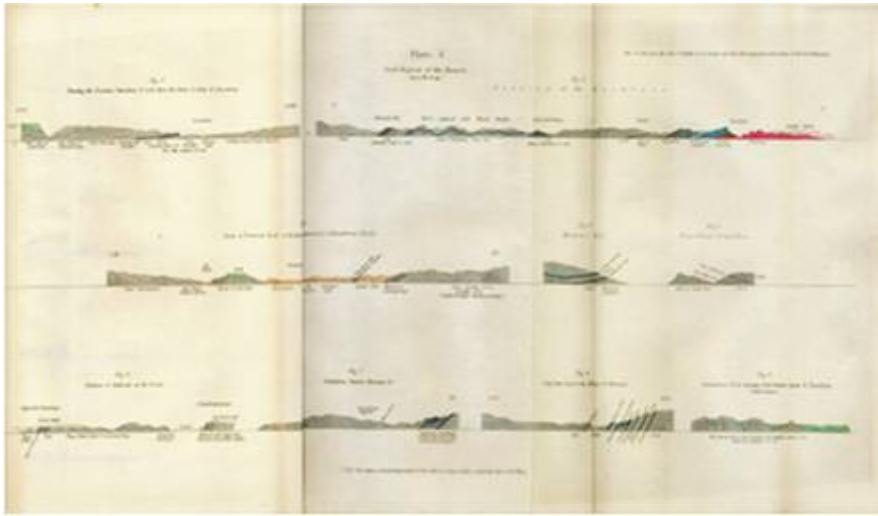


Fig. 8. Plate 1 of *The Geology of Russia* (1845) comprising 9 cross-sections of coal-bearing localities ('Figures 1–9') in the Donetz coal basin.



Fig. 9. Expanded view of Plate 1, 'Figure 1', "Section of the Kalmiuss", from *The Geology of Russia* (1845).

Key localities in the Donetz coal basin

A close-up of the southern end of the Kalmiuss River section is shown in Fig. 10. The sandstones (in brown) overlying the porphyry (in red) are labeled as Old Red Sandstone. The steeply dipping blue layers are fossiliferous limestones interbedded with the sandstones and shales (shown in gray) of the Carboniferous. The black layer is a coal seam within the grits of the Carboniferous.

Fig. 11 portrays the southern part of the Kalmiuss River section by Ivanitski. Compare this section with the one by Murchison (Figure 10) for the same stretch of the river valley. Note that the unconformity between the vertical porphyry and the northward-dipping sandstones and limestones at Karakuba is indicated on both sections. Being able to refer to Ivanitski's section no doubt assisted Murchison to quickly recognize the Paleozoic systems comprising the stratigraphy in the Kalmiuss River valley section.

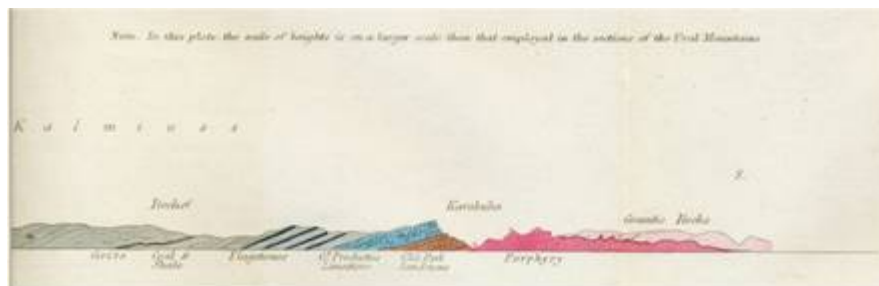


Fig. 10. Close-up view of the southern end of Plate 1, 'Figure 1', from *The Geology of Russia* (1845).



Fig. 11. Ivanitski's section from the southern part of the Kalmius River. Compare to the section by Murchison in Fig. 10. Ivanitski's section is from the British Geological Survey archives, GSM 1/126 (62).

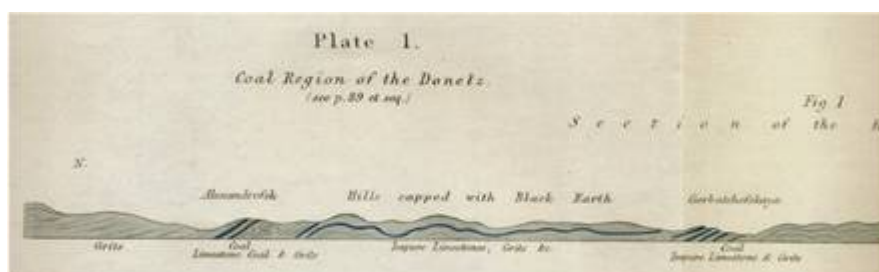


Fig. 12. Northern end of the Kalmius River section, Plate 1, 'Figure 1' from *The Geology of Russia* (1845).

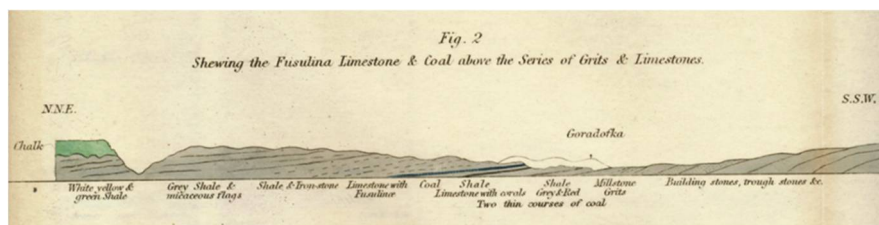


Fig. 13. Cross-section in the vicinity of Goradofka, from Plate 1, 'Figure 2', *The Geology of Russia* (1845).

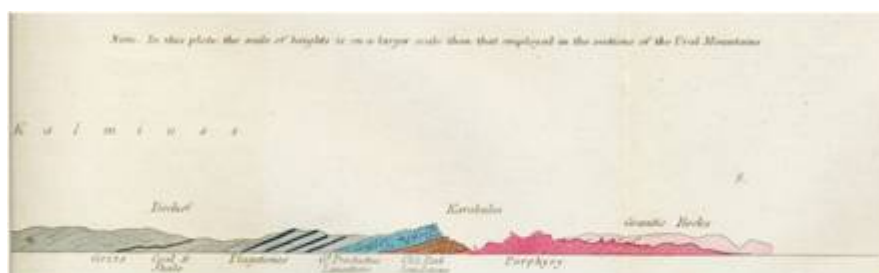


Fig. 14. Cross-section in the vicinity of Bachmuth from Plate 1, 'Figure 3', *The Geology of Russia* (1845).



Fig. 15. Ivanitski's section in the vicinity of Bachmuth. Compare to Murchison's section in the same area (Fig. 14). From the British Geological Survey archives, GSM 1/126 (62).

Fig. 12 portrays the northern end of the Kalmiuss River section in 'Figure 1' of Plate 1. Note that the Carboniferous rocks are folded in this part of the section. Murchison described the 7 feet thick coal seam at Alexandrofsk as thinly bedded, bituminous, and containing pyrite. The coal was mined by the government in shallow shafts located not more than 100 feet above the Kalmiuss River. The depths of the shafts were limited by the influx of groundwater. Steam engines were not in use to pump the groundwater. The coal at Alexandrofsk is overlain by a limestone containing *Productus*, *Spirifer*, and large *Lithodendron*. Murchison thought that the limestone was similar to the 'mountain limestone' in England and Ireland.

Fig. 13 reproduces 'Fig. 2' from Plate 1 of *The Geology of Russia* (1845). It portrays the northward dipping Goradofka section near the stratigraphic top of the Donetz coal basin. The Carboniferous strata comprise flagstones, grits, shales, limestones and coal seams. The grits were quarried and used locally for door-posts and troughs. The limestones contained fusulinids and trilobites and the coals were bituminous. Note that the north end of the section has Cretaceous chinks unconformably overlying the Carboniferous strata. Presumably, the Carboniferous strata continued at depth to the north, and if they contained coal seams, Murchison suggested that those seams might remain within reach of vertical mine shafts for some distance.

Fig. 14 is a line of section oriented SW-NE that passes through Bachmuth (see Figure 5). The section is noteworthy because it exhibits a synclinal structure with Permian beds occupying the center of the fold at Bachmuth. The section also shows Cretaceous chalk unconformably overlying the Carboniferous to the southwest of Bachmuth.

The Bachmuth section prepared by Captain Ivanitski (Fig 15) bears a strong resemblance to 'Figure 3' in Plate 1, prepared by Murchison (see Fig. 14). Once again, Murchison likely benefited from data gathered by Captain Ivanitski as they both depicted a syncline centered on Bachmuth. Murchison assigned the core of the syncline to

the Permian, a system he was in the process of defining in 1841 (Murchison, 1841; Benton *et al.*, 2010; Benton and Sennikov, 2021). By comparison, Ivanitski assigned the red sandstones and shales in the vicinity of Bachmuth to the Triassic. Thus, Murchison was the first to apply the newly developed Paleozoic system nomenclature to these rocks.

The section at Krasnoi Kut on land owned and occupied by General Papkoff is shown in 'Figure 4' from Plate 1 of *The Geology of Russia* (1845) (see Fig. 16). The section depicts

- Two anthracite coals that were mined in adits in the hillside and were in beds about 3 feet thick. According to Murchison, they were 'excellent' seams of anthracite being indistinguishable from iridescent British varieties.
- Murchison noted that the coals at this site were far enough to the east to be anthracite as compared to bituminous coals that occurred to the west. He thought that this may be due to heating from below by emplacement of igneous rocks that "*may have converted the superjacent ordinary coal into anthracite, and have indurated the associated grits, sandstones and schists*" (Murchison *et al.*, 1845, v. 1, p. 101).
- Murchison wrote that the line of transition from bituminous coal in the west to anthracite coal in the east, and the chemical make up of the coals, were being studied by Captain Ivanitski and M. Le Play.
- Murchison also noted that the coal mined at this locality was used in steam engines in a nearby manufactory established by General Papkoff.

Fig. 17 portrays another anthracite coal-bearing section, this one at Popofka. This is 'Figure 5' of Plate 1 from *The Geology of Russia* (1845). Murchison noted that the

- Coals at Popofka, in the eastern part of the Donetz Coal Basin, are high quality anthracite seams about 3 feet thick and were "... chiefly worked by galleries, in which the poor

Cossack miners have followed it to short distances from its natural outcrop on the sides of the brooks" (Murchison *et al.*, 1845, v. 1, p. 102). Murchison also noted that if steam engine water pumps were to be introduced, the seams potentially could be followed to greater depths and below the groundwater table.

- Mining of this anthracite coal was encouraged by Count M. Woronzow, the Governor of the district. The Governor wanted the popul-

ation to move away from scarce wood as a source of fuel. The coal being mined at Popofka was transported by light carts to Novo Tcherkask and to the iron forges of Lugan.

- Mines at Popofka were described by Captain Ivanitski in the 6th volume of the *Journal of the Imperial Mines*. Ivanitski was also conducting experiments on the heat produced by the coal, at the behest of General Tcheffkine.

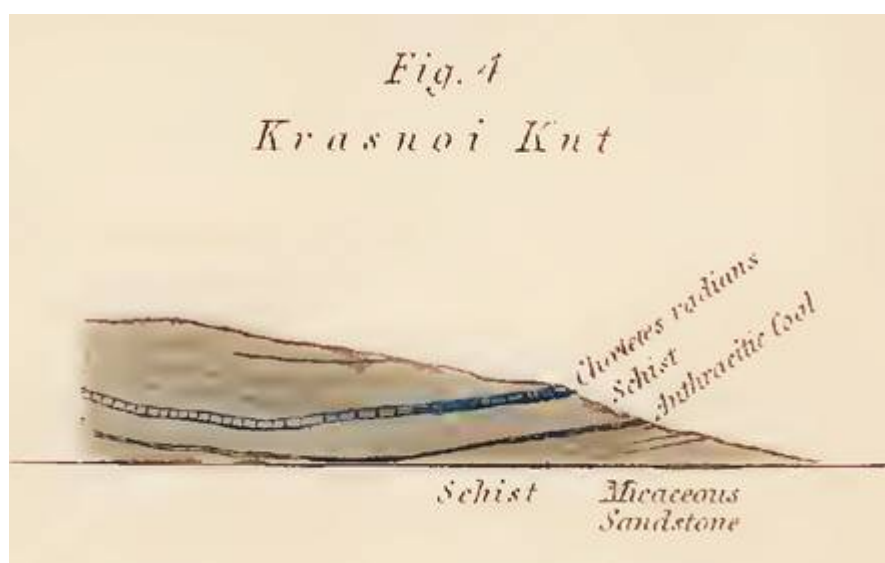


Fig. 16. Section at Krasnoi Kut, the residence of General Papkoff, from Plate 1, 'Figure 4', of *The Geology of Russia*, (1845).



Fig. 17. Section at Popofka, from Plate 1, 'Figure 5', *The Geology of Russia* (1845).

Fig. 18 contains a shaft section of the productive Lissitchia-Balka coal mines. The section was prepared by Captain Ivanitski and it recorded multiple bituminous coal seams in black, interbedded with limestones, shales, sandstones, grits and 'schist'. Note that these bituminous coals occurred in the western part of the Donetz coal basin.

Murchison used Ivanitski's hand drawn shaft section in Fig. 18 to produce the detailed section

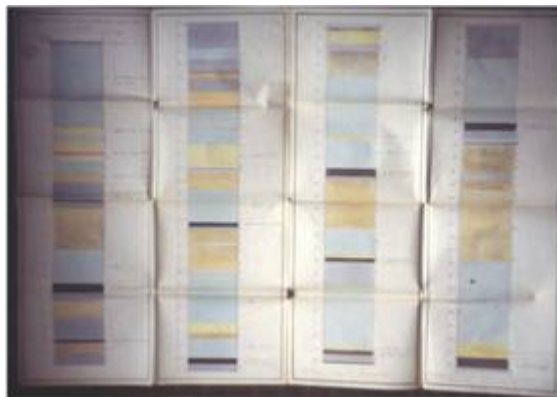


Fig 18. Shaft section at Lissitchia-Balka prepared by Captain Ivanitski. From the British Geological Survey archives, GSM 1/126 (77).

on page 111 of Volume 1 of *The Geology of Russia* (Fig. 19). As with Ivanitski's original section, Murchison's published section comprises interbedded sandstones, shales, limestones and coals. There are 12 labeled coals and the section appears to record multiple cycles of deposition. Murchison interpreted the coals to be 'submarine' in origin, but from a modern perspective, the section more likely comprises multiple transgressive and regressive sequences which deposited cyclothem with terrestrial coals.

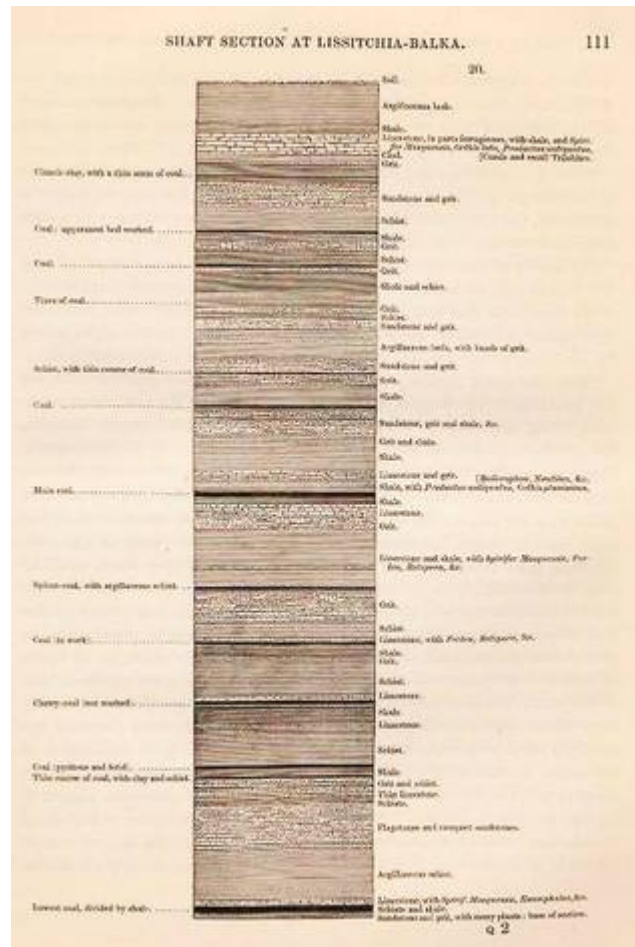


Fig. 19. Shaft section at Lissitchia-Balka by Murchison, from *The Geology of Russia* (1845), p. 111.

Synthesis of observations in the Donetz coal basin

Fig. 20 reproduces a portion of the stratigraphic column on the right-hand margin of Plate 6 of *The Geology of Russia*. It provides a summary of many of the observations and interpreta-

tions made by Murchison concerning the Carboniferous System in Russia. The Carboniferous System is divided into a Lower (dark blue) and Upper Carboniferous (light blue). The Carboniferous is also divided into a 'North Region' without coal on the left and a 'South Region' with coal on the right.

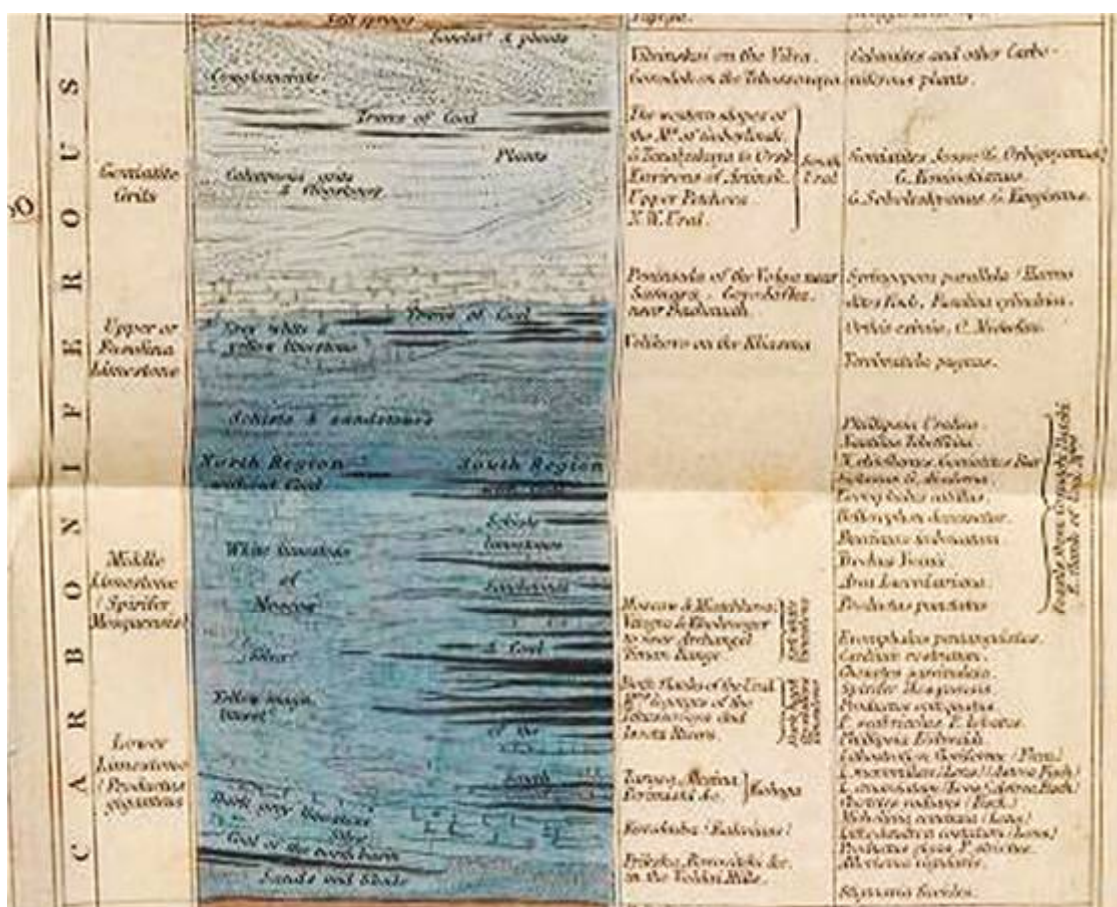


Fig. 20. Regional stratigraphy of the Carboniferous System, from Plate 6 of *The Geology of Russia* (1845).

The right-hand side of the column portrays the stratigraphy of the Carboniferous System in the Donetz coal basin. The base of the Donetz section occurs at Karakuba on the Kalmiuss River. The top of the Donetz section occurs at Gorodofka near Bachmuth. Note the multiple coal seams interbedded with sandstones, limestones and 'schists', similar to the detailed stratigraphy of the shaft section at Lissitchia-Balka shown in Fig. 19.

Conclusions

This paper documents Murchison activities in the Donetz coal basin and provides a good example of his collaborative fieldwork methodology in action.

- First, he researched in advance by reading

available publications and consulting with knowledgeable geologists such as Alexander von Humboldt.

- Second, he assembled relevant maps and publications to assist in his campaign; in this case he made extensive use of Captain Ivnitski's geologic map and cross sections.
- Third, he interviewed local experts and visited their collections. Of most use was the Donetz basin fossil collection of M. Le Play of Paris.
- Fourth, he traveled with other scientists to verify his observations. In 1841 he was accompanied by Edouard de Verneuil and Alexander von Keyserling while investigating the Donetz coal basin.
- Fifth, he announced his findings both at meetings and in print, most notably in Chapter 6 of *The Geology of Russia*.

In addition, this paper discusses Murchison's contributions to understanding the geology of the Donetz coal basin. Some of his major findings include the following:

- First, Murchison and his team provided careful documentation of the occurrence and extent of coals throughout the Donetz coal basin, both on the geologic map and in the associated cross-sections.
- Second, they established that the coal fields in the Donetz basin were in rocks of the Carboniferous System that dipped in a generally northward direction.
- Third, the base of the Carboniferous System was recognized by its contact with the underlying Devonian System and older crystalline rocks.
- Fourth, the top of the Carboniferous System was overlain by the Permian System.
- Fifth, Murchison recognized that the depths of mines were limited by groundwater, and

that the introduction of steam driven pumps would greatly increase the production from many of those mines.

- Sixth, Murchison recognized a regional change from bituminous coals in the west of the Donetz coal basin to anthracite coals in the east, and attributed that gradation to heat emanating from the emplacement of granitic rocks at depth.
- Seventh, Murchison recognized that the Carboniferous stratigraphy of the Donetz coal basin was distinct from the Carboniferous rocks in the vicinity of Moscow.

As a final note, the coal deposits of the Donetz coal basin remain of strategic value. They have likely played an important role in Russia's invasion of Ukraine. The Donetz coal basin was occupied in 2014 at the same time as the Crimean Peninsula, indicating that the coal deposits continue to be prized highly by Russia.

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