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THE LAKE IL'MEN CLINT, RUSSIA: A POTENTIAL DEVONIAN GEOPARK

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The Devonian rocks exposed on the shores of Lake Il'men, some 150 km SSE of Saint Petersburg, are important historically in the context of the recognition of the Devonian System. Moreover, they provide unique potential for a range of geological studies today. The non-geological heritage of the area – its flora, fauna, past and current industrial use and cultural links – is also a very worthy one. Since 2001 the area has been recognised as a Specially Protected Natural Territory. A 'Geopark' is a unified area of local or wider extent that has been so designated based on its significant geological and associated natural and cultural heritage. There are many positive criteria for considering that the Lake Il'men area could acquire the appellation of a Geopark. Scientific investigations dedicated to understanding the geodynamical conditions operating at Lake Il'men would resolve how to best to help promote the future preservation of this unique natural area.

Key words: Devonian; Frasnian; Geopark; Lake Il'men; Murchison

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Introduction: the Geopark concept. A Geopark is a unified area of local or wider extent with ageological heritage of local, national or international significance. Within the area designated as a Geopark there are normally several localities («points») that are recognised to be of particular geological interest. The significance of associated cultural aspects of the area is also integral to the Geopark concept. The archaeology, industrial heritage, wildlife and flora of an area combine to enhance its interest and educational significance. All members of the public should be able to visit any Geopark and information about the identity and significance of each individual Geopark should be accessible and understandable to all regardless of age or background. A Geopark should aim to elucidate, educate and stimulate interest in the area in question in the context of a changing planet. While highlighting aspects of geological significance is clearly a prime aim it should also inform about the sustainable use and need for any raw materials, for example, rock, minerals or water, that may be harnessed from the surrounding environment and be of economic and social value. Respect for the integrity of the environment and landscape is also a core aim of a Geopark. Geoconservation, promoting informed geo-tourism and geo-education are important aspects of the Geopark concept.

There are many countries world-wide with areas formally designated as «Geopark», at various geographical scales. Furthermore, many Geoparks network together symbiotically, on a local, regional or national basis, especially within Europe. Under the auspices of UNESCO the European Geoparks Network now consists of over 60 Geoparks in more than 20 countries. Part of the Altai area of Russia was officially recognised as «Geopark Altai» in 2015. It is something of an anomaly that there are no designated Geoparks in the European part of Russia.

The Lake Il'men site. The potential Geopark site represents a rare and outstanding natural geological exposure on the southern shore of Lake Il'men, situated immediately south of Novgorod some 150 km SSE of Saint Petersburg (Fig.1). Staraya Russa is the nearest regional center. The lake is large, with a surface area of almost 1000 sq km, but it is relatively shallow, with an average depth of some 2.6 metres and a maximum depth of about 10 metres. The water level of the lake can show considerable seasonal variation. In Spring, with input from numerous tributaries, local flooding can occur. Dry periods can witness a reduction of the area of the lake. The basin of the lake is large, involving about 50 inflowing rivers; a single outlet ultimately drains via the Volkhov River into Lake Lagoda and onwards to the Neva and into the Gulf of Finland.

After the last (Valdaian) glaciation climate warming and ice melting resulted in the formation of water bodies including Lake Il'men at the site of a preglacial depression in the lowland area of the Eastern European Platform. More than 90 % of the lake depression is filled with glacial and



Fig.1. The River Volkhov-Lake Il'men drainage basin (after A.F.Safronov)

post-glacial deposits. The Quaternary complex is represented by upper Pleistocene sediment, of glacial, glaciolacustrine and glaciofluvial origin, and Holocene deposits derived from lakes, rivers and marshes.

The underlying rocks are assigned to the Frasnian (Late Devonian) age of geological time (373-383 Ma). They are well exposed particularly on the southern shores of Lake Il'men and also in the banks of the associated rivers Perekhoda, Psizha and Savvateyka. The geology affords commendable opportunity for detailed study in both time and space, the latter based on the wide lateral extent of shallow-water facies of a Late Devonian subtropical epicontinental sea basin and platform tectonic structures. Transgressive and regressive cyclic depositional patterns and various unconformity surfaces can also be observed. The outcrop on the southern shores of the lake, from the village of Korostyn in the west to the village of Ustreka in the east, forms about fifteen kilometers of accessible 5-12 metres high cliff – the so-called Il'men «Clint» of

Scandinavian usage (Fig.2, 5). These cliffs are actively being eroded by basal slip on the underlying clays and are constantly being renewed as fresh exposure. Building behind the cliff line is currently limited to impermanent traditional wooden dachas, but that may not be the case in the future. The land on the plateau area is for sale commercially as plots for the construction of individual cottages. Such development may in time encroach near to the site although the active erosion should prevent building on the cliff itself.

Pioneer studies of the geology of the Lake Il'men area. The area of Devonian rocks of the Eastern European Platform is known as the Main Devonian field. Beginning in the middle of the 18th century both foreign geologists and researchers from the St Petersburg area studied the geology of the Lake Il'men region (Fig.3-5) and made comparisons between the Devonian of west Russia, central Europe and the United Kingdom. Amongst researchers who made early observations of the sedimentary layers of the clint were academics and naturalists such as J.G.Lehmann and G.P.Helmersen. Lehmann, a German scientist, left general notes from the time he lived in St Petersburg (1761-1767). He was invited to work in St Petersburg as a chemist and director of the Imperial Cabinet of Natural Materials and he made an early description of the geology of the southern Priyolmenye. It was probably Helmersen or Count Alexander de Keyserling who initiated the invitation for the celebrated Scottish pioneer geologist Sir Roderick Impey Murchison (Fig.6) to visit the

area. Murchison had played a fundamental role in recognizing and establishing not only the Silurian System based on sequences in Wales and the Welsh Borderland, but also the Devonian system based on rocks in the county of Devon in south-west England. But at the time of his visit to Russia Murchison had a significant problem in establishing the Devonian as a separate system and which was proving very controversial. In Scotland there was clearly terrigenous Old Red Sandstone sediments with distinctive fossil fish, whereas in Devon there were limestones with brachiopods and corals that were somewhat intermediate between the comparable Silurian and Carboniferous faunas. Murchison had visited continental Europe in the summer of 1839 and importantly had met von Buch in Berlin and studied his collection of Russian fossils. These discussions and the fossil collection provided the impetus for Murchison to see the Russian sections for himself.



Fig.2. An exposure of the Buregskaya Formation on the shores of Lake Il'men. The cliff is 6-8metres high

In 1840 Murchison travelled separately and together with E. de Verneuil, Meyendorff and de Keyserling, who was an explorer, a major administrator and a formidable figure in the mining industry. They made a long excursion from St Petersburg, up to Arkhangelsk and then circuitously to Nishni Novgorod, Moscow and back to St Petersburg. For this expedition Murchison was always

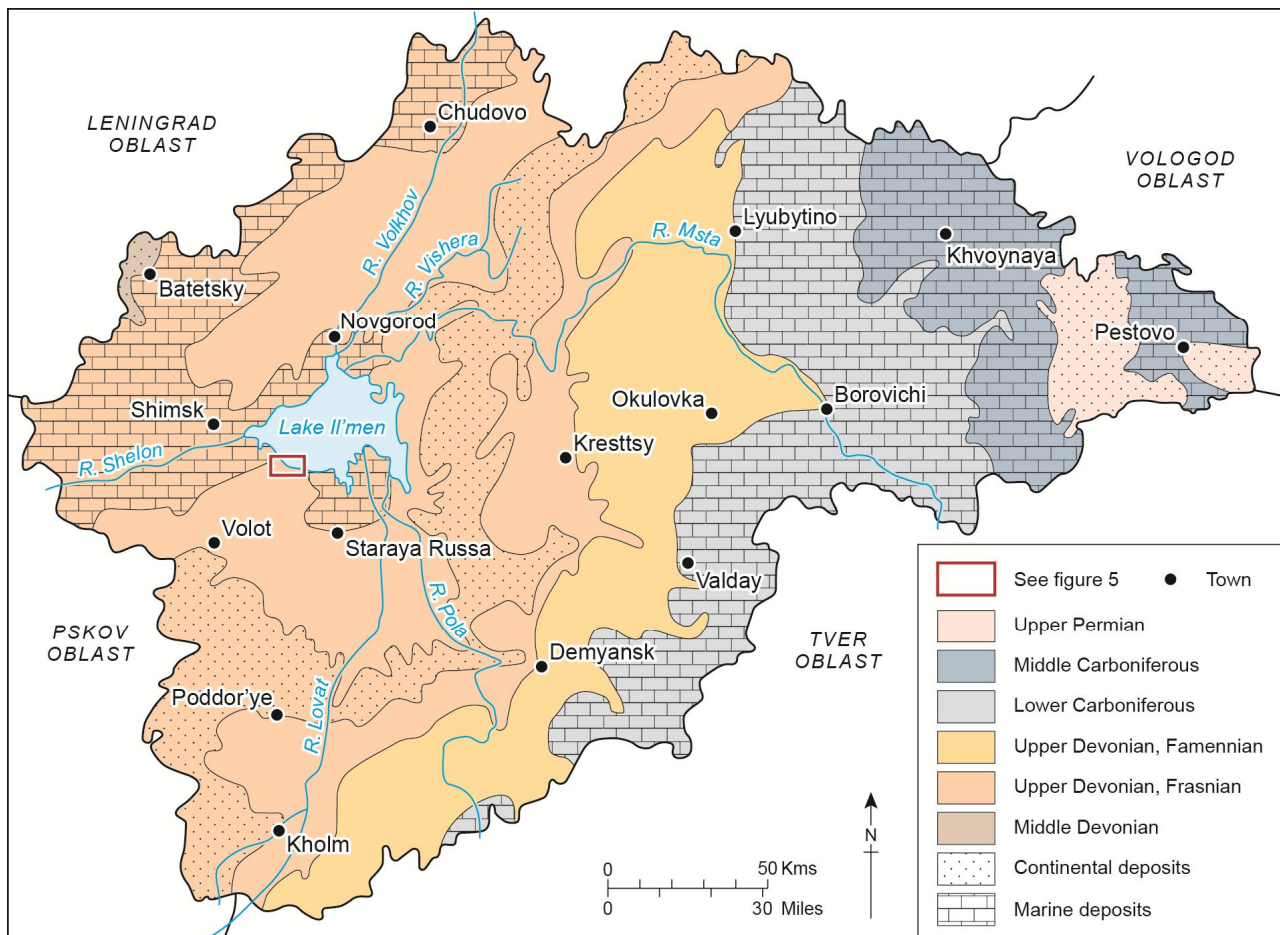


Fig.3. Geological map of the Novgorod Oblast [4]

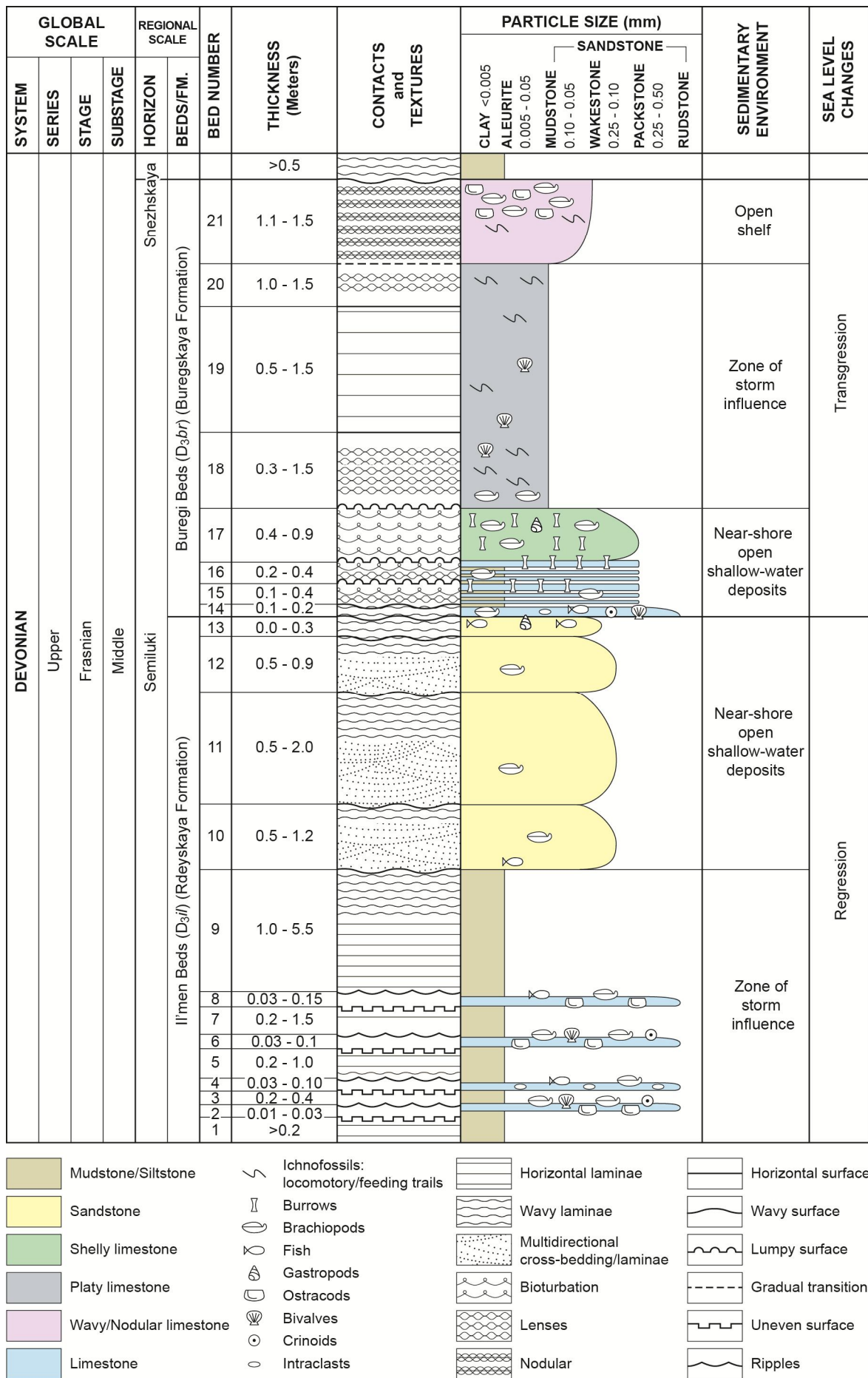


Fig.4. Schematic diagram of the stratigraphy of the Lake Il'men region [12]

accompanied and assisted in the field by Lieutenant N.I.Koksharov, then a newly graduated geologist. Koksharov was a mineralogist and later became, inter alia, the founder of the Mineralogical Society of Russia, an academician and the Director of the Corps of Mining Engineers. In 1840 Murchison also had important meetings in St Petersburg including with Helmersen and saw his geological map of Russia. Amongst the first geological sections they visited were on the banks of the Volkoff that flows between lakes Ladoga and Il'men (Fig. 1). It was here that they first encountered beds that contained both marine Devonian brachiopods and fish, demonstrating that the Old Red Sandstone of Scotland and the marinelimestones of Devon were lateral equivalents. It was on the return from this long excursion that Murchison visited Lake Il'men and he provides us with a brief description of the sections [21, p. 44] that is still recognizable today. Importantly the Il'men Clints is another locality where Devonian brachiopods and fish can be found together and unlike the Volkoff River localities remains relatively untouched and accessible since the time of Murchison and Koksharov.

The earliest fundamental stratigraphic studies were published by Murchison and his associates after their trip to the River Volkhov and Il'men Clint [19-21]. The first geological map of the European part of Russia was compiled by G.Helmersen [3], and a more detailed map by Murchison and others appeared in 1845. In spite of such progress the correlation of Devonian deposits was still a contentious issue. A letter of November 1857, from Professor K.I.Pander to Professor A.F.Folbort, noted that, «Yesterday I received a very kind letter from Murchison. He writes to me, by the way, that in England many geologists still deny the correspondence of the Russian Devonian deposits, so rich in mollusks, the Scottish sediments containing only the remains of fish. He says that I can give him important support in this matter, and I want to seriously tackle this issue the other day and send him an article...» [2, p. 1].

The geology of the Lake Il'men site.

The geology of the site consists of a complex



Fig.5. Geology of part of the Il'men Clint area [8]



Fig.6. Sir Roderick Impey Murchison (1792-1871), pioneer geologist who was amongst the first to describe the Devonian faunas of the Lake Il'men region

of Devonian carbonate-terrigenous sediments, with fossils (Fig.7), in a monocline dipping gently to the southeast at an angle of about 7 minutes [see 5]. Low amplitude folds and flexures and normal and reverse faults complicate the monocline. The Frasnian deposits formed in a large epicontinental marine basin situated more or less at the palaeo-equator [16, 22]. The pattern of sedimentation in the South Il'men area indicates three cycles, each separated by basin-wide lacuna. These cycles formed the basis of the recognition of the Rdeyskaya, Buregskaya and Snezhskaya formations, respectively (Fig.4). The succession is also important in containing the stratotype sections, established by Hecker [1], of the Il'men and Buregskaya beds of the Semiluksky regional stage of the Frasnian. The lithological and other geological characteristics of the succession are documented in numerous publications [5, 8-15, 17].

The lower part of the Lake Il'men succession exposes the Il'men Beds of the Rdeyskaya Formation, consisting in its lower part of blue mudstones with thin lenses of bioclastic limestone. Injection of the plastic clays has produced diapir-like structures in places. The bioclastic limestones contain brachiopods, crinoids, ostracods, algae, conodonts, bivalves and rare aulopodid and rugose corals. Fish remains and trace fossils also occur. The upper part of the Il'men Beds is represented by white and red laminated and cross-bedded sandstones and siltstones. The deposition of the sands represent a rare incursion of detrital sand from basement rocks exposed in Scandinavia. These accumulated during an early Late Devonian sea level high (Semiluksky Regional Stage), when a deeper sea covered the area. These Late Devonian high stands represent some of the world's highest sea levels. A bed of ferruginous sandstone with ferruginous nodules, up to 0.4 m thick, occurs at the top of the Il'men beds. The unit contains rare lingulid brachiopods, gastropods, fish remains, algae, trace fossils and borings. This unit divides and changes thickness towards the eastern and western parts of the Il'men cliff. The top surface of this unit is uneven, with grooved features and ferruginization that suggests subaerial exposure. This unconformity, between the Rdeyskaya and the Buregskaya formations, is traceable south from the Lake Onego area to the Baltic and Belarus.

The overlaying Buregskaya Formation is composed mostly of brown argillaceous platy and in some cases dolomitized limestones. Its basal part contains numerous brachiopods such as productids, spiriferids and atrypids and also bivalves, gastropods, cephalopods, algae and conodonts plus crinoidal and bryozoan fragments. Plates of large placoderm fish are also found in this part of the succession. Abundant trace fossils and rare moulds of bivalves and gastropods characterize various parts of the platy limestones. In the middle and towards the top of the formation the limestone shows wavy/lense-like bedding and a paler color and at the top of the formation there are nodular limestones with rare brachiopods, ostracods and trace fossils. The limestones of the Buregskaya Formation also show a series of clinoform structures [15]. The faunas of the Buregskaya Formation in some cases show a rare mixing of Devonian marine and «terrestrial» faunas. It was the recognition of this mixed assemblage that provided the proof for the Devonian System at close-by localities on the Volkoff River that were visited by Murchison, de Keyserling and Koksharov.



Fig. 7. Fossils from the Il'men Clint; from left to right: brachiopod bed; a plate of an armoured placoderm fish; and oogonia from the chlorophyte alga *Chara*



The Buregskaya Formation is overlain unconformably with sharp contact by the Upper Frasnian Snezhskaya Formation, which consists of siltstones with inter-bedded sandstones and carbonates. The beds at the contact are in some places ferruginized and stained dark red, suggesting a break in deposition. At other localities a «bone Breccia» is recognised at the base of the Snezhskaya Formation.

Aspects of the geology of the Lake Il'men Clint as observed and documented by Murchison in his field journal can clearly be recognized in terms of modern stratigraphical units: «The Devonian rocks of this end of the otherwise flat Ilmen Lake are seen as cliffs of 40 to 50 feet, both on the edges of the lake, and on a small water-course by Burozi. The beds here have a tripartite aspect. The upper consist of green-coloured and greyish, occasionally purplish, compact, brittle, thin-bedded limestones (1 to 2 inches), splitting into numberless small cakes. These beds generally have a yellowish external aspect, and become white downwards. They are often spotted and veined blood red, and are much distinguished by tubular elongated bodies. They are seen in their maximum thickness to consist of about 30 feet and to rest on 6 and 8 feet of blood red, impure, rough, shelly concretionary limestone full of *Terebratula aspera*, Dev. var, the *Terebratula* of Tchudova; *T. helmerseni*; two Devonian spirifers; small spread *Productus*, three *holoptychii*, etc; corals scarce» [see18]. The «tubular elongated bodies» is presumably a reference to the trace fossils common especially in the lower part of the Buregskaya Formation; the lower, brachiopod-rich sequence clearly matches parts of the Rdeyskaya Formation; and the third part of Murchison's «tripartite» sequence presumably alludes to what we now know as the Snezhskaya Formation.

Erosion and landslip. Weathering, erosion and landslip have all conditioned the current appearance of the Il'men Clint, as can be seen in the locally developed talus slopes, landslides and sections in danger of collapse. Detailed study of the rock lithologies and their physical properties and pertinent geological processes and related structural and engineering issues is essential to determine how weathering, erosion and potential landslides might impact on the future integrity of the site. It is acknowledged that plastic deformation of water-saturated sandy and clay lithologies (e.g., of the Il'men Beds; see [6]) and the occurrence of joint-rich horizontal limestone and other types of fissures are instrumental in propagating plastic landslide-streams and landslides of solid rock. Gravitational processes appear to be activated particularly in the Spring and Autumn. Understanding the role that underground water pressure, lake levels and the porosity and permeability of the rock units have on the stability of the lake shore outcrops is also very important. An integrated monitoring of geological, geomorphological, hydrogeological and botanical aspects of the site is required. A scientific program dedicated to understanding the geodynamical conditions operating along the cliffs of Lake Il'men would resolve how to best to help promote the future preservation of this area of unique natural heritage.

Cultural and Natural History aspects of the site. Lake Il'men is navigable and has always been an important part of vital trading routes in northern Europe, from the Varangians to the Greeks. This water trade route linked northern Russia, the Baltic region and Scandinavia with Byzantium. The first known name of the Lake is 'Ilmer' which, linguistically, is of Finno-Ugric origin and means 'air lake'. Its environs were originally home to representatives of various ethnic groups that included the Balts (whose modern descendants included the Lithuanians and Latvians) and the Baltic Finns such as Ests, Vods, Izhorians, Veps and Chuds. Although several archaeological sites are known on the southern shore of the lake, they are currently poorly understood. In the 8th-9th centuries Slavs that are referred to as 'ilmen Slovenes' settled on the banks of the lake and for some time the lake was known as the Slovene Sea. In medieval times the Lake Il'men area became part of the Novgorod Republic, the East Slavic Principality that was a member of the Hanseatic League and stretched in the north to the eastern part of the Gulf of Finland. After its conquest by the Principality of Moscow the Novgorod Republic ceased to exist in the later 15th century, a change in status marked by an agreement signed in the village of Korostyn located in the western part of the Lake Il'men area.

In the town of Staraya Russa on the southern flank of Lake Il'men there is a long-established spa based on naturally flowing undergroundwater rich in dissolved salts [see 7]. In former times residents traded in salt, and the city was considered to be richer than Novgorod. Indeed, in the early 19th centuries, salt extraction became industrial in scale. Initial chemical analysis of the spa water was undertaken by Ilya Petrovich Tchaikovsky, the father of the illustrious 19th century Russian composer Pyotr Ilyich Tchaikovsky. At the beginning of his career I.P. Tchaikovsky worked in the southern Priyolmenye, near the salt-water outlet, which was used to obtain table salt. The center of the salt production was at Staraya Russa. I.P. Tchaikovsky documented the composition of the rocks that were excavated from wells and he tried to understand the origin and distribution of the saline water, publishing his scientific results in the Journal of the Mining Cadet Corps. Salt production stopped in the second half of the 19th century due to competition from more extensive rock salt found near the Urals. The cooling towers, in which the salt was evaporated, are now destroyed. The modern spa center was founded on the site of the old sources. Its infrastructure was much destroyed in the Great Patriotic War but was subsequently restored and began to receive visitors again in 1946. Some flowing wells still remain in the public park. Importantly, in the town there is the original well drilled by cable tools in the 1830's. These are freely accessible and the discharge is such that the area remains unlikely to be ever developed. These wells are still vigorously flowing with mineralized water from the Middle Devonian rock formations (Fig.8). Parts of an original wooden-lined well remain and is actively flowing and seen to be discharging gas (argon) through the sediment. Sources of saline pressure groundwater also occur in other parts of the area of the potential Geopark.

The cliff of Lake Il'men was a natural line of defense and was fortified by the invaders during the Great Patriotic War. A determined attack was made on these emplacements beginning 22/23 February 1943 by a Siberian regiment formed mainly from men from Yakutia – Yakuts – together with Russians, Ukrainians, Tatars, Byelorussians and others. In the historical literature they are known under the name «Yakut Arrows». The assault on the fortified cliff had to be made by walking silently along the ice of the lake and climbing the cliff. In this tragic battle there were more than 30 % losses. The fallen lie buried at the site in a mass grave near the shore of the lake. It is marked by monuments to those who fell.

There are many artistic works associated with the lake. The 19th century Russian composer Nikolai Rimsky-Korsakov set much of the action for his famous opera «Sadko» in Novgorod and on the shores of Lake Il'men and in the legendary realm of the sea king. «Sadko in the underwater Kingdom» is a famous painting by Ilya Repin, the distinguished Russian artist.



Fig.8. Flowing well from Middle Devonian aquifer near the spa town of Staraya Russa

About 40 species of fish are known from the lake and the Il'men Clint area is the home to several rare and in some cases endangered species. These include the plants *Anemone sylvestris*, *Lithospermum officinale*, *Iris sibirica*, *Jovibarbaglobifera*, *Astragalus sarenarius*, *Carex ornithopoda*, *Allium schoenoprasum*, *Dactylorhiza baltica* and the insects *Aeshna viridis*, *Carabus violaceus*, *Exochomus quadripustulatus* and *Halyzia sedecimguttata*.

Potential for future studies.

The unique Devonian succession exposed at the Il'men Clint, with its



varied rock types and fossils, has potential for many lithological, geochemical, palaeontological, stratigraphic and palaeogeographic studies as well as a range of hydrological and geodynamical investigations. The large aerial extent of natural outcrop would facilitate establishment of models for a wide range of clay-rich, sandy and carbonate sedimentary environments.

What the Il'men section displays is a thin cratonic section of terrigenous sediment washing out from the margins of the Old Red Sandstone continent. This means it uniquely contains a mixture of marine fossils with the fish that inhabited the lakes and rivers of the ORS continent together with its margins. The rock successions preserved on the Old Red Sandstone continent are generally very thick, often many kilometers having been preserved in rapidly extending fault bounded basins. In contrast, the Il'men sections preserve a record of events around the edges of the ORS continent and particularly the duration and magnitude of sea level high stands. They are the exposed part of the extensive Main Devonian Field well known across the region that as an entity allows us to study these transgressions and other sea level changes on a regional scale. These localities on Lake Il'men are also of historic significance from their association with Murchison, de Keyserling and Meyerhoff, who were informed of their existence and guided to them by the local network of geologists. Although the localities on the Volkoff were the first visited these on Lake Il'men are the ones that have survived and can be viewed today as they were in the 1840's.

The Il'men Clint provide a continuous and constantly refreshed series of exposures within a beautiful lake setting that can be safely observed. They can be studied at a variety of levels from detailed studies for professional specialists and University and school students through to exciting children into the geology and associated sciences. There is a constant supply of fossils such that everyone can find and recognize vestiges of past life.

Establishing a «Lake Il'men Geopark»: requirements and resources. Formally designating the area as a Geopark would bring with it various responsibilities and resource requirements. There should be unfettered access to all points on the Geopark by all who wish to visit the area. Provision of information on the geology and other aspects of area of the Geopark and its sites is clearly necessary. This can be done by, for example, providing permanent on-site information boards and pamphlets for visitors. A dedicated visitor-center could also be established. Some form of site management to monitor and where appropriate suggest and provide appropriate maintenance of the points on the Geopark should also be a major consideration. This could be done by various means, such as appointing a «warden» who would take on unpaid or paid responsibility for looking after the site. Any way to elucidate and promote the geology, landscape and cultural and natural history heritage and importance of the Geopark should also be a priority.

The importance of the region in recent times was signaled in 1962 when the Il'men Clint was subject to state protection. Moreover, since 2001 the area has been recognised as a «protected area of regional importance». On balance there is a substantial body of geological, cultural and other criteria to provide the basis for the establishment of a Geopark in the Lake Il'men region. All stakeholders in the area could perhaps now consider the next step forward.

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