Polish Geological Institute Special Papers, 13 (2004): 155–162
Proceedings of the Conference "Geological heritage concept, conservation and protection policy in Central Europe"

GEOSCIENTIFIC SIGNIFICANCE AND TOURIST VALUES OF ZMEYNYI (SNAKE) ISLAND

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Abstract. The peculiarities of the historical development of Zmeynyi Island in the Black Sea area and its geological structure have been investigated. These features and the island's aesthetic attraction allow to regard it as one of the best geosites of Ukrainian nature. New geological data obtained during the field geological investigations on the island allow to define the age of widespread conglomerates and sandstones. The lithological peculiarities of rocks, tectonical position and regularities of sedimentation are investigated in detail.

Key words: siliceous conglomerates, sandstones, geological monuments of Ukraine, Upper Devonian, Zmeynyi (Snake) Island.

Abstrakt. Przebadano osobliwości rozwoju historycznego oraz budowę geologiczną wyspy Zmeynyi na Morzu Czarnym. Te elementy oraz walory estetyczne pozwalają traktować wyspę jako jedno z najlepszych ukraińskich geostanowisk. Dzięki nowym danym geologicznym, uzyskanym w wyniku prowadzonych badań, określono wiek szeroko rozprzestrzenionych na wyspie zlepieńców i piaskowców. Przebadano dokładnie cechy litologiczne skał, ich pozycję tektoniczną oraz przebieg sedymentacji.

Słowa kluczowe: zlepieńce krzemionkowe, piaskowce, geologiczne pomniki Ukrainy, dewon górny, wyspa Zmeynyi.

Zmeynyi Island, lost in boundless space of the Black Sea, was always distinguished in its insuperable attractive force for all those who caught the sight of it or who had heard something about it. Like the moon that causes oceanic tides, the island attracted and pushed away seafarers and travellers, historians and writers, scientists and explorers. Even though, it is rather tiny island, only 630 × 360 m, its uniqueness doesn't leave any people indifferent.

Severe but picturesque rocks, together with the products of their destruction in the shape of gigantic boulders along the seacoast, together with the vivid signs of tectonical activation at the Post Devonian time — cracks, crevices, grottoes, layer displacement, their deformation and numerous changes of their location, create original and unique landscapes of the island.

The historic past of the island is no less unique. But before exploring its mysteries, one should address oronymics, that is a part toponymics of relief. One of the most ancient names, that had reached our time is White Island. Dionisiy Periglet writes, for example: "On the left side of Euxinian Pont opposite Boristen in the sea lies the famous island of heroes and people call it White, as the birds that inhabit the island are of white colour" (Agbunov, 1985). There is a supposition that the name might be stipulated by the rocks that make up the island that is conglomerates the colour of which varies from white-gray to white.

In further sources, the island often appears under the name of Achilles to whose honour, the Temple built on the top of the island, was devoted. In ancient authors' pericles the island was also called the island of Levka, Sherpilor, Makaren (the island of Blessed) and, after some period of oblivion, in Later Middle Ages, it was called as the island of Phydonisy or Zmeynyi (Snake). It's unknown whether snakes used to inhabit the island but its shape slightly reminds a representative of those species.

Some concrete geographical facts on the location of the island were given in *Description of the Earth* by Pseudo-Scimna Hioskogo (90 years BC). "Just opposite it (the mouth of the Istra) in the sea lies the island of Achilles. A lot of rivers birds inhabit it and it itself is a magnificent sight for those who arrive. One can't see any land from it, though the shore is in 400 stadis from it, as Demetry states." Very interesting facts about the island can be found in *Description of Helene* by Pavsany, where he wrote: "In Euxinian Pont opposite the Istra mouth, there is an island named

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after Achilles that is called White. It is covered by thick forests and is full of wild and domestic animals".

In 134, Kvint Eppy Flavy Arrian made his trip across Euxinian Pont. He also paid his attention to the island of Achilles in his short pericle. Besides the known things, he wrote, for example: "There are no people on the island, one can see only some goats; people say everybody who comes here offer them to Achilles. In the Temple, there are a lot of offerings: cups, wedding rings, and precious stones." It's curious that even now almost 2000 years later there are only some people on the island and goats are still grazing there. Lots of interesting legends and real facts about the island are given by Phylostrat Junior in his work *A story about heroes* (Agbunov, 1985). The presented fragments vividly describe the exclusively great role of the island in the life of the ancient Black seaside.

In the Middle Ages, both the Temple of Achilles and the island on which it stood were lost and forgotten. Only in late Middle Ages, when the interest to ancient antiquities arose again, the forgotten manuscripts reminded people about the island. It was already known by its new name — Phydonisi or Zmeynyi island. At the beginning of the 19th century, the particularly active learning of ancient northern Black Sea cities began. The scientists examined manuscripts of ancient authors and tried to find the allusions to the cities that used to flourish here. In 1823, Captain Kritsky visited Zmeynyi Island. In its north-western part, he saw the ruins of the ancient temple on the highland. There was a strong foundation, made of big blocks of white lime, and lower fragments of walls surrounded by the debris of marble cornice and capitals. Kritsky drafted a plan of the island with the remains of the temple that was printed by Keller in 1826.

After establishing a quarantine post on the island, the officials who served there made numerous amateur excavations the results of which were surprising. In a thin layer of deluvium, they found marble slabs with inscriptions dedicated to Achilles, a great number of coins, wedding rings, ceramic plates and pots, and their fragments.

In 1841, Murzakevitch, one of the founders of the Odessa Society of History and Antiquities, made his own investigation. Together with his companions, he was struck by the awful sight that spoilt all the positive impressions and excitement of their arrival in Saint Land. On the highland, there were "piles of stones put in cube sazhenes and those stones were the remains of the Temple of Achilles" (Murzakevitch, 1984). It became clear that the construction of a lighthouse was decided to begin and the builders in order to make their life easier simply cleared away the remains of the Temple, as Murzakevitch wrote: "This vandalism was made with such efforts that nothing remained from Achilles Temple; everything was razed to the ground" (Murzakevitch, 1984).

Pyatyshev, under whose direction (Madership) the exploration of island was carried out in 1964, considers that it is quite possible that there are a lot of emptiness in the bowels of the earth or caves in which valuables and statues of gods were hidden when enemies were approaching. But it is one of the mysteries of the island that awaits discovery, together with some other mysteries of the ancient past of the island.

Not less unique and outstanding is the geological past of island that required hundreds million years during which the island was created as one of the most valuable objects in Ukrainian geological heritage. It is one of those places where one can see the appearance of Devonian rocks on the Earth surface in the shape of picturesque cliff, and it's the only place where they are represented by original large-gravel conglomerates with thin layers of multicoloured aleurolites and sandstones. The existence of the island also testifies to the continuation of Dobrudja plicated structure in the eastern direction.

One can find first brief information on the island's geological structure in Poruchik's work printed in 1916 (Poruchik, 1916). More systematic geological explorations were made starting with 1945. The results of this work are given in Myrgochi's work (1911), and also in the works by Myratov (1964; Myratov *et al*., 1977), a well-known explorer of the Crimea. Other information can be found in the works by Drumia (1958; Drumia, Ivanchuk, 1962) and Ivanchuk (1957).

All the investigators think that the island is a fragment of eroded gertsinsky structure of Dobrudja, and the rocks that constitute it were dated as early Mesozoic period (Lias or Trias).

In 1956, Ivanchuk, Drumia and Kavikovsky visited the island and explored it more thoroughly (Ivanchuk, 1957). According to these authors, the complex of sedimentary rocks, mostly roughly crushed, that takes part in the island formation, can be divided into three levels: lower, represented by an alternation of quartz like sandstone streaks and quartz conglomerates; the middle layer is made of alternation of motley schists, sands and weakly cemented conglomerates; and the top level is characterised by roughly crushed rocks, similar to the upper level.

The detailed lithological-petrographical analysis of rocks allowed the authors to divide the bottom level into 3 packs, into 6 packs in the middle level, and in the upper level, that is regarded as identical to the bottom level, no packs were distinguished. The signs of fauna and flora were not noted at that time, and the thick roughly crushed rocks that constitute the open part of the island, were dated at Early Triassic. It was made by the analogy with Ceis layers that are characteristic of the Danube region of Dobrudja.

From the tectonical point of view, the authors regard the island as monocline divided into two almost equal parts by a big submeridional fracture. Palaeographical conclusions of the paper do not coincide with the results of some later investigations (Drumia, Ivanchuk, 1962). In 1965, a group of geologists: Negodayev-Nickonov, Bobriusky, Sinegyb and others described the section of the island rocks and gathered a collection of samples. For the first time, the prints of mollusc shells and ostracode were found in the southern part of the island seaside.

On the base of the analysis of the palaeomagnetical investigations carried out in the island in 1967, Garkavenko, Tretyak and Gladchenko came to the conclusion on the Ordovician age of rocks. Garkalenko distinguished big block raisings in the Black Sea: Zmeynyi and Vilkovsky (Garkalenko *et al*., 1969), Tkachenko, Pazyuk and Samsonov carried a careful exploration of the island. The results of their investigation are given by Tkachenko *et al*. (1969).

The authors' point of view is that the tectonical nature of this local and unique construction of island is beyond any doubt. Examination the geophysical investigation data proved

that the island was situated within the mobile region of wide tectonically weakened zones of three directions. Fractures of two directions — sub-meridional and north-western ones — are visible on the island. The third one — the sub-latitudinal zone is located somewhat to the south of the island, marked by a zone of moderate gravity gradients and based also on the magnetic prospecting data. They are the continuation of the Sulinsky tectonical line, known from the beginning of the 20th century, that divided the indivisible in the past geosynclinal region into 2 parts — Dobrudja horst proper and crest like depression, genetically connected with it (Tkachenko, 1969).

In the section of terrigenous formation which the authors call flesh, they distinguish four packets: conglomerate–breccia-conglomerate, conglomerate–sandstone, motley clay and sandstone–breccia-conglomerate. It should be noted that this division is rather conditional.

Fig. 1. Quartz-siliceous and quartzite pebbles and boulders with cavities of leaching

According to our observations, among disintegrated material of the whole terrigenous formation of the island there is practically not a single angular unrolled fragment, and the use of the term "breccia or breccia-conglomerate" is not justified. There is angularity of pebbles but only of secondary importance at the expense of microcracks and single cleavage at certain angle (Fig. 1).

A very important achievement of the above-mentioned work was the discovery of nuclei and shells of ostracode in grey-green and greenish clays and aleurites, among which Abushik (AllGI) recognised: *Leperditia* sp., *Cyrherellina* sp. and *Carinocloedenia* sp. Based on the existence of such a palaeontological complex, the authors correlated the layers that contain them with Chertcovsky layers of Podolia, where they, together with Borshchevskian, are considered as the border between the Ludlov stage and Early Devonian. Samsonov singled out Kagulsko–Bakal ledge of East European Platform which Zmeynyi Island is part of (Samsonov, Krasnoschek, 1969).

In the 1970th, a detailed geological investigation of Zmeynyi Island was made by Odessa University geologists (Sulimov, Blagodatnov *et al.*). They came to the conclusion that Erian phase of Caledonian tectogenesis appeared on Zmeynyi Island as well as within Dobrudja during the formation of rough crushed molasse (Sulimov *et al.*, 1975). The island is in the joint zone of structures of Dobrudja, Miziyska and Skiff plates and East European Platform, and they are the only place of Palaeozoic appearance in this zone.

In south-western part of the island sea-side, imprints of testaceous fish *Irregulareaspis* and nuclei of pelecypods were found in clay aleurolites. It is known that in Ardennes and in Hercynian massifs of western Europe, in shale layers there are remains of testaceous fish among Low Devonian pudding siliceous conglomerates. In aleurite clay of the northern shore of the island, the nuclei of foraminifer *Blastammina* sp., and tubular formations of *Rhabdammina* sp. and *Hyperammina* sp. (Gurevitch's definition).

Besides, clay aleurite rocks also contain *Pseudozygobollina moldaviensis* Trand. msc., *Araucaria* sp., a lot of shells of *Healdianella* sp., telodonts *Telodus afflevis* (Pander), acantodes, fragments of gastropods, specula of sponges, the remains of harofits *Sycidium* aff. *eriana* (Dawson), and others (Sulimov *et al*., 1975). The authors consider that this complex of fauna remains allows us confidently refer the deposits to the lower parts of Devonian. The rocks of the lower packet of the ostracode complex together with deposits of Largutskian suite of the Predobrudja flexure are the biostratigraphical analogue of the Ivanitsk horizon of Podolya and Lviv depression. It is curious that one and three axle sponges and primitive foraminifers were found even in conglomerates.

In 1975, the drilling of the Morska-1 borehole was completed at the depth of 509.0 m. Investigation of the borehole core showed that Late Silurian and Early Devonian rocks participated in the geological formation of the island. The most complete data on the geological structure of the island first were given in paper of Sulimov *et al*. (1975) as well as in publications of Astahov, Gorac (1984) and Gorac *et al*. (1985).

The oldest rocks, according to the drilling data, are clay-carbonate rocks of Upper Silurian age, in which two lithological packages were singled out: the lower one, represented by limestones with lamprophyre layers, and the upper one consisted of an alternation of marls, argillites and limestones. The limestones contain numerous remains of ostracodes, brachiopods and sometimes graptolites. In general, thickness of Upper Silurian rocks is 206.0 m. The borehole section is differently interpreted in the publication of Aston and Gorac (1984) in which the thickness of Silurian is cited as 121.0 m and it is related to Prigorodskian, Varnitsky, Trubchinsky and Zvenigorodsk suites of the Dniester clay section.

In the later publication of Gorac *et al*. (1985), that part of the section is compared with Stavanskian and Sklavinskian horizons. As Silurian rocks, the clay-carbonate rock mass has been established in which on the base of lithological features Sulimov distinguished two packets: the lower and the upper ones. The rocks contain a lot of fossils: nuclei of ostracodes and brachiopods, fragments of corals, trilobites, cronies and

Fig. 2. Steep rocks in a south-eastern part of the island

In the background appear many-coloured clays, sandstones and aeroliths

specula of sponges. This rock mass of 97 m of thickness is compared with the upper part of Jalpuchscian suite of Danube Predobrudja (Gedinnian stage).

In the Sulimov papers (Sulimov *et al*., 1975; Sulimov, 1984), the clay-carbonate rock mass of the island, penetrated by a borehole at the 53.0–388.0 m interval, is regarded as an analogue of Nerushaiskian suite. Stratigraphically, the section of lower Devonian on Zmeynyi Island is increased by the Zmeinoostrovscian suite of conglomerates in which Sulimov distinguished three differing in thickness packs: the bottom one — aleuropelite, the middle one — psephite and the upper one — psammito-psephite (Sulimov, 1984).

In 2002, in accordance with the plan of complex development prime measures of Zmeynyi Island's territory, authorised by the order of the Cabinet of Ministers of Ukraine, the State Geological Survey of Ukraine was entrusted to execute geological survey of the north-western part of the Black Sea shelf. A field DGE *Dneprogeophysic* group carried out the geological investigations of the island outstripping the surface ones with the purpose of searching for water supply sources on Zmeynyi Island. One component of the work was the geological investigation of the island aimed at the careful study of all outcrops with special emphasise on the peculiarities of tectonical structure and lithology. Certain volume of laboratory analysis was also included, the results of which were taken into account during the further characteristic of the island's geology.

One could agree with Sulimov's point of view that the whole section of the island's outcrops (that is — three lithological packets) reflects an uniform cycle of accumulation, but the apportionment, for example, of the lower aleuropelite packet does not correspondent to the factual data. The conglomerates of the lower part of the section of Zmeinoostrovsciscian suite do not differ from the upper ones, and aleurolites can be found at all its levels. Later, the middle and upper packets of the Zmeinoostrovsciscian suite were attributed to the Phydonisy suite, and Zmeinoostrovsciscian suite was left with only artificially allocated aleuropelite packet, the stratigraphical position of which remains uncertain.

Recognising the fact that the terrigenous formation of the island represents the uniform stratigraphical body and that its detailed section has been repeatedly described by different authors, I'll dwell upon on the brief characteristics of the main lithological types of rocks.

Conglomerates are the most widely spread on the island. They are large and middle size fragmented rocks cemented strongly by siliceous-chalcedony material with pieces of white and light grey quartz (Figs. 2, 3). The degree of rolling is average, sometimes bad; separate pebbles are flatted, the orientation of their long axis coincides with stratification. Pebbles material is coloured from white to dark grey; it may by red-brown and ochre like. The size of fragments is from 0.5–1 to 12 cm; in the south-western part of the island it may reach 20 cm. In the basal part of each layers an intensive leaching is widely developed.

Pebbles material is characterised by microcracking due to which pebbles break into small fragments even at the insignificant dynamic pressure. That phenomenon became an occasion for many authors to allocate the rocks to breccia instead of conglomerates. According to microscopic research, fragmented material of conglomerates belongs to sandstones, aleurolites

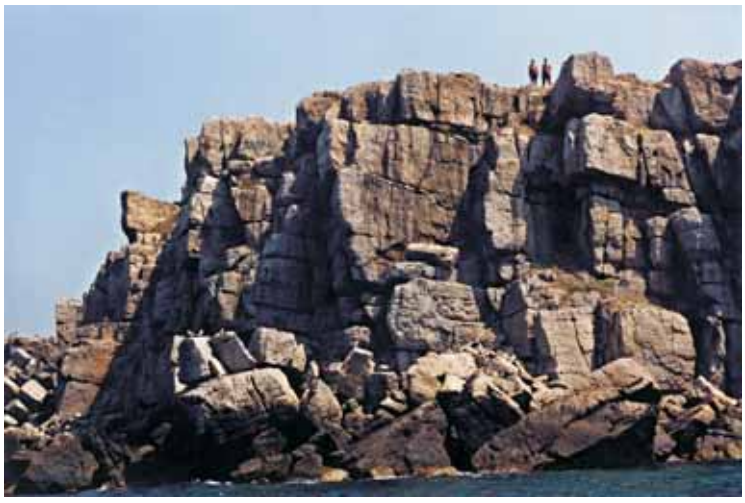

Fig. 3. Sea, rocks, seagull and… topographers

Fig. 4. Tectonical fracture in Devonian conglomerates

and siliceous rocks. Fragments of sandstones are fine grained and contain quartz grains of 0.05–0.5 mm in diameter as well as separate tabular grains of plagioclase, cemented by hydromicas cement of porous and at places of basal type.

The clays are composed of thin scaled material of hydromicas type which explain schistose structure of the rocks. The results of sampling and further thermal analysis of northern seaside clays of the island (outcrop 109), carried out by us in 2002, turned to be surprised. The thermograms of all analysed samples have appeared of the same type and they correspond to the standard samples of thermoinert substance. On heating curves (actually straight lines), there were no thermal peaks which would testify the phase change in substance. The thermoinertness of the investigated rocks, their appearance and physical properties suggested that clay–aleurite rocks from outcrop 109 were not clay but siliceous rocks, composed of amorphous silica (Fig. 4).

Rocks from outcrop 109 were similar to products of weathering that developed on acid effusive rocks. At the same time, according to the microscopic research data, the clay material (72%) has a complex sight and average birefringence N_g–N_p= 0.018–0.025, which is typical of montmorillonite. The clay substance is made of elongated interlaced plates and leaves, with the oriented scale location; it contains small quantity of primary mica and single inclusions of opal or volcanical glass. Within the limits of the southern coast, there is a system of cracks in clays. The cracks are filled with strongly cemented material of limonite–hematite composition, the intercrossing of which create frame-cellular forms.

Quartz sandstones are very hard, with thin bedding of light grey and grey colour, here and there brownish because of non-uniform ironing. In microsections, fragmented material is mainly of quartz character with separate grains of feldspars and quartzite, with grains size of 0.05–1 mm. Cement is opal-chalcedony. Among crystalline, cryptograined masses, one can notice relics of sponge specula and skeletons of radiolarian. Sandstones have uniform thickness; they often pinch out and pass into quartz–sandstone and quartzites, of which blastopsammite and mosaic structure are characteristic.

The considered rocks: argillite-like clays, argillites and slightly cemented fine-grained sandstones, which are structural varieties of the described above greenish-grey aleurites, take part in the terrigenous formation (Figs. 5, 6). The results of the chemical analysis of aleuritic clays prove that their most probable composition is montmorillonite.

The results received during the investigation of palaeontological remains from aleuritic clays of the island are quite unexpected. During a study of fossil microphito remains, Furtes from the Institute of Geological Sciences NAS of Ukraine described a spore and pollen complex of plants typical for Upper Devonian (Famennian stage).

The complex included: *Archacotriletes ramanus* Nekr., *A. larvatus* Naum., *A. sincerus* Kedo, *Archaeozonotriletes notatus* Haum., *A. orlovikus* Nekr., *A. proprius* Nerk., *A. livnensis* Nerk., *A. angulatus* Nerk., *A. yasjamicus* Tschibr., *Trachitrileter solidus* Haum., *T. nigratus* Kedo., *Retusotriletes commutus* Haum., *Leiosphaeridia plikata* Nekr., *Leiosphaeridia* sp. etc. Besides, Poletaev investigated the imprints of pelecypodes which were quite satisfactorily preserved, among which the remains of *Schizodus* cf. *devonicus* Verneuil, characteristic for Frasnian stage of Upper Devonian were defined.

It is not enough to make final conclusions concerning the age of the terrigenous formation of Zmeynyi Island's rocks, considering the great interval of divergence (from Lower to Upper Devonian) but the problem has been risen and demands solution.

Fig. 5. Abrasion of rocky coast Snake in operation

Fig. 7. A crack of tectonical breaking

Fig. 6. Characteristic selective denudation of aleurite-conglomerate rocks on the island

In 1985, in the book *Geological monuments of Ukraine* Zmeynyi Island was regarded as an important geological monument of nature but so far it has only remained a perspective object of the geological heritage that has no official nature protection status. Its picturesque indented rocky shores with grottoes, its famous historic-cultural past and the unique peculiarities of the geological structure deserve the stricter conservation at the level of geosites of European importance (Fig. 7).

CONCLUSION

For many decades Zmeynyi Island was closed for visitors. After passing decision about its civil use, the task of complex studies of historical legacy of island and valuable nature complexes became of present interest. All outcrops of meaning rock formations were investigated. The geological age of rocks is essentially specified and defined as Upper Devonian. Undoubtedly, Zmeynyi Island is one of the most valuable geosites of Ukraine.

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