

Listing a Geological Rarity of ‘Stone Balls’ in Kysuce Among World Geotourism Destinations

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Abstract. Kysuce, situated on the border with the Czech Republic and Poland, belongs among distinctive regions in the Slovak Republic. This region offers tourism many interesting sites. Few decades ago, Kysuce offered tourists and visitors well-preserved national architecture, which is nowadays concentrated in an open-air museum Vychylovka. Thanks to the rich afforestation and a sophisticated network of signs for hikers, hiking has been very popular. The ground relief and climatic conditions also encourage winter sports. The world-wide development of geotourism has also concerned this region. Despite a low-varied geological structure, there are unique geological formations that have attracted attention for years. For example, tourists visit the interesting mineralized springs and a remarkable crude oil seep in Korňa. Geologically unique are also the occurrences of ‘stone balls’ from sandstone and conglomerates. This phenomenon has attracted attention of both geologists and esotericism supporters.

1. Introduction

Kysuce is one of the distinctive regions situated in the north-west Slovakia. Kysuce spreads on the territory of two counties, Čadca and Kysucké Nové Mesto. From the north to the west the region borders the Czech Republic, and from the north to the east Kysuce borders with Poland. The southern section adjoins the Upper Považí and the eastern border touches the region of Orava. The followings mountain ranges are found in the territory: Kysucké Beskydy, Javorníky, Střední Beskydy and Kysucká vrchovina. The territory is mostly covered with forests, meadows, pastures and fields. For this reason, a part of the area is protected within the Kysuce Protected Landscape Area. In the past, visitors were mainly interested in the beauties of the natural life and national architecture. Recently, geotourism has developed as a new form of tourism world-wide. Accordingly, many scientific works have published dealing with the issue, for example [4, 6, 7, 8, 9, 10, 14]. As for the inanimate nature in Kysuce, it has been rather monotonous as for the geological development, but several unique natural specimens may be found there. As a result of the environmentalists’ efforts, many of the interesting sites have become listed. Among the geological attractions in the region there are the ‘stone balls’, the occurrence of which has been registered in several exposures in a narrow belt from Klokočov to Milošová. These geological formations are concretions, which are occasionally found in other European and world localities.



2. Brief geological structure of Kysuce

The Kysuce region has been predominantly formed by a flysch belt, whose beds are characteristic of an irregular rhythm of development [5, 11, 15]. Sandstone and claystone beds mainly alter. There is also a narrow klippen zone constituted by predominant limestone. The whole region belongs to the Outer West Carpathians. This zone is a part of extensive Western Carpathians, which make part of Carpathians that belong to the extensive European Alpine Orogene.

2.1 Flysch Belt

This belt is made up by clastic sedimentary rocks that sedimented in the Paleogene. The rock localities are not identical to the sites of their sedimentation. From the site of their origin, they were moved in the form of nappes several tens of kilometres generally northwards, but it was north-westwards in this region. The units in the region may be classified to the inner Magura Zone (Bystrica Unit and Rača Unit) and outer Silesian-Krosno Formation (Silesian Unit).

2.2 Klippen Zone

This zone makes a narrow belt in the south-eastern part of Kysuce. The rocks in the zone formed in the period of Jurassic to Lower Cretaceous. It is the case of various types of limestone, in places turning into marlstone that also contains concretions all the way to chert layers (irestone, radiolarite). In the Middle and Upper Cretaceous marlstone sedimented. This zone represents a border between the Outer and Central Western Carpathians.

3. Concretions

3.1 General characteristics and formation of concretions

Spherical to egg-shaped aggregates sometimes occur in the sedimentary rocks or soils. They often have irregular shapes and are called concretions. They highly vary in size; there may be millimetre aggregates to rare sizes of several-metre specimens. The aggregates start with a core around which minerals begin to concentrate and solder (*concretio* in Latin). The core of the concretion is an allochthonous element that may be of:

- an inorganic origin, for example rudaceous or psammitic clasts,
- an organic origin, for example a tooth, shell or leaf,
- an anthropogenic origin, for example a shrapnel.

Bacteria also participated in the formation of some types of concretions. Concretions have different mineralogical and petrographic compositions. From the mineralogical point of view, concretions mainly contain sulphides (pyrite, marcasite), oxides and hydroxides (hematite, goethite), carbonates (calcite, aragonite, dolomite, siderite), sulphates (gypsum, barite) and silicates. As for the deposits, at present we find interesting especially the so-called manganese concretions or iron-manganese concretions. These are polymetallic concretions that contain around thirty metals. They appear in various concentrations on the bottom of the world oceans. These are gigantic reserves of mineral resources to be mined in the future. World-wide the sizes of such aggregates vary. If the concretions are in the size of metres and have a spherical shape, they attract the attention of scientists but also that of the general public. As a result of the public attention, supernatural origin may be associated with them. The most often, the concretions are found on consolidated clastic sediments, such as sandstone, siltstone and claystone. Throughout the diagenesis, calcareous, phosphatic or silicic cementing material begins to deposit around a solid particle. Concretions form via the process of gradual surrounding mass replacement. If the porosity of a parent rock is identical, the concretion may develop regularly in all directions and this way, an isometric (spherical) shape of a concretion forms. If the porosities differ, concretions of irregular shapes form. The colour of a concretion is usually that of the parent rock. Concretions are characteristic of a significantly higher hardness than the rock inside of which they are found, and thus are more resistant to weathering. Recently, the topic was discussed in [1].

3.2 World occurrences of large concretions

In some localities very advantageous sedimentary environments have made conditions for the development of concretions that have the size of several metres. Analogous to Kysuce, such natural formations have been noticed. Those unaware of geological mechanisms have attributed them with various theories of their origin. These natural formations have become attractions for tourists in many world localities as they enthuse through size and shapes. Tourists may learn about such sites of interest from the Internet, catalogues and promotional materials. Among the occurrences world-wide, the most known localities are the following:

Qasr El Sagha u Fajjúmu, Egypt - In this locality concretions of an average axis of 1 – 4 m are found. Their maximum size is up to 9 m. These are weathered concretions made of sandstone and calcareous cement. The concretions are mostly flattened, some are elongated.

Moeraki Boulders, South Island, New Zealand – On the seashore there are concretions that are mostly of the spherical or almost spherical shape. The majority of them has the size from 1.5 to 2.2 m. About one third of the concretions has the size from 0.5 to 1 m. These are clayey-calcareous concretions with fissures inside.

Kotu Boulders, Hokianga Harbour, North Island, New Zealand – There are occurrences of analogous septarian concretions on the seashore as in the above mentioned locality. Their average size is 3 m.

Bowling Ball Beach, Mendocino, California, USA – In places the beach is studded with many sandstone concretions, the so-called ‘cannon balls’ that weathered away from reef deposits.

Cannonball River, North Dakota, USA – The concretions there, the ‘cannon balls’, have given the name to the river. The sandstone concretions with calcareous cement are found along the river and have been extracted from the subsoil by the river. The largest concretions there reach the diameter of 3 m. Similar concretions are found in many places in the USA, for example in the north-eastern part of Utah and central Wyoming.

Rock City, Minneapolis, Kansas, USA – In this locality there are gigantic ‘cannon balls’ from 3 to 6 m. It is a natural monument in the prairie. On an area of 500 x 40 m there are about 200 concretions in three clusters. These are sandstone concretions with calcareous cement, the sculpture of which gives evidence of weathering.

Kettle Point, Ontario, Canada – The weathered concretions are located on the shore of Huron Lake. The concretions from black claystone layers contain calcareous cement, they are of a spherical shape and slightly flattened. Their size ranges from 0.3 to 1.5 m on average. The local name for the concretions is ‘kettles’. Local people and visitors often carry them away or break them.

Haines Junction, Yukon Territory, Canada – The concretions are disintegrated in a hilly terrain. In size they are up to an average of 0.4 m. Unfortunately, tourists usually take them as souvenirs.

Zavidovići, Bosnia and Herzegovina – It is one of the few European occurrences of gigantic concretions. In the afforested locality there are two large spherical concretions that have been disintegrated from flysch. These natural formations in the locality are protected.

Gongxi, Hunan Province, China – Large numbers of concretions have recently been found during the construction of a road in Bandeng Hill and Zhanlong Hill. The oval concretions with carbonate cement have from several tens of centimetres to metres in diameter.

Apart from the occurrences, there are also discoveries of similarly large concretions, for example in Alaska, Greenland, Svalbard as well as in Mexico. Some of the localities get due attention of tourists. Mostly, the sites are enlisted among protected natural monuments. However, there are also sites that may be damaged or even destroyed due to the competent authorities’ lack of interest.

4. Occurrences of large concretions in Kysuce

4.1 Geological-petrographic characteristics of Bukovec sandstones

The geological conditions in some parts of Kysuce allowed for the formation of concretions, which may be classified as ‘cannon balls’, in the layers of clastic sediments during diagenesis. These concretions combine onto a small section of the flysch belt that builds a substantial part of the geological bedrock

of Kysuce [1, 12]. It formed in the site of Magura Zone nappe thrust onto the Silesian Unit. Occurrences of the concretions have been registered in the close vicinity of the line which is situated roughly on the connecting line Klokočov – Raková (Korchán) – Milošová (Megoňky). This part of the flysch belt dominates with sandstone layers over claystone. The concretions make part of the Bukovec Sandstone Belt. The concretions were first described in the nearby town of Bukovec u Jablunkova in the Czech Republic. **Medium to coarse-grained sandstone**, which is found there, forms massive layers. There are silicic sandstones that are feldspathic in places and grey-blue or grey-brown in colour. The cement is silicic or calcareous. The sheet jointing is irregular and the thickness of the bars ranges from 0.2-3 m. Among the bars there are thin layers (mostly 0.1-0.5 m thick) of dark **claystone**. Tectonic effects significantly manifest on the claystone. As a consequence of the tectonic manifestations, we find healed joints in the sandstone. The **siltstone** therein may be divided into two types. The first type of siltstone with the clasts of quartz, feldspar, and chert mainly form layers of 0.5-3.0 m. The second type are siltstone with clasts usually up to 10 cm, which are made up from various rocks from distant source areas. There are occasional layers of such siltstone of 0.5-2.0 m thick. One of the first more familiar occurrences comes from the surroundings of Klokočov. Near one crossroads there are two pieces of such concretions that were likely to be transported there in 1928 during the road constructions from a stone quarry in Kornica. Many concretions from the quarry ended up in the past in the local citizens' gardens. One of the local sites 'Klokočovské skálie', located in Klokočov-Hlavice, was declared a protected natural phenomenon back in 1973.

4.2 Occurrences of concretions in Milošová-Megoňky

This locality belongs among the youngest and most representative sites of discovery within Kysuce. The locality is near the settlement Vyšné Megoňky, a part of Milošová that belongs to the town of Čadca. The site of discovery is near the border with the Czech Republic. The sandstone concretions were discovered there in 1988, when a layer with such concretions had been discovered in the local quarry Padyšák during stone quarrying. The size of concretions is 0.3-2.6 m, but in the wall there is a mould of a fallen out concretion whose diameter could have been 5 m. Around thirty concretions were discovered there and some are said to have had 3 m in diameter. At first, hardly any attention was given to them and many could have been transported to various places as rarities. People's imagination resulted in many press articles by various authors reporting on the apparent origin of the balls. Legends appeared that attributed the balls with fertility for women, or that gold was found inside the balls, or that they were remnants of extra-terrestrial visitors. In 2003 the locality was declared a natural monument. Megoňky/Megonky is nowadays a popular destination for many tourists.

One access is possible from Čadca-Milošová along the local road. Tourist may also hike from the Czech Republic starting at a railway station Mosty u Jablunkova and continue along a marked route towards Šance – Motyčanka – Filůvka. Guide signs are also situated in the protected locality [1, 12].

5. Conclusions

The occurrences of stone concretions discovered in Kysuce have been challenging human attention for years. This geological phenomenon, found also in other world-wide sites of discovery, has become a popular destination for tourists. The world-wide development of geotourism in the recent years helps to promote interesting natural phenomena to a wide spectrum of interested people. This untraditional form of tourism begins to develop in Slovakia too. Recently, many scientific works have also dealt with the geological topics [2, 3, 13] as well as mining tourism. The rich mining history of Slovakia has been preserved in many regions. Unfortunately, as for the geological structure Kysuce does not contain significant deposits to be mined. On the other hand, Kysuce offers several geological rarities that may be found only in a small number of world localities. One of the rarities are the concretions and the second is a natural crude oil seep in Korňa.

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