

Geological and tourist attractions of southern Bornholm

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Abstract: The following article presents the description of seven geological and tourist routes in the southern part of the Danish island called Bornholm. The fieldwork, which took place during the expedition of the Geography Students' Scientific Group from the Faculty of Earth Sciences, Nicolaus Copernicus University in Toruń, included photographic documentation and the location of rock concentrations by means of a GPS receiver. The researched routes reveal both geological diversity of the island – Precambrian, Palaeozoic, and Mesozoic rocks, as well as tourist sites, such as round churches, historical windmills, rune stones and numerous attractions of major cities of the island.

Key words: geological and tourist route, Bornholm Island, round churches, rock concentrations

Introduction

The expedition of the Geography Students' Scientific Group from the Faculty of Earth Sciences, Nicolaus Copernicus University in Toruń to the Danish island of Bornholm took place between 21st and 27th September, 2012 under the slogan "Bornholm Repeats Itself". The expedition was inspired by the article by Bernard Cedro and Tomasz Duda entitled "Bornholm's Geological Attractions" published in *The Geological Quarterly* in 1996.

The scientific objective of the expedition was to map out geological and tourist routes across Southern Bornholm, including the most important tourist attractions of the island and rock concentrations revealing its geology. Based on the descriptions from Cedro and Duda's article, geological concentrations and interesting tourist sites were documented by means of a GPS Garmin receiver. The field work was preceded by analysis of available materials in the field of geology, tourism, and history of the island. The Geologic and Tourist map was developed using ESRI's ArcGIS Desktop 9.3.1 software.

Characteristic features of the researched area

Bornholm is a Danish island located in the Baltic Sea. It is undoubtedly a place where the diversity of landscape is truly amazing. On such a small island of merely 588 square kilometres and whose coastline does not exceed 158 kilometres, we can find all plant formations typical of the Scandinavian countries, as well as metamorphic, igneous and sedimentary rocks, dating back to various geological periods (Fronia, 2009). The northern and eastern part of the island is built of solid granite rock, the characteristic feature of which is massive cliffs. The southern part of the island is a place where mainly Palaeozoic and Mesozoic sedimentary rocks can be found. The south-west of the island is characterised by sandy beaches, at times exceeding 200 metres in width, with dunes (Piórska *et al.*, 2007).

Compared with the rest of Denmark, Bornholm is deficient in water reservoirs. Approximately 0,3% of the island's surface is occupied by sources of fresh water, only 1% of that which can be found in the whole of Denmark. In the northern part of Bornholm, many lakes can be found, the majority of which are of glacial origin. Small, shallow lakes are all over the island. Apart from these natural water reservoirs, there are many waterholes formed after disused quarries or pits have been ok filled with water (www.bornholm.net/Jeziora-bagna-i-stawy.pl). There are also a number of short and narrow rivers flowing across the island, the longest of which, Øle Å, is 22 kilometres long. Some of the rivers are only periodic. The most characteristic feature of all watercourses on the island is the fact that they flow from the centre of the island and into the sea (Piórska *et al.*, 2007). Apart from its numerous geological attractions, Bornholm can also boast about its fascinating historical sites, round churches, vintage windmills, and a well-developed network of bike lanes facilitating travelling around the island.

Geological structure

Bornholm is an exposed horst of the Precambrian Baltic Shield, situated on the north-eastern edge of the Trans European Suture Zone (TESZ) and ultimately formed by a set of faults along the longest tectonic lineament, called the Tornquist – Teisseyre'a zone (Cymerman, 2004). The area of the contemporary island was formed 1.7 billion years ago and constituted a part of a mountain range.

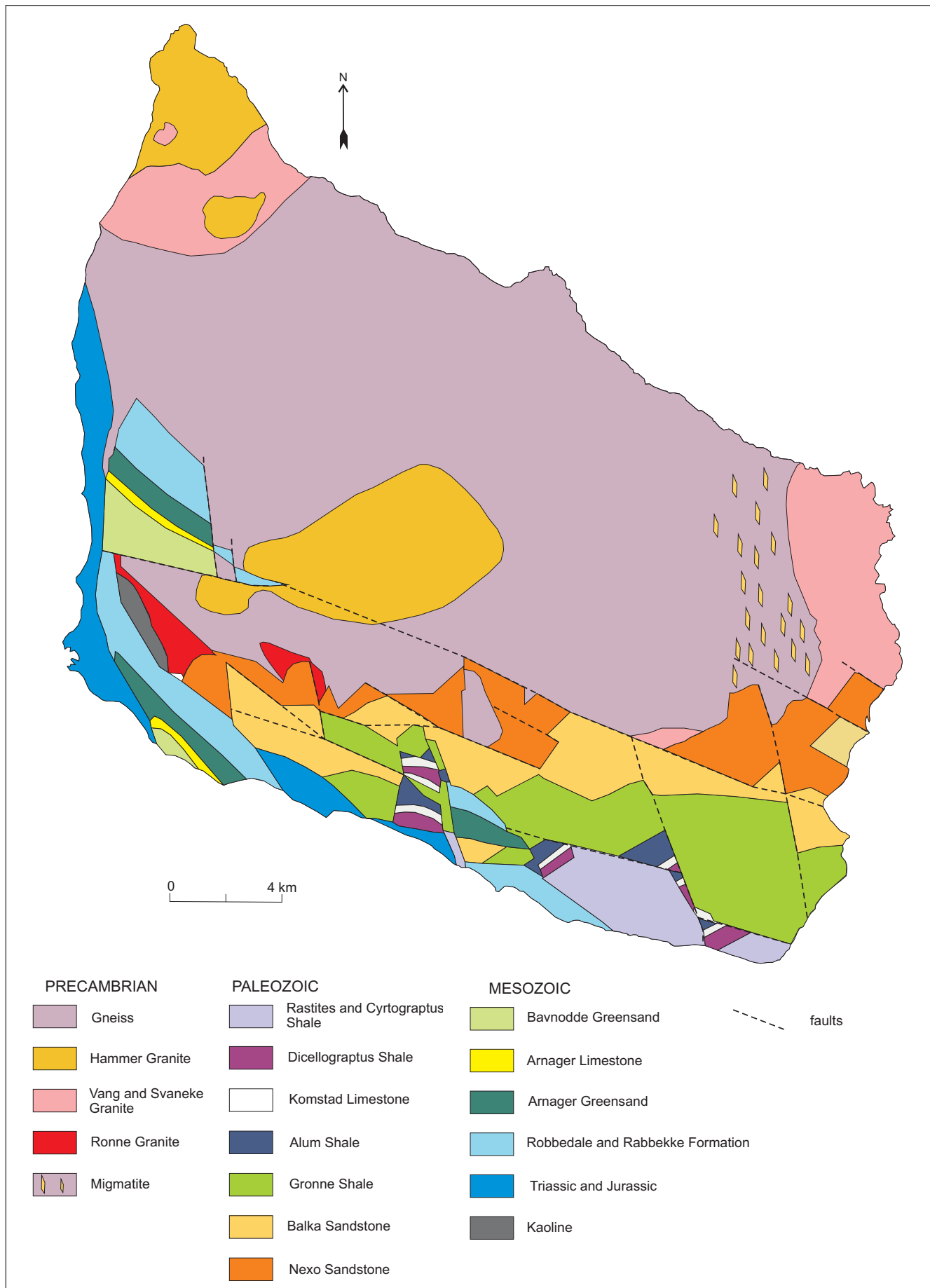


Fig. 1. The geological map of Bornholm (without Quaternary sediments); after (Gry 1960)

Large parts of Bornholm consist of pre-Quaternary crystalline bedrock with a discontinuous, thin cover of Quaternary sediments (Jakobsen, 2012).

Currently, around two-thirds of Bornholm's area is formed of hard granite and gneiss rock, whereas the remaining third of the island's area in the south is formed of Palaeozoic and Mesozoic sedimentary rocks, which are highly erosive (largely sandstones, but also to a lesser extent slates and limestone) (Fig. 1). This is one of few places in Europe where, on a limited area, one can find rocks from different geological periods.

The present appearance of the island's surface is due to the activity of the glacier, which slid over the island twice. Despite a number of processes involving glacial abrasion, an older crystalline basement with numerous faults is predominant on the island (Andersen, 1996). One of the most pronounced terrain features on Bornholm is fracture valleys, which are sub-glacially eroded faults and fracture zones within the basement rocks (Jakobsen, 2012).

The southern area of the island consists of mainly Palaeozoic and Mesozoic formations and partly of Precambrian rocks. Precambrian rocks are almost exclusively crystalline rocks: gneiss, granite and diabase. They were formed from 1700 to 1200 million years ago (Larsen, 1971). From the four types of granites distinguished by Gry (1960), Hammer, Vang, Svaneke and Ronne, only two (Ronne and Hammer) can be found on Bornholm. These rocks are exposed mainly in disused quarries to the east of the island's capital – Ronne (Cedro, Duda, 1996).

The Paleozoic sediments were formed from the Cambrian to the Silurian period and their thickness reaches around 500 metres. The Cambrian formations that are exposed in this part of the island are sandstones: Balka and Nexø, green slates Broens Odde included in the Laes's formation, as well as Rispebjerg sandstones belonging to the same formation. The Cambrian Series 3 is represented by Exulans and Kalby limestone located in the Øle Å River valley. These formations are covered with a 1.5 metre thick layer of alum slates, on top of which a thin stratum of stinkstone with phosphorite conglomerates can be found. The Furongian is represented by black mudstones containing stinkstone called Olenid's alum slates. The sediments of the Ordovician begin with the Dictyonema dark alum slates, on top of which Skelbro and Komstad limestone can be found. The Middle Ordovician (Llanvirn) is mainly represented by slates such as Dicollograptus dark grey slates, light-grey mudstones around 4,5 metres thick, Tetraspis slates, and Dalmantina slates, consisting of grey mudstones. The Silurian begins with dark grey mudstones of considerable thickness called Rastrites slates, on top of which *Cyrtograptus* slates can be found. The characteristic feature of the Ordovician and Silurian sediments is the presence of graptolites. The sediments of the Upper Palaeozoic, Devonian, Carboniferous, and Permian are not exposed on the surface (Gravesen, Bjerreskov, 1984).

The Mesozoic sequence occurs in narrow fault blocks, along the south and west coasts and offshore in the Rønne Graben, west of Bornholm, covering around 2500 metres of sediments and spanning a period from the Late Triassic to the Late Cretaceous (Gravesen *et al.*, 1982).

The Jurassic contains three major formations:

- The Ronne formation, including the following lithostratigraphic units: Munkerup (loams, ranging from grey loam through red loam to brown and white loams and sandstones), Sose Bugt (fine-grained, laminated sands with carbon detrital minerals as well as silt and grey loam) and Galgeloke (the predominant formations include traverse stratification of fine-grained white or yellow sands and loams) (Gry, 1960).
- The Hasle formation, dominated by ferriferous fine-grained sandstones of yellow and brown colour (Gry, 1960).
- The Baga formation consisting of traverse stratification of fine-grained and medium-grained sands, loams and thin deposits of coal (Gry, 1960).

Within Lower Cretaceous sediments, three formations can be indicated (Gravesen *et al.*, 1982):

- The Rabekke formation, including two lithostratigraphic units: Homandshald and Skyttegard. The sediments characteristic for this formation are brown medium-grained sandstones with siderite concretions and multicoloured, frequently sandy loam with silt.
- The Robbedale formation is divided into two lithostratigraphic units: Osteborg and Langbjerg. The first unit is represented by fine-grained quartz sand or silica, the thickness of which reaches 18 metres, whereas the lithology of the second unit is dominated by the sediment of medium-grained and coarse-grained sands with local rock pebbles.
- The Jydegord is formed from the lithostratigraphic units of Tornhoj and Rodbjerg, which consists of sands of varied grains, horizontally laminated silts and loams with iron particles. The Rodbjerg unit is characterized by horizontally laminated olive-grey loams with silt, fine-grained sand, and infrequent thin layers of sandstones, mudstones, and ferriferous loams containing pyrite, mica, and sporadically septarian concretions.

The Upper Cretaceous formations consist of Bavnodde green sands (with the fossils of ammonites, belemnites, and bivalves) Arnager green sands, as well as Arnager limestone. The green colour of the sandstones stems from the substantial glauconite contents (Cedro, Duda, 1996).

Geological – tourist routes – 7 routes

I. Through the dunes (Slusegård – Nexø)

11 Slusegård (55°0'6,35"N; 14°59'49,8"E) – the estuary of the Øle Å River, the excavated site of the no longer existing Iron Age settlement. An additional attraction is one of three oldest and well-preserved watermills on Bornholm – Slusegardmølle, dating back to 1800 (Jakubowski, 2009) (Fig. 2).

12 The Øle Å River Valley, the exposition of slates, age: the Silurian; location: the Øle Å River Valley. The most significant exposition can be found to the north of Slusegård (55°0'4,85"N; 14°59'51,04"E).

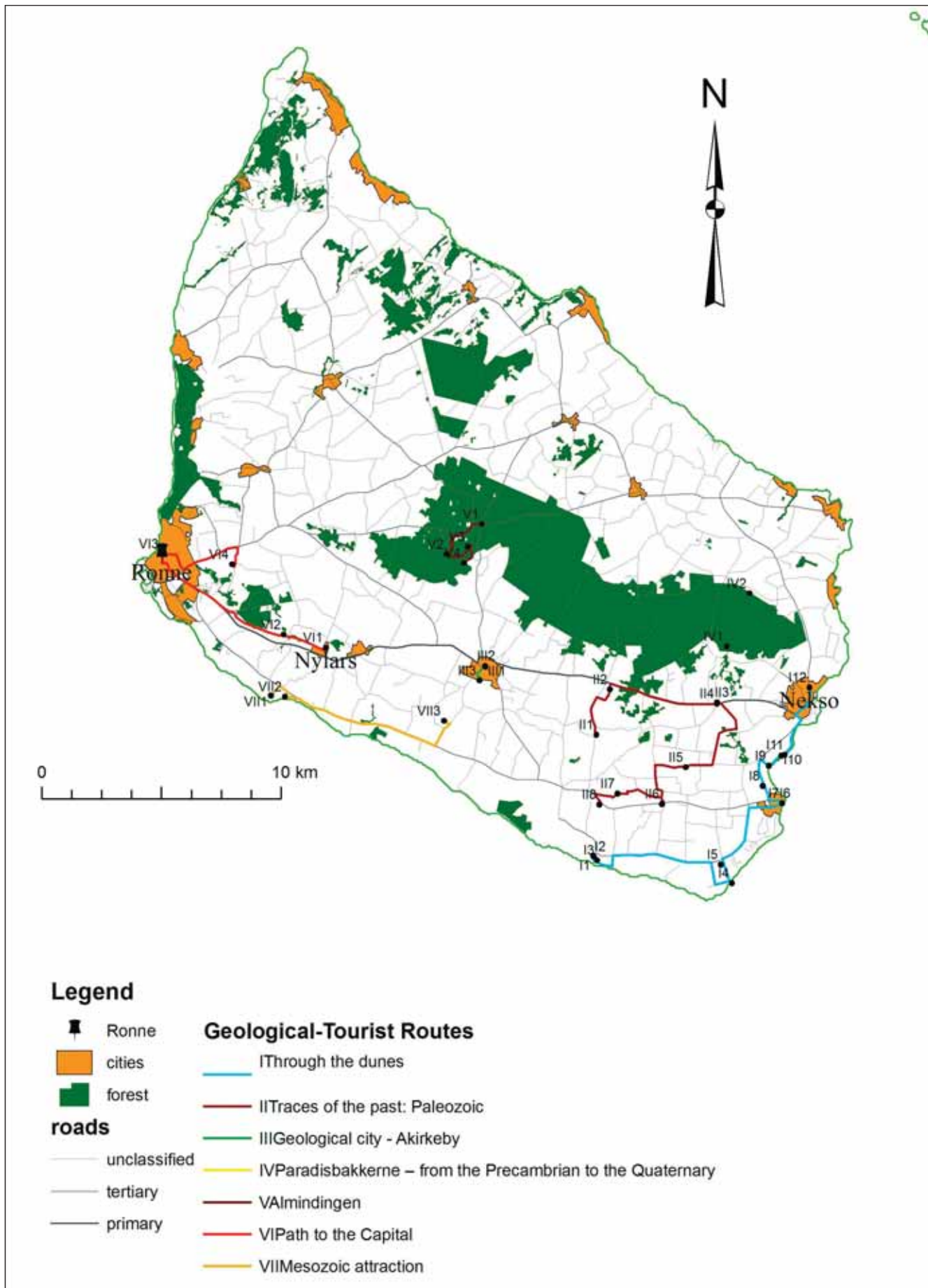


Fig. 2. Geological – Tourist routes of southern Bornholm, I. Jamorska



Fig. 3. The Øle Å River Valley – Cyrtograptus slates, photo I. Jamorska



Fig. 5. Dunes of Dueodde and Dueodde Fry lighthouse, photo I. Jamorska



Fig. 4. Monolith – the intersection of 15° longitude E and 55° latitude, photo I. Jamorska



Fig. 6. Dueodde – large gun emplacements, photo I. Jamorska

Geology: The sediments that can be found here are dark grey mudstones frequently referred to as Cyrtograptus slates (Fig. 3), due to numerous graptolithina found within them.

13 Tourist spot – a monolith, the location of which is at the intersection of 15° longitude E and 55° latitude (Fronia, 2009). The solar time of the 15 longitude E applies to the Central European Time zone including Poland, among other countries (Fig. 4).

14 Dueodde (54°59'39,5"N; 15°5'20,62"E) – a summer resort famous for its sandy shore and dunes. There is a wide beach with fine-grained sand, as a result of which it is an attractive place for seaside relaxation (Fronia, 2009). The Dueodde Fyr lighthouse is situated in the vicinity of the resort, (Fig. 5).

15 Dueodde – large gun emplacements (55°0'3,7"N; 15°4'51,47"E). On both sides of the Skrokkegardsvejen road, there are two large naval gun emplacements of reinforced concrete (Fig. 6). The construction of which was commenced by the Germans during the Nazi occupation of the island in 1940 (Fronia, 2009). Bornholm, with its convenient location, was a perfect military site to control the waters of the Baltic Sea. However, because of the outbreak of hostilities with the Soviet Union, the construction work on the naval gun emplacements was suspended (Jakubowski, 2009).

16 Broens Odde Green Slates (the Laes formation) – period: the Furongian; area: the coastal area south of Snogebaek (55°1'31,5"N; 15°7'7,27"E); geology: these are strongly bioturbated mudstones containing glauconite grains as well as phosphorite concretions.

17 Snogebaek (55°1'31,5"N; 15°7'7,27"E) – a fishing village well-known for its miniature settlement and wooden quay. Moreover, one of the most famous fish smokehouses on the island is located on the marina. One can taste the best-known delicacy of the island – a smoked herring with sea salt, raw yolk and onion or radish – the so-called “bornholmer” (Jakubowski, 2009).

18 Ornithological Reservation Hundsemyre (55°1'53,74"N; 15°6'19,95"E) – the bird sanctuary of Hundsemyre began in 1977. The purpose of which was to protect the open water surfaces, the reed areas, the meadows, the scrubs and the woods, and to protect the birds from disturbance. It is one of the largest peat moors on Bornholm. During World War One, 8000 tons of peat, and during World War Two, 50000 tons of peat were extracted from the site.

19 Balka (55°2'21,59"N; 15°6'31,5"E) – a seaside resort on the east coast of the island, located at a bay with a narrow, but sandy beach. To the north of the village, along the coast, there is a sea bird sanctuary, where birds nest in the heather-covered heath (Fronia, 2009).

110 Langeskanse (55°2'36,43"N; 15°6'59,29"E) is the largest battery on Bornholm. It is 600 metres long and from 0,5 to 2 metres high. The battery is built of horizontally placed sandstones covered by a thick layer of turf. It is not known when Langeskanse was created.

111 Nexø Sandstone: period: the Cambrian; area: (55°2'37,35"N; 15°7'7,96"E) in the coastal area to the north of Nexø; near to Gadeby.

Geology: The sandstone was deposited in Eocambrian or Early Cambrian directly on the Precambrian basement rocks of Bornholm, and was thought to have been derived from the breakdown of these rocks (Jensen, 1977). It is a subarkosic sandstone, with subangular grains of quartz and feldspar in a red coloured matrix (Fig. 7).

112 Nexø: (55°4'10,22"N; 15°7'57,31"E) the second largest town on the island, a well-known harbour, which is a destination for Polish ferries departing from Kołobrzeg. The biggest tourist attractions of Nexø are: the biggest fishing harbour on Bornholm; the Nexø Museum – retelling the history of the town; the Museum of Bornholm Railway; and the Nexø Kirke – Saint Nicholas's Church (Fronia, 2009). Additionally, Nexø boasts of an interesting settlement pattern, with numerous wooden houses and a historical windmill on the northern outskirts of the town.

II. Traces of the past: Paleozoic (Pedersker – Slusegard)

111 Balka Sandstone (55°2'50,22"N; 14°59'40,02"E)

Area: a disused quarry on the left side of the Olenevej road in the direction of Pedersker (Fig. 8).

Age: Lower Cambrian.

Geology: The sandstone was deposited in a flood channel on a tidal surface, which was part of the coast that was exposed at low tide and flooded at high tide. Flood channels are winding grooves, which function as drainage channels during ebb tides. The windings cause the characteristic deposit forms, which manifest themselves in the quarry as slanted sandstone layers 10 to 40 cm thick, separated by thin layers of clay. These kind of deposits were created by the constant sideways movements of the channel, which deposited sand on one side of the channel and removed it for the other. The original channel, now filled with sand and clay, was about 2 metres deep. Parts of the bottom are vaulted and exposed a couple of meters in the quarry. Slanted layers can be discerned, at the end of the vaulted bottom, they slant towards the west, a former channel deposit. A dark layer can be discerned on the vaulted surface itself, on the channel's bottom. It is a rippled clay deposit with numerous worm tracks made by different creatures (Andersen, 1996).



Fig. 7. Quarry of Nexø Sandstone situated near to Gadeby, photo I. Jamorska



Fig. 8. Quarry of the Balka Sandstone – Pedersker Sandstenbrud, photo I. Jamorska

II2 The Stubmølle Windmill (55°3'52,12"N; 15°0'7,32"E) – one of thirteen Dutch vintage windmills, which were erected on the island in the 18th century, at the same time superseding traditional architecture of the island (Fronia, 2009).

II3 The Nexø Sandstone: period: The Cambrian; location: the quarry to the North of Gadeby (55°3'43,01"N; 15°4'21,12"E).

II4 Bodils Kirke (55°3'41,51"N; 15°4'20,97"E) – a church dating back to the 12th century with a tower erected around the year 1200. There are three runes that can be found inside the church (Rosborn, 2010).

II5 Jaettestuen (55°2'12,68"N; 15°3'15,99"E) – one of many knolls overgrown with trees, typical of the Bornholm landscape, resembling a mound called the Passage Grave

(Jakubowski, 2009). The Passage Grave was built in the Stone Age, around 3200 BC. It was built for the leading members of society and used for burials for hundreds of years.

II6 Povls Kirke (55°1'21,16"N; 15°2'24,70"E) – St. Paul's Church, dating back to the 13th century. Inside the church, there is a well-preserved southern portal with sculpted images and frescoes from the 15th century (Rosborn, 2010).

II7 Rispebjerg (55°1'32,05"N; 15°0'38,66"E) – an archeological site from two different historical periods (Fig. 9). The Stone Age is represented by traces of two circles of heavy wooden post reaching into the sky. It was a sacred place, in which worshippers of the sun sacrificed animals in honour of their deity. The Iron Age, in turn, is represented by a high steep bluff and bulwark of a settlement, situated over the Øle Å River valley, which offered protection for the local population (Fronia, 2009).

II8 The Øle Å River Valley, the exposition of slates (55°1'15,86"N; 14°59'56,95"E); period: The Silurian; location: the Øle Å River valley. The most prominent exposition of slates can be seen to the north of Slusegård.

Geology: The sediments located here are mainly dark grey mudstones also called Cyrtograptus slates, on account of the prominent presence of graptolithina (Andersen, 1996).

III. Geological city – Akirkeby

III1 Aakirkeby (55°4'14,03"N; 14°55'9,98"E) – the largest town located in the middle of the island with the population of 1,600. The town was located with a legal charter in 1346. In the Middle Ages, Aakirkeby was considered to be the capital city of Bornholm.

III2 Aa Kirke (55°4'14,49"N; 14°55'8,86"E) – the most significant historical building of Aakirkeby is an evangelical church in Roman style, dating back to the beginnings of the 12th century.



Fig. 9. Rispebjerg – the archeological site, situated over the Øle Å River Valley, photo I. Jamorska

Aa Kirke is the greatest and oldest church on Bornholm. It is famous for its twin towers and a baptismal font dating back to the early 12th century. The baptismal font was sculpted in Gotland sandstone by Master Sigraft of Gotland. It is engraved with an inscription in runic characters. On account of its building material, the church itself constitutes a geological attraction. The building material for the construction of the church was supplied by the local population. Within the walls of the church one can find: green Jurassic sandstone forming the apse, foundations and quoins, rusty brown slates tightly placed in the external walls of the matroneum, as well as the eastern quoins of the nave, the Silurian limestone from Komstad – forming the remaining part of the nave and the towers (Hansen, 2008).



Fig. 10. NaturBornholm – the modern center of Nature and Education, photo A. Sokólska

III3 NaturBornholm (55°3'54,10"N; 14°54'57,59"E) – a modern Centre of Nature and Education erected on Klintebakken (Fig. 10). NaturBornholm is frequently referred to as a "key to Bornholm." The edifice is located in the vicinity of perfectly visible European geological dividing line in the Tornquist – Teisseyre's zone (55,063; 14,909) (Fig. 11). If one stands astride, one foot is separated from the other by 1,2 billion years. On Klintebakken, three types of rocks can be found: gneiss, Nexø sandstone and Balka sandstone (Piórska *et al.*, 2007).

IV. Paradisbakkerne – from the Precambrian to the Quaternary

IV1 Paradisbakkerne (55°5'0,50"N; 15°4'36,66"E) – is a group of hills, located in the east of Bornholm, in the region of Hovedstaden. The hills rise to the height of 30–50 meters above the surroundings in a forested area which also has a number of small lakes. The forest area of Paradisbakkerne is ecologically diverse and contains rich flora and fauna. There are many valleys from the north to the south. In addition to rift valleys, there is also evidence of the last Ice Age with glacial boulders and glacial striations. The geological formation in the area is Paradisbakkegranit. It is almost black with green crystals. The main component of granite is feldspars.

IV2 The Migmatite Quarry.

Period: The Precambrian.

Location: (55°6'14,05"N; 15°5'22,22"E) the northern part of Paradisbakkerne region, the Proestebo quarry: we take the Ibskervej road and turn left into the Paradisbakkevejen road. Having covered around one kilometre, we turn left into a dirt road leading straight to the quarry (Fig. 12).



Fig. 11. European geological dividing Line – TT zone, photo I. Jamorska



Fig. 12. Proestebo – the Migmatite Quarry, photo I. Jamorska

Geology: The Paradisbakker migmatites are found within the 2 kilometre wide stretch along the Svaneke granites. This is a rock formed on the border of magmatism and metamorphism, revealing a considerable degree of foliation. The mineral composition of migmatites includes such minerals as quartz, feldspars, and biotite (Andersen, 1996). The Proestebo quarry is partly flooded. The northern walls of the quarry rise up from the water. The outcome of the migmatisation can be best observed in the southern part of the quarry.

V. Almindingen

V1 Almindingen (55°7'27,65"N; 14°54'42,28"E) one of the three largest forests occupying 20% of the island's surface. It covers 2,400 hectares and it is an entirely artificial community of trees, mainly coniferous. In the 14th century, the majority of the primeval forest was cleared because of a shortage of fuel on the island. The complete destruction of the forest was stopped by a forest ranger Hans Romer, who initiated the construction of an 8 kilometer long stone wall around the remaining trees in 1800 (Fronia, 2009).

V2 Rytterknaegten (55°6'43,14"N; 14°53'22,36"E) – the highest spot on the island with the altitude of 162 metres above the sea level (Fig. 13). The Royal Tower was built here in honour of King Frederick VII in 1856, and later, towards the end of the 19th century, a viewing platform was added, from which the panorama of the island can be admired (Fronia, 2009).

V3 Granite Hammer.

Period: the Precambrian.

Location: (55°6'55,27"N; 14°54'11,99"E) mainly in the northernmost part of Bornholm, but also in the centre forming the highest elevation on the island (162 metres above the sea level).

Geology: Hammer granite is the most leucocratic of the main varieties of Bornholm granite. The colour of this type of granite ranges from pale grey to pink. Bright fine-grained and medium-grained granites predominate. In hand specimens, numerous, characteristic, small, red lustric specks appear. The specks originate from coatings on single grains by a substance supposed to contain ferric ions (Jorgart, 1996). This type of granite can be observed in exposures (Fig. 14) along the trail leading to the highest point of the island called Rytterknaegten.

V4 The Ekkodalen Valley.

Period: Tertiary.

Location: in the central part of the island – Almindingen (55°6'32,40"N; 14°54'2,82"E)



Fig. 13. Rytterknaegten – the highest spot of the Island, photo D. Piątkowska



Fig. 14. Granite Hammer – exposures along the trail leading to the highest point of the island, photo D. Piątkowska

Geology: this a cleft valley around 60 metres wide and 12 kilometers long created during extreme tensions in the Earth's crust, in the hard bedrock – granite (Fig. 15). At a subsequent stage, the bergschrund was filled with an igneous rock – diabase (Borówka, 2011). In time, under the influence of erosion, the diabase, less resistant to abrasion, was washed away. In this way, creeks flowing from the centre of

the island to the sea were created in the bergschrunds (Piórska *et al.*, 2007).

VI. Path to the Capital (Nylars – Ronne)

VII Nylars – in a village situated 7 kilometres to the east of Rønne, there is the Nylars kirke ($55^{\circ}4'26,82''N$; $14^{\circ}48'50,85''E$) – the best-preserved of all four round churches found on Bornholm, erected around the year 1150 (Zralek, 2012). The oldest wall paintings, dating back to 1250, can be admired inside, whereas in front of the church there are two runic stones (Fronia, 2009).

VII Slau's Stones, Uglegard Farm ($55^{\circ}4'40,92''N$; $14^{\circ}47'9,87''E$) – this place was established by Hans Schouw Andersen, also known as "Slau". In his years of active employment, Slau was a farmer, who spent his whole life on the Uglegard Farm. In 1988, after being awarded early retirement due to an illness, he had time on his hands, and certain artistic abilities emerged that no one knew he had. These abilities found their reflection in this stone park where visitors encounter the fairytales of Hans Christian Andersen, the Norse gods and much more (Fig. 16). All of these stones were dug up from the land of Uglegard Farm. The shape of some was enough to inspire some fantasy, while other stones were shaped with a hammer, chisel and angle grinder. At first only sandstones were decorated. Later on Slau also applied the old Bornholm granite.



Fig. 15. The Ekkodalen Valley, photo A. Sokólska



Fig. 16. Uglegard Farm – Slau’s Stones, photo A. Sokólska

VI3 Rønne (55°6'19,48"N; 14°42'9,68"E) the capital city and the largest town of the island, situated on the south-western coast. The population of the town is about 15,000, the number which constitutes a third of all the inhabitants of Bornholm. Rønne is the administrative and cultural centre of the island, as well as an attractive seaside resort. The town is of compact urban development with narrow and winding streets and colourful bungalows on both sides. While sightseeing the town, the following sites are well worth a visit: a harbour smithy built in 1735, a lighthouse from 1880, the Store Torv fair, a stone sculpture made of Bornholm granite working as an original sundial; the smallest house, on the corner of Vimmelskaftet and Bagergade St., Bornholms Museum, with fine archeological, and historical collections of exhibits documenting the history of the island (www.bornholm.modos.pl).

VI4 A Quarry in the Vicinity of Knudsker.

Period: the Precambrian.

Location: (55°6'11,47"N; 14°44'57,56"E) to the north-east Ronne; heading for Snornebaken we turn right into the road to Knuds Kirkevej.

Geology: it is one of the biggest quarries on the island, where granite Ronne is extracted (Fig. 17). This rock is slightly darker than granite Hammer. As a result of its remarkable contents of dark minerals, mainly biotite and hornblende, with a scarce amount of quartz, it is called granodiorite.



Fig. 17. Stenbrud – the biggest quarry of Hammer Granite on the island, photo A. Sokólska

The granite Ronne is crisscrossed by numerous pegmatite intrusions, which can be observed on the walls of the quarry (Cedro, Duda, 1996).

VII. Mesozoic attraction – Arnager and the Palaeozoic mosaic – Laesa River

VII1 Arnager (55°3'17,13"N; 14°46'47,77"E) an enticing seaside resort situated 3 kilometres away from Ronne. Arnager has a small harbour and a 200 metre long wooden pier, which leads to a small marina. To the west of the village, there is the Bornholm airport.

VII2 The Arnager Cliff.

Location: (55°3'16,69"N; 14°47'21,78"E) to the west of the Arnager pier (Fig. 18); Age: Late Cretaceous; Geology: the cliff is made of the Arnager limestone, which contains biomicrite calcium carbonate with a substantial addition of fine-grained quartz sand and silt. The Arnager green sands with predominant glauconite and phosphorite grains, as well as phosphate conglomerates are exposed in the base of the cliff (Cedro, Duda, 1996).

VII3 Laesa Valley and the geological profiles (55°2'56,89"N; 14°53'39,89"E).

The bottom of the profile consists of 4 km of Dycyonema shale and the top consists of 4 to 5 km of Komstad limestone from the early Ordovician period. The shale is an alum shale corresponding to the late Cambrian period. The deposits were made without interruption over the dividing line between the two geological periods (Fig. 19) (Andersen, 1996).

The uppermost part of the shale is lighter in colour and contains small chunks of pyrite, phosphorite, and anthraconite. The shale was formed in an aquatic environment and contains graptolites and brachiopods. The shale is topped by a layer of hardened limestone known as Komstad limestone. The colour of the limestone varies from light grey to black. The limestone contains the fossilizations of extinct cephalopods, orthoceratites, trilobites, and brachiopods. The bottom layer of the limestone consists of a 10 cm layer of conglomeratic phosphorite (Fig. 20) with rebided pieces of phosphatized alum shale (Andersen, 1996).



Fig. 18. The Arnager Cliff – made of limestones and Green sands, photo D. Piątkowska

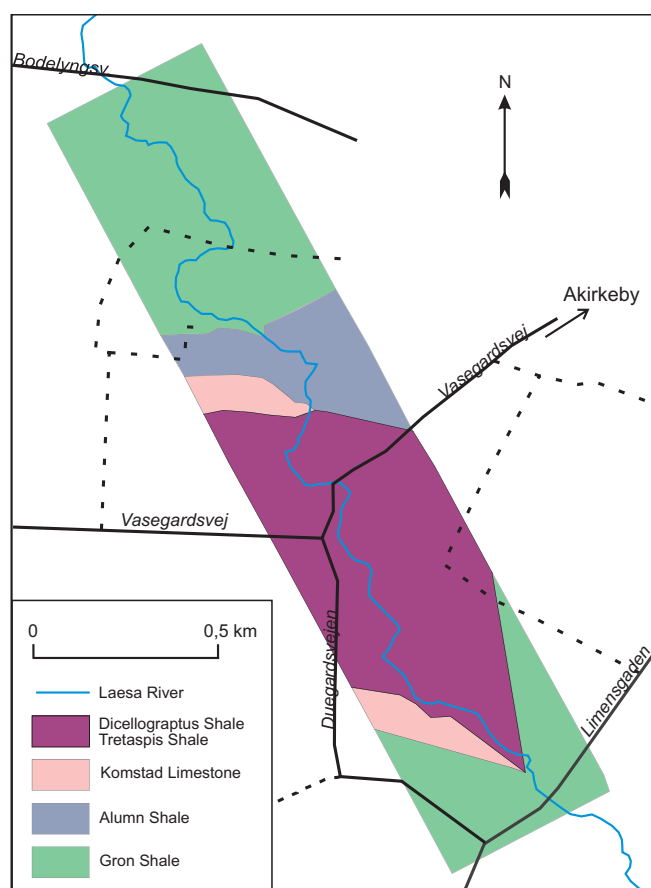


Fig. 19. Geology of the Leasa Valley (after Nielsen, 1988)



Fig. 20. Alum shale – exposures in the Leasa Valley, photo D. Piątkowska

Conclusions

Bornholm geotouristic educational trails are designed to promote history and landscape of the region. The recorded geographical coordinates help locate the geo objects in the field.

The unique location of the Bornholm island and its geological variety makes the island a perfect spot for geological field trips for students of Earth Science.

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