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ROCK MINING INDUSTRY IN HISTORY. GEOSITES AND GEOLOGICAL AND ENGINEERING ASSESSMENT THEREOF

1. Introduction

Over the Cretaceous and Neogene periods, the Vistula River Valley was a cradle of the mining industry, colonization, and industry based on local rock material. The history of this region is an example of a strict symbiosis of geological conditions and unique landscape forms with the development of local architecture, mining skills, decoration skills, and economic development. As early as in the 6th century, the pre-historic mining and settlement related to the easily-yielded flintstone in the Palaeolith period developed into the mines of chalk and other carbonate rock materials used as construction materials for strongholds, sacral objects, dwelling objects. The growth of mining sector for siliceous chalks and geizes, chalks, marls and limestones was particularly intense in the 16th and 17th centuries. That growth was accompanied by the growth of the processing infrastructure: lime kilns, coopery, pottery. The convenient location on the Vistula bank facilitated product sales to other regions. The 20th century was marked with a short-term blooming of the mining industry in one town of Annopol: phosphite as well as rock materials for use in cement manufacture and construction industries.

At present, Upper Cretaceous and Neogene carbonate rock materials are used on a low scale for general purpose and by road construction sectors (limestones, sand limestones, sandstones and siliceous chalks) as raw materials or additives for cement manufacture or lime manufacture (limestones, marls, chalks). Those materials are being pushed away from the 'valued regional construction material' position by more durable materials from outside the region. As the economic situation worsened eventually, historical traces of the regional mining and construction trade, a part of the region's cultural heritage, eventually vanished [6, 7].

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A briefly increased interest in local rock materials was related to Karol Siciński's architectural activity for restoration of various objects in the town of Kazimierz Dolny, whereas, the short-time intensification of mining efforts in the Kazimierz Dolny and Nasiłów siliceous chalk deposits was related to the work for Vistula river control. As the industry-scale siliceous chalk mining (Nasiłów, Kazimierz Dolny, Piotrawin, Annopol) and geize mining (Nałęczów) ceased, numerous picturesque outcrops, which used to be sources for local construction materials, either get covered with plants, or are used as local waste depots.

The establishment of Geopark in the Vistula River Valley, with a number of geosites included, will be protected from the oblivion of the unique traces of the mining and construction trade with their roles in shaping the natural, settlement, and architectural spaces within the region (Fig. 1).

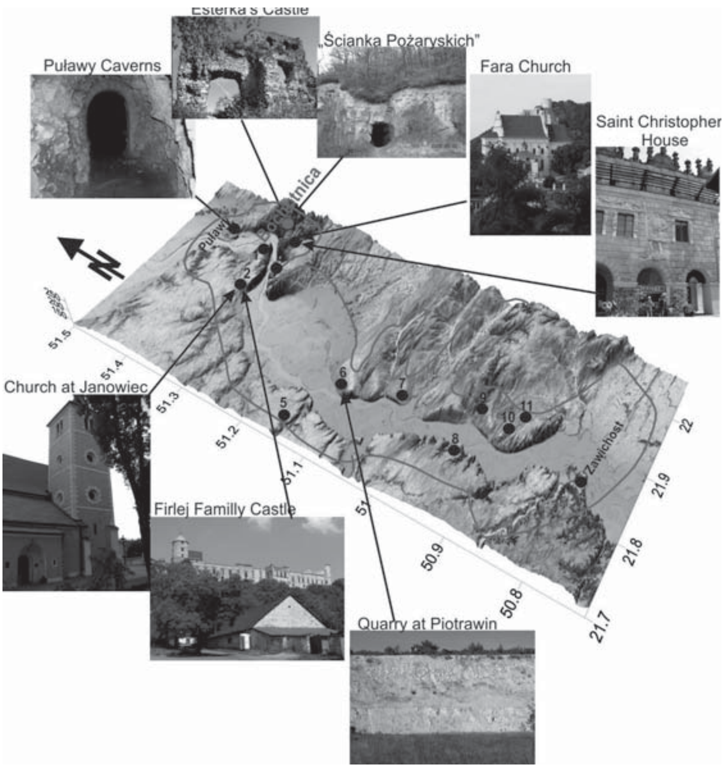


Fig. 1. Examples of locations of rock mining remnants and relation thereof with local architectural objects. 1 — Nasiłów, 2 — Janowiec, 3 — Kazimierz Dolny, 4 — Podgórz, 5 — Dziurków, 6 — Piotrawin, 7 — Józefów nad Wisłą, 8 — Nowe, 9 — Świeciechów, 10 — Annopol, 11 — Gościeradów. Grey line limits area of Geopark

2. Geosites

The earliest Geosite is related to the Palaeolith-period utilization of silica concretions from Turonian carbonate rocks by nomadic humans. Silica concretions presence within the

Rachów and Gościeradów anticline was localized by J. Samsonowicz in 1923. This presence consists of numerous locations, their width up to 1.5 km and length approx. 10 km, on the east Vistula River Valley side from Świeciechów and Annopol up to Wólka Gościeradowska. Ball-shaped silica concentrations were utilized from either shallow-located primary deposits, or secondary deposits in siliceous chalk waste material. Both open-pit and cavity mining methods were used. From the earliest times, the widest application was that for the Świeciechów material: numerous mining activity traces, obliterated already, were found at Świeciechów Lasek, on the river valley slope [1, 4]. Besides, the Vistula River Valley features widely--exposed Maastricht siliceous chalks, which indicate regional open-pit mining towns at: Kazimierz Dolny, Janowiec, Piotrawin, Nasiłów, Annopol. Underground mining remnants are located at Puławy and Bochotnica. Rock utilization from both closest-located underground and open-pit mining sites is visible within Kazimierz Dolny not in its architecture but also in the ton-planning — in the form of underground corridors, or streets built on former surface utilization levels [5]. Siliceous chalk had been utilized by the chamber method at Puławy since the 17th century or even earlier, and was probably used for construction of the Czartoryski family palace. Numerous corridors and chambers are currently known as "Puławy Caverns".

In the deep cut-outs of the Vistula river gorge section, Neogene geize rocks are locally visible on the border between Creaetaceous and Tertiary periods. These stands are located on the Bystra River Valley slope between Nałęczów and Nowy Gaj, inaccessible in practice. Whereas, the best known 'Ścianka Pożaryskich' geosite at Bochotnica is registered in the IUGS Global Geosites data base. The latter is a Mesozoic-Cenozoic border stratotype, a documentation of the facial and paleobiological variety of flora and fauna, therefore it is a significant indicator of paleoclimatic changes and sedimentation environment changes. A shallow underground mine at Bochotnica was surely the source of construction materials for the so-called Esterka's Castle.

The siliceous chalk and geize mining industry within the Vistula River Valley was a long-time tradition which spanned over centuries, a tradition which originated in the early Middle Ages and was commemorated in the stone architecture of the town of Kazimierz Dolny (Fara Church founded by King Władysław Łokietek, Castle, Saint Christopher house and others) and in the vicinity (the Firlej family castle, the 16th century church at Janowiec, numerous 19th century objects around Nałęczów, with the so-called "the grey series" being the basic construction material.

The phosphite mining at Annopol is a relatively young industry. The phosphite concretion utilization from Lower Cretaceous sand deposits commenced in 1925. At the initial stage, the open-pit method was used at the deposit outcrop area. The underground utilization with application of shafts, fore-shafts and a dense system of corridors was launched in 1940. A waste depot (for the waste from material concentrating process up to 14.5–15% P_2O_5) was located nearby. Later on, the spot was afforested. The spoil waste was in part used for excavation filling. Yet, the careless mine closing process of the early 1980s has beed followed with undesirable effects. The shallow excavations, which were only poorly secured by the fall method, create discontinuous deformations reaching up to the surface. Besides, unstable excavation remnants are the cause of a disaster hazard. That stand requires an urgent revitalisation due in consideration both history and education needs as well as for the protection of ichtiosaur remains found therein.

3. Engineering assessment

A commencement of preventive, maintenance and restoration procedures of the geosites along the Geopark tourist routes will call for a general estimation of geological and engineering requirements in the vicinity thereof, and for a detailed geomechanical assessment of wall and rock preservation status for each geosite. This data will be the starting point for technical and economic prerequisites for tourist safety solutions within each object.

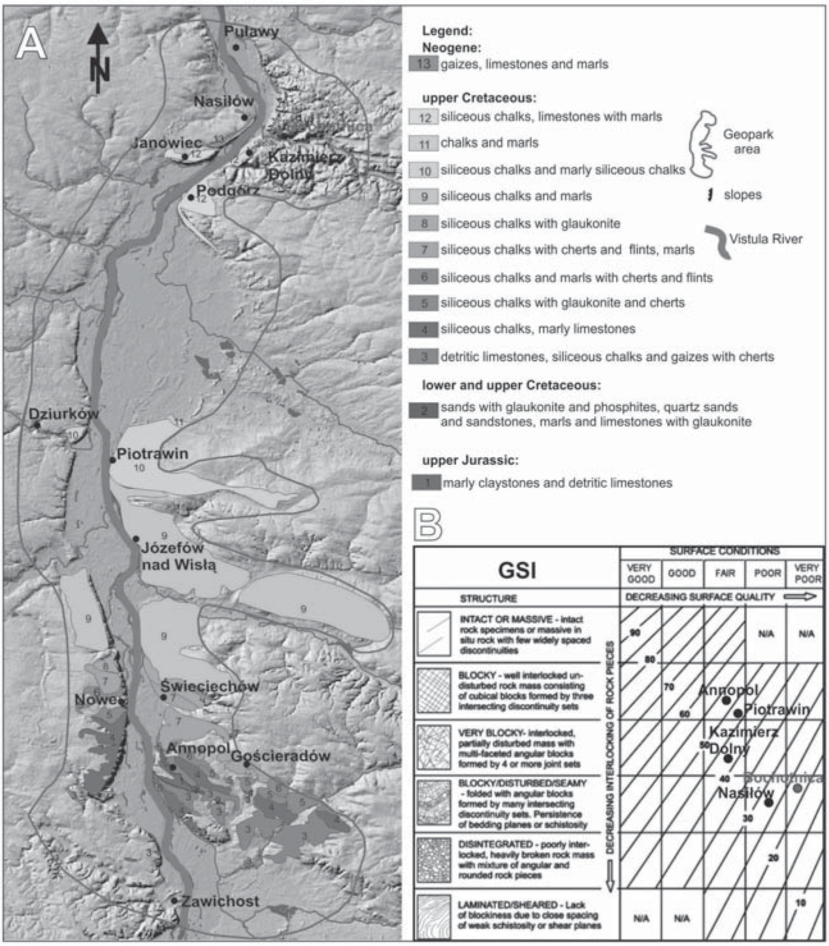


Fig. 2. Geosite locations against the geology map (A) with rock massif feature assessment for selected geosites (B) in their vicinity

The area of the Geopark is diversified with regard to the morphology, rock properties, and deterioration of surface and sub-surface rockbed layers. The Geopark area will have direct contact with variable water level from Vistula river.

Therefore, three factors are the determinants of the general geologic and enginering conditions, hence, those factors describe the level of technical problems which need to be faced while opening the geosites with their surroundings for tourist traffic. Those conditions are as follows: susceptibility to weathering and stability loss (depending on the rock type), slope angle, and flooding when Vistula river water is high.

Figure 2 shows the general characteristics of rock massif, against the geological structure at geosite areas, with examples of the valorisation in the GSI system (Geological Strength Index [3]).

Figure 3A shows the location of geosites against the slope angle, in division in classes as follows: small inclination (0–2°), medium inclination (2–10°), steep (>10°) with the valley edges indicated and against the potential flooding hazard in case the flood wave would accumulate in the Vistula gorge section, that accumulation being shown in figure 3B for each

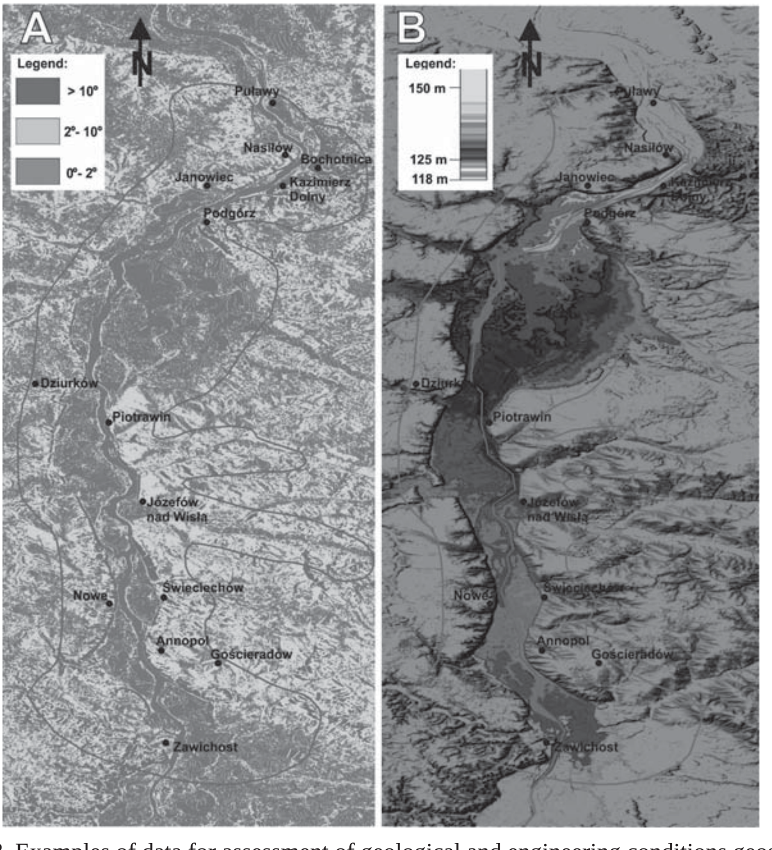


Fig. 3. Examples of data for assessment of geological and engineering conditions geosites.
A — slope angle map. B — potential hazard map — for flooding due to flood water accumulation within the Vistula gorge section (map reproductions do not feature cartographic properties)

1 metre step. Both the present Geosite status and the rock massif susceptibility for slow weathering-induced transformations are defined by a set of technical parameters determined according to respective procedures depending on the object type. The parameter determination is based on field tests of massif features and on lab stress and strain tests of the rock material from that massif. A set of results of comprehensive field and lab tests for each geosite should be contained in a Geomechanical Assessment Sheet to be synchronised in the GIS system

GEOMECHANICAL ASSESSMENT SHEET

Designation	**Bochotnica**
Coordinates	**Φ 51 20 35 N** **Λ 21 59 34 E**

WEATHERING PROFILE

FIELD TESTS

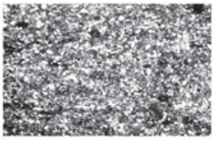
ROCK MASSIF ACC. TO PN-EN 14689-1:2006	
Description	
rock type	sedimentary, siliceous-carbonate, siliceous chalk with bioclasts
massif structure	massive, layers
Discontinuities	
layer thickness	thin, thick
discontinuity spacing	medium
rock block size	medium
block shape	polygonal blocks
discontinuity opening type	from partly opened up to very wide
discontinuity fill material	clay filler, stone rubble
water content	small
rock mass weathering	grade 3 - very weathered

ROCK FISSURITY ACC. TO PN B-02480	
linear	12 mb
per surface unit	6,95 m/m^2
per volume unit	2,58 m^2/m^3
class	III - intensely cracked, IV - very intensely cracked
ROCK MASS RATE IN POINTS-RMR (ACC.TO BIENIAWSKI)	
strength Rc	15 MPa
RQD	40%
discontinuity spacing	10
ground water	0
discontinuity type	0
discontinuity orientation	-60
sum (per 100)	15
class	V - very weak masiff

LABORATORY TESTS

NATURAL STATE	
bulk density (PN-EN 1936)	1460 kg/m^3
porosity (PN-EN 1936)	40%
bulk water absorption (PN-EN 13755)	37%
abrasion (PN 84/B-04111)	4,5 mm
uniaxial compressive strength (PN-EN 1926)	15 MPa
Young modulus (ASTM D 3148-02)	4 GPa
Poisson's ratio (ASTM E-132)	0,12
DETERIORATION SUSCEPTIBILITY ASSESSMENT	
swell (expansion)	0,11%
skurcz	0,09%
frost resistance (PN-EN 12371)	good
salt-induced deterioration index (I)	0,8-0,9

MICROSCOPIC IMAGE FOR NATURAL STATE



DIGITAL ANALYSIS OF POST-SALT CRYSTALLIZATION

Fig. 4. Geosite geomechanical properties assessment sheet

with geological and engineering condition maps and with other documentation. An example of the Geomechanical Assessment Sheet for the medieval underground siliceous chalk mine at Bochotnica is shown in Figure 4.

Both the data contained in the Assessment Sheet and the field data are indicating that the Bochotnica mine roadside, ceiling and floor are located in the monolithic zone of the weathering profile. The massif is graded as intensely cracked and very intensely cracked, very weathered, but dry in practice. Cracks filled with a clay material located inconveniently towards the outcropped walls. According to the Bieniawski [2] grading system (complying with PN-EN 14689 requirements), the massif around the mine headings is graded V – very low strength. The geomechanical lab tests for monolithic zone material samples indicate that those rocks are very light, of high porosity and low strength. Nevertheless, those rocks feature a low susceptibility to frost and moisture as well as to anthropogenic corrosion-inducing factors like salt, swell and shrink. Their micrite structure, having a content of small-size Foraminifera and silica sponge needles, is of a low susceptibility to microcracking, which impedes aggressive solution circulation and corrosion centre growth. On the other hand, the GSI provides us with reasons for forming a conclusion that the Bochotnica Geosite (so-called "Ścianka Pożaryskich") is located within an unfavourable conditions zone due to the very bad technical status of the massif, and due to the > 100 slope angle creating a slope stability hazard.

4. Summary

At the beginning of the 2010 the Vistula River Valley Geopark was established and is located mainly within the Lublin province. The Geopark was formed in response to an idea to link geological heritage with the local economies – to protect geological monuments in a way that would also protect the local community as well. This two years project (2010–2011), is being developed in partnership with the University of Warsaw together with the Maria Curie-Skłodowska University and Polish Geological Institute. The project includes the comprehensive assessment of rock slope and massifs stability and geological trails, the adaptation and revitalisation of geosites for visitors, tour guides, and the creation of a geological guide and an audiovisual documentary of the Geopark. The fundamental part of this project is promoting the education about Earth Sciences, history of rocks, minerals, fossils and landforms to the wider public and the geological heritage conservation in a simplified way to improve awareness of the role of geology in the historical development of the region.

Despite difficult recent geotechnical conditions, a process of protection application work and making that particular geosite and others exposures (materials therefrom were use for numerous historic objects) will be a valuable example of implementation of the New Athens Chart directives aimed at "preservation of cultural wealth and differentiation as resulting from the long history, skilfully connecting the presence and past with future".

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