# Geo TOURISM

## GEOTURYSTYKA

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AGH University of Science and Technology

Volume 16 2019 Issue 3–4 (58–59)

Geo TOURISM
GEOTURYSTYKA
vol. 16, 3–4 (58–59) • 2019

Contents • Spis treści

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The articles published in "Geotourism" have been given a favorable opinion by the reviewers designated by the editorial board.

**Cover photo:** The tor balanced on a pedestal at the Kahfah Formation in Saudi Arabia (by M. Kaminski)
**Back cover photo:** The so-called "basalt rose" visible in the wall of the quarry "Wilcza Góra" (by DE2)

**Head of Publishing of AGH University of Science and Technology Press:** Jan Sas
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**Technical Editor:** Monika Filipek
**Cover Designer:** Pracownia Kreatywna Bezliku
**Typesetting and Desktop Publishing:** Wydawnictwo JAK

The electronic version of the journal is the primary one.
eISSN 2353-3641
ISSN 1731-0830
DOI: https://doi.org/10.7494/geotour
Circulation: 150 copies



"Geotourism/Geoturystyka" is a scientific magazine published by AGH University of Science and Technology (Krakow).
In the years 2004-2009 the magazine was published in cooperation with Stanislaw Staszic Scientific Association (Krakow).

**Editorial Office:**
AGH University of Science and Technology
Faculty of Geology, Geophysics & Environmental Protection
al. Mickiewicza 30, 30-059 Krakow
POLAND
https://journals.agh.edu.pl/geotour
geotour@agh.edu.pl

Wydawnictwa AGH (AGH University of Science and Technology Press)
al. A. Mickiewicza 30, 30-059 Kraków
tel. 12 617 32 28, 12 636 40 38
e-mail: redakcja@wydawnictwoagh.pl
http://www.wydawnictwoagh.pl

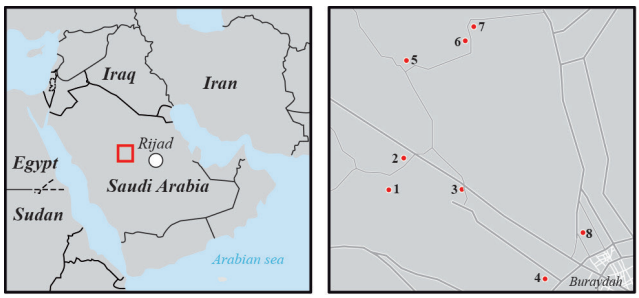
# The Paleozoic formations of the Al-Qassim Province in Saudi Arabia as potential sites for geotourism

## Paleozoiczne formacje prowincji Al-Qassim w Arabii Saudyjskiej jako potencjalne obiekty geoturystyczne

**Michael A. Kaminski[1]*, Thomas F. Garrison[2], Carl E. Yoder[3]**

[1] *Geosciences Department, King Fahd University of Petroleum and Minerals, 31261 Dhahran, Saudi Arabia*
[2] *Department of Chemistry, King Fahd University of Petroleum and Minerals, 31261 Dhahran, Saudi Arabia*
[3] *Preparatory Year Program, University of Qassim, 1162 Al Qassim, Saudi Arabia*
[1] *kaminski@kfupm.edu.sa;* [2] *thomasg@kfupm.edu.sa;* [3] *cyoder1@vols.utk.edu*

* Corresponding Author




Article history:
Received: 3 August 2020
Accepted: 21 September 2020
Available online: 2 November 2020



**Abstract:** *The Paleozoic formations in the Middle East contain some of the world's richest petroleum deposits, as they include excellent source and reservoir rocks. The Paleozoic rocks were deposited on the northern continental shelf of the Gondwanan continent at relatively high latitudes, and provide evidence of the Late Ordovician glacial event and associated sea-level changes. They also contain unique fossil remains. The Paleozoic formations exposed in the Al-Qassim Province in Saudi Arabia are well-suited to become important sites for geotourism. Because the sedimentary formations are well-exposed and are easily accessible, they have strong capacity for development as tourist destinations. In this paper, we describe eight localities and their significance as potential educational sites for geology and palaeontology, as well as the archeological and economic significance of the Paleozoic formations of Saudi Arabia. The cultural and tourist infrastructure is summarised and a two-day field excursion is proposed.*

**Keywords:** *geology, palaeontology, Paleozoic, geosites, Saudi Arabia*

**Treść:** *Utwory paleozoiku na Bliskim Wschodzie reprezentowane są zarówno przez skały macierzyste, jak i zbiornikowe, dlatego zawierają bogate złoża ropy naftowej. Zostały one zdeponowane na kontynentalnym szelfie Gondwany w chłodnym klimacie i wykazują ślady warunków glacjalnych i zmian poziomu morza związanych z glacjacją. Występują w nich także unikalne skamieniałości. Formacje paleozoiku w prowincji Al-Qassim w Arabii Saudyjskiej mają duży potencjał dla geoturystyki. Ponieważ są one łatwo dostępne i dobrze odsłonięte, mogą służyć jako ciekawe atrakcje turystyczne. W niniejszej pracy opisano osiem obiektów geoturystycznych, przedstawiając ich geologiczną (w tym paleontologiczną) charakterystykę wraz z ekonomicznym znaczeniem badanych formacji. Proponując dwudniową wycieczkę terenową po utworach paleozoiku, wskazano także dwa obiekty archeologiczne. Omówiono również infrastrukturę kulturalną i turystyczną.*

**Słowa kluczowe:** *geologia, paleontologia, paleozoik, obiekty geoturystyczne, Arabia Saudyjska*

## Introduction

Due to the recent introduction of tourist visas, Saudi Arabia is rapidly becoming an attractive tourist destination for the adventurous traveller. Centuries ago, the Al-Qassim (sometimes spelled Qasim) region was an important stopover for pilgrims on their way to Mecca. Nowadays, Al-Qassim is a vital agricultural and economic centre in Saudi Arabia and is becoming a popular tourist destination. The outcrops in the Al-Qassim region provide a glimpse into the changing climates of the northern coast of Gondwana during the Paleozoic era.

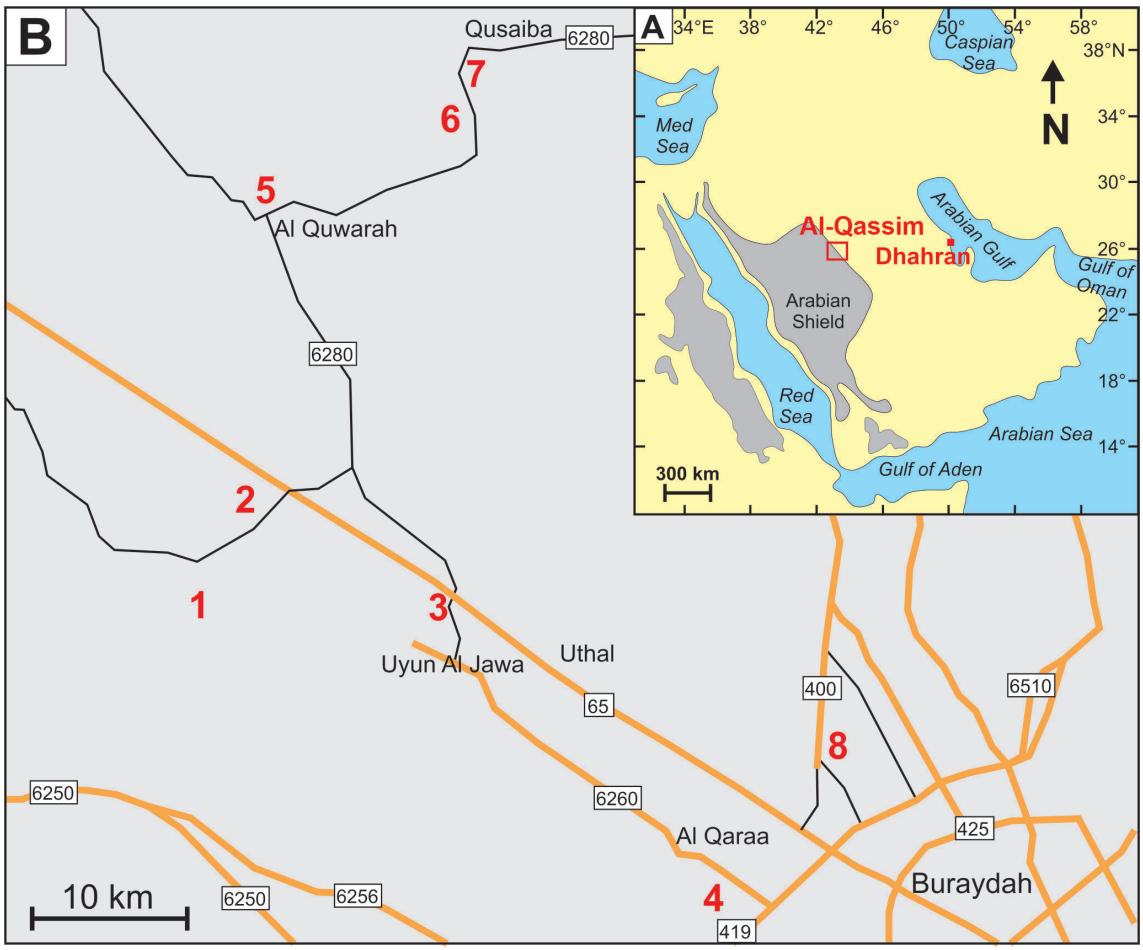



Fig. 1. Location of the geotouristic localities in the Al-Qassim Province of Saudi Arabia: A – insert map showing the position of the Al-Qassim Province on the Arabian Peninsula; B – geotouristic localities numbered in red. Base map from Google Maps

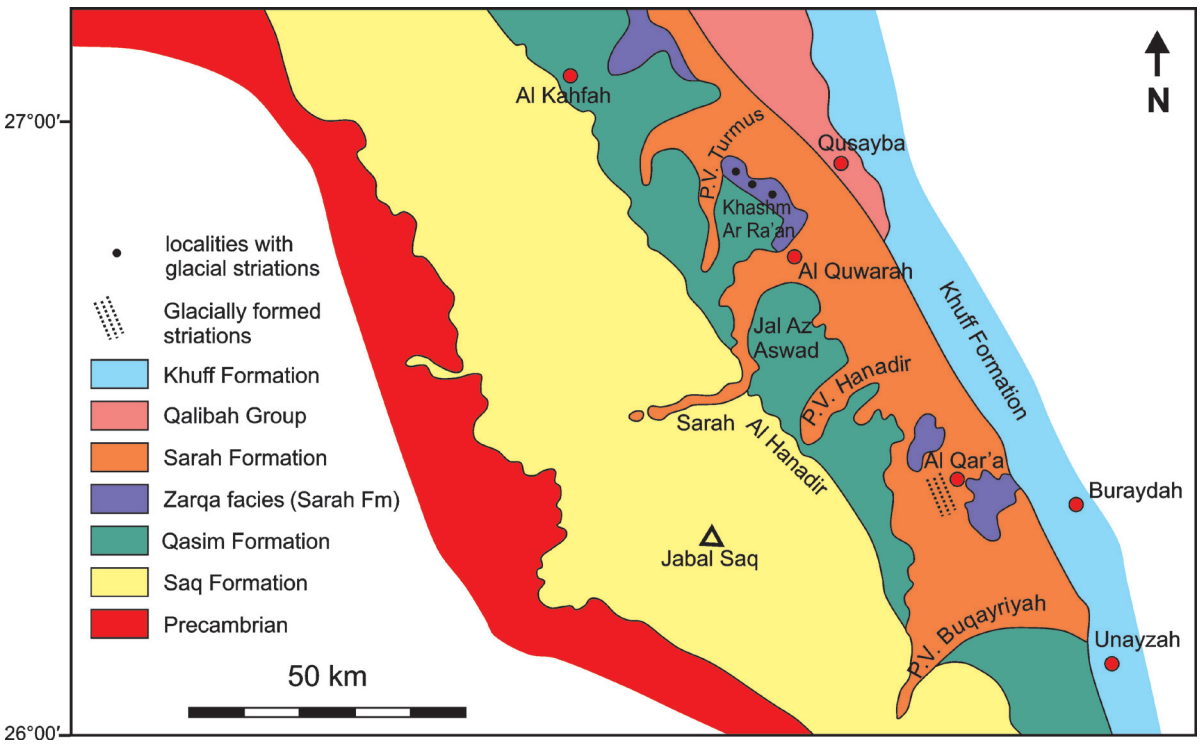



Fig. 2. Simplified geological map of the Al-Qassim Province, modified after Vaslet (1990)

These Paleozoic formations store enormous riches of hydrocarbons, which drive the economy of Saudi Arabia and surrounding countries through oil and gas production. The best and most accessible exposures of these oil and gas-bearing formations are found near Buraydah (sometimes written as Buraidah) (Fig. 1).

Al-Qassim is one of the thirteen provinces in Saudi Arabia and its capital is Buraydah (population 467,410 according to the 2010 census). Qassim University is the main higher education institution in the province, and is currently expanding its campus after becoming a co-educational institution. The local economy has been traditionally based on agriculture. While the region is most famous for dates, other important crops include wheat, citrus fruits, and melons. Modern green houses are used to grow an expanded range of fruits and vegetables. Camel and sheep are important livestock, integral to the economy and culture. One of the largest camel markets in the world is located in the outskirts of Buraydah. The regional source of water is the Cambrian sandstone aquifer, and bottled drinking water and soft drinks from Al-Qassim are available on supermarket shelves across the Middle East.

Geological exploration in the Al Qassim region began after the discovery of petroleum by the Standard Oil Company of California in 1935, and formations from this area were mentioned in the *Geology of the Arabian Peninsula: Sedimentary Geology of Saudi Arabia* by Powers *et al*. (1966). The eight geosites described below are located to the north of the Buraydah, and most are near the main highway leading north. The Paleozoic stratigraphy can be described as a slightly tilted layer cake, with rock units becoming progressively younger in a northeasterly direction (Fig. 2). Paleozoic sediments were deposited on the passive margin of the Gondwanan continent beginning in the Late Cambrian, and the Ordovician to Silurian marine sediments reflect the eustatic sea level changes that took place as a result of the Late Ordovician glaciation. Three large scale shallowing upward sequences of clastic marine sediments are exposed in the Al Qassim region. The claystone or shale units represent the maximum flooding horizons, and form the slopes of bluffs and ridges (also referred to as cuestas). These soft sediments are capped by more durable marine sandstones or limestones. The ranks of stratigraphic units mentioned below (Fig. 3) are in accordance with the *Saudi Arabian Code of Stratigraphic Classification and Nomenclature* (Saudi Stratigraphic Committee, 2013).

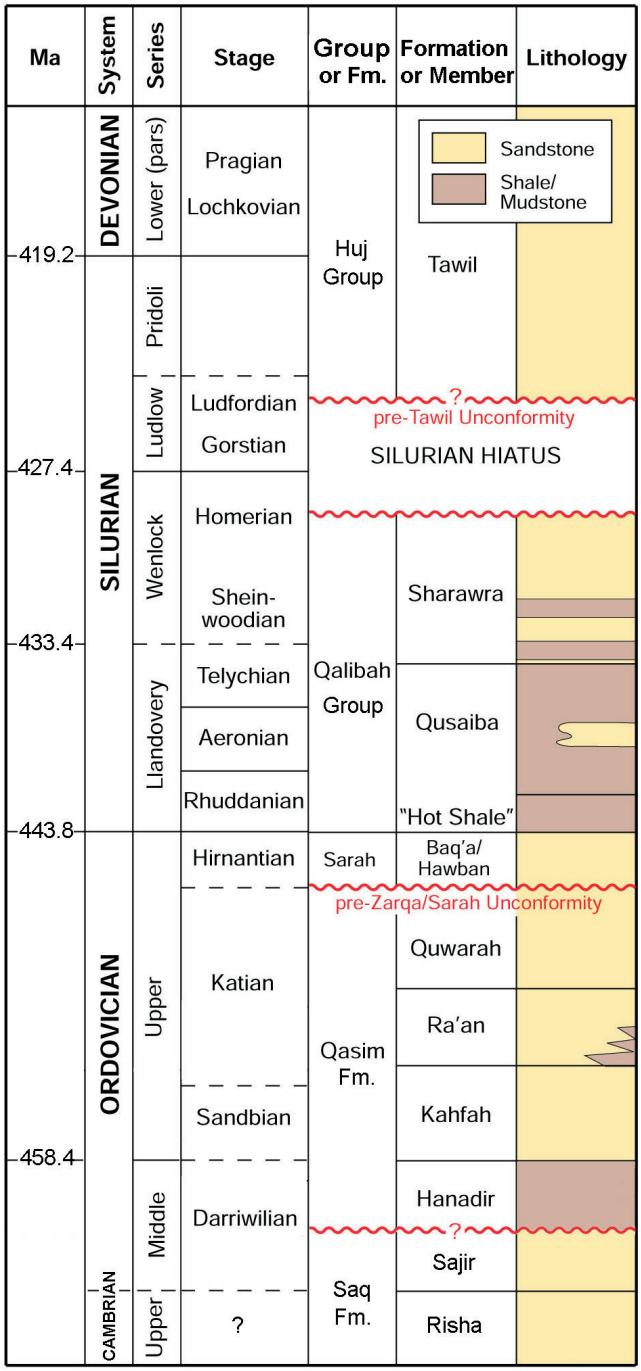



Fig. 3. Lower Paleozoic litho- and chronostratigraphy in the Al-Qassim Province, modified from Zalasiewicz *et al.* (2007). The rank of the lithostratigraphic units is according to the Saudi Stratigraphic Committee (2013)

## Geosites

### *Trip 1: Cambrian to Ordovician*

Our first excursion takes us to view the Lower Paleozoic sedimentary rock formations north of Buraydah. The King Abdulaziz Road exits the city and merges into Highway 65 at the intersection with the Western Ring Road on the outskirts of Buraydah (Fig. 1). Traveling in the direction of Hail, the thickly bedded Cambrian sandstone of the Saq Formation is exposed in road cuts along the highway. This area is known for its agricultural products, and the sandstone of the Saq Formation is the local aquifer. At Exit 571, the road signposted

to Tiraq passes a couple of farms on the left-hand side and after 6 km reaches a rubbish dump. Approximately 300 m past the rubbish dump, an unpaved track enters the road on the left, marked by a tractor tyre (26°35.0784'N, 43°23.4332'E). The track descends a slope and enters a broad wadi[1] with a dry playa lakebed (Fig. 4A). On the right-hand side, there is a line of cliffs formed by the dark grey shale of the Hanadir Member of the Qasim Formation. The track branches off to the right at the base of the slope. On the opposite side of the playa lake, the track continues to the highest point along the cliffs. Our destination is at the end of this line of cliffs where an archeological monument (Fig. 4B), a stone inscribed with Thamudic lettering and surrounded by a chain-link fence, is located at the base of the cliff (26°34.3334'N, 43°22.1898'E) (Fig. 4C). The site is known as Al-'Asoudah. Looking toward the west, we observe in the middle distance a gently undulating plain covered with dark slabs of sandstone. The field appears dark because many of the rock slabs are coated with desert varnish.

### *Location 1a: Cambrian–lower Middle Ordovician Saq Formation (26°34.7468'N, 43°22.6255'E)*

Location 1a is one of the most famous localities for trace fossils in the whole of the Middle East. It is here that Denis Vaslet collected specimens of trilobite traces for the famous trace fossil expert Adolf Seilacher (Tübingen) who described the ichnospecies *Phycodes fusiforme* from this locality (Seilacher, 2000). After crossing the pink shale of the lowermost Hanadir Member, we see the disconformity between the Sajir Member of the Saq Formation and the Middle Ordovician Hanadir Member of the Qasim (spelled with one "s") Formation (Fig. 4D). The Sajir Member had been reported to be of Early Ordovician age, based on comparison with similar facies in Jordan (Saudi Stratigraphic Committee, 2013), but recent studies by a team lead by Saudi Aramco paleontologists (Le Hérissé *et al*., 2017) suggest a Middle Ordovician (early Darriwilian) age for the upper part of the sandstone of the Sajir Member. The chitinizoan index species *Siphonochitina formosa* was found in the topmost Sajir Member, constraining the age to late-early Darriwilian. Therefore, the hiatus between the two formations is of short duration, if it exists at all (Marco Vecoli, personal communication, 2020). The upper unit of the sandstone of the Saq Formation (Sajir Member) is marine, and was deposited in a sandy tidal flat environment. The thin-bedded slabs of sandstone exposed at the top of the formation near the unconformity are often ripple-marked and covered with abundant trace fossils created by the activities of trilobites (Fig. 4E). The best localities for trace fossils are the shallow gullies where the occasional rainstorm washes away the sand, exposing slabs of reddish sandstone. It may be necessary to turn the slabs over to reveal the trilobite traces. Most of the traces represent the feeding or foraging activities of arthrophycids (*Phycodes*), but it is also possible to observe locomotory trails (*Cruziana*), and resting traces (*Rusophycus*) of trilobites.

[1] The term "wadi" refers to a dry desert valley formed by an ephemeral stream or river.

### *Location 1b: Middle Ordovician Hanadir Member (Lower Qasim Formation) (26°34.2658'N, 43°22.0751'E)*

Returning to the Al-'Asoudah archeological site at the base of the cliff, we observe a vertical section through the exposed part of the shale of the Hanadir Member. The Hanadir shale forms the basal unit of the Qasim Formation, which is from the Middle Ordovician age. The Hanadir Member is a petroleum source rock in the subsurface, and a recent major discovery in this formation by palynologists at Saudi Aramco (Vecoli *et al*., 2017) has recast what we know about the historical geology of land plants. Vecoli and co-workers (2017) discovered tetrad cryptospores originating from primitive bryophytes (mosses) that had been growing in wet areas along the coastline of the Gondwanan Continent. The occurrence of cryptospores in sediments of Middle Ordovician (Darriwilian) age in Saudi Arabia suggests that the colonization of land by primitive plants first took place in Gondwana. Previously, the earliest land plant fossils were found in the Middle Silurian (Wenlock) in the Czech Republic (Libertín *et al.,* 2015).

Opposite the archeological site, there is a small gully containing large fallen blocks of sandstone. At the head of the gully, we observe a thick lens-shaped sandstone body (Fig. 4F). On the left side of the gully shale of the Hanadir Member is exposed (Fig. 5A), which yields abundant tuning-fork shaped graptolites (*Didymograptus protobifidus* and cf. *bifidus*), as well as the occasional fragment of a trilobite (Fig. 5B). The presence of graptolites belonging to the Didymograptus murchisoni Zone at this locality provides an exact age (middle part of the Darriwilian) for shale of the Hanadir Member.

### *Location 1c: uppermost Ordovician Sarah Formation*

Above the graptolite locality at the head of the gully, there are fallen blocks of amalgamated conglomeritic sandstone. This is the uppermost Ordovician sandstone of the Sarah Formation, which serves as a petroleum reservoir rock in the subsurface. The sandstone forms sinuous elongated sandstone bodies that in places are in contact with the underlying shale of the Hanadir Member, an important hydrocarbon source rock. At this locality, we observe a lens-shaped cross section through one of the sandstone bodies, whose origin reflects an interesting aspect of the latest Ordovician Gondwanan glacial event.

The latest Ordovician (Hirnantian) was a cold period in Earth's history, and a large continental ice sheet formed over parts of the Gondwanan continent. Plate tectonic reconstructions place the South Pole in northwest Africa at the time (Fig. 6), and a continental glacier extended out in all directions, reaching present-day Saudi Arabia (Vaslet, 1990).

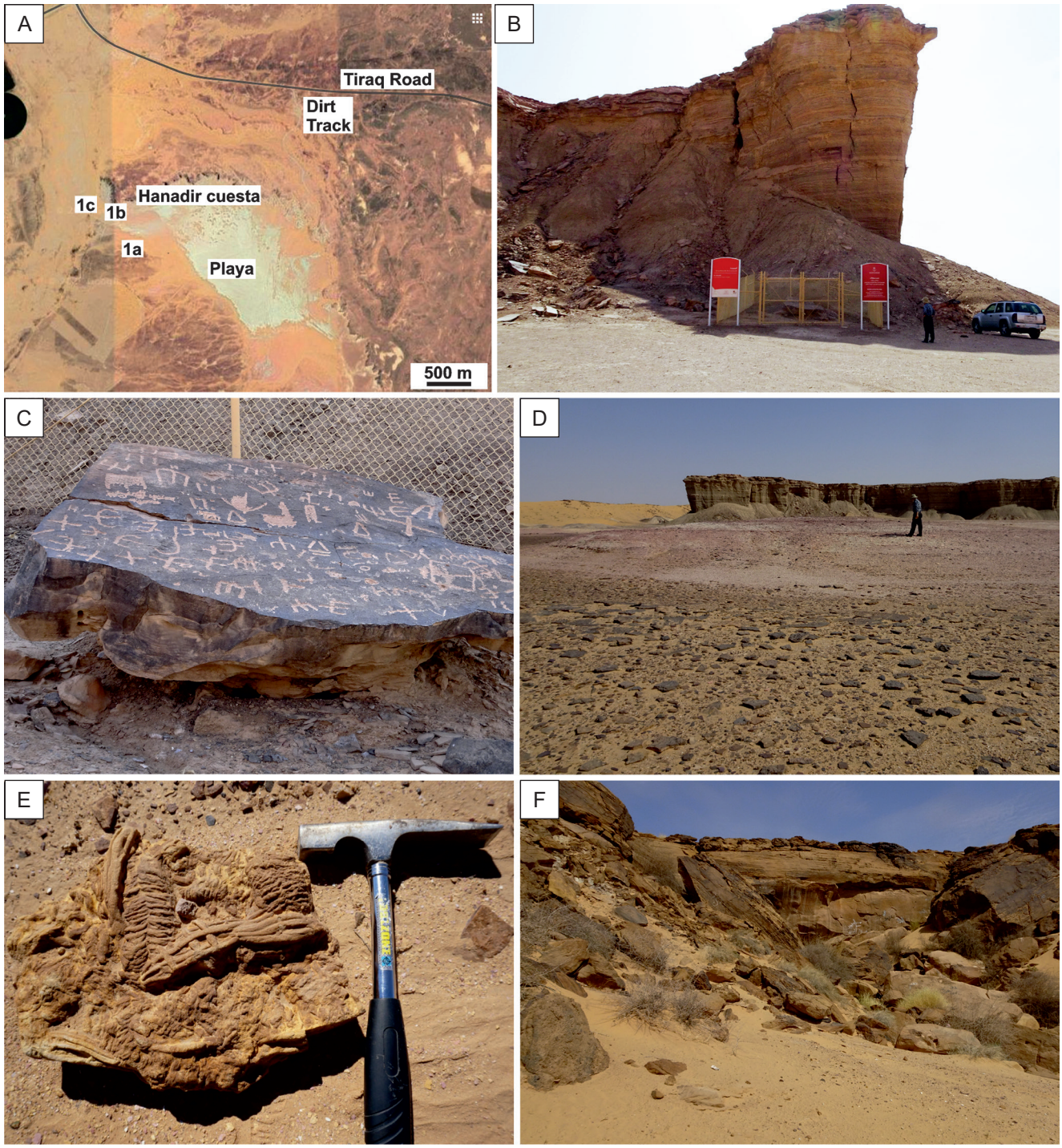



Fig. 4. Geotouristic objects described in the text: A – map of Locality 1; B – archeological site "Al-'Asoudah" at Locality 1; C – the inscribed stone at Locality 1; D – view of the contact between sandstone of the Sajir Member of the Saq Formation and the Middle Ordovician Hanadir Formation at Locality 1a (the slabs of sandstone of the Sajir Formation are in the foreground, and the Hanadir cliffs are in the background); E – trilobite and arthrophycid trace fossils on a slab of sandstone of the Sajir Formation at Locality 1a; F – channelised uppermost Ordovician sandstone of the Sarah Formation in a side gully at Locality 1b. Photos M. Kaminski unless otherwise noted.

At the margins of the melting ice sheet, rivers of melt water flowed out from beneath the ice, similar to glacial rivers that can be seen in modern-day Greenland. The melting Hirnantian ice sheet also had such rivers, which carved their channels into the underlying Ordovician marine sediments, forming structures known as "tunnel valleys". The glacio-marine sandstone of the Sarah Formation contains rounded quartz pebbles derived from the basement rocks of the Arabian Shield (Fig. 5C), and were deposited in these incised tunnel valleys.

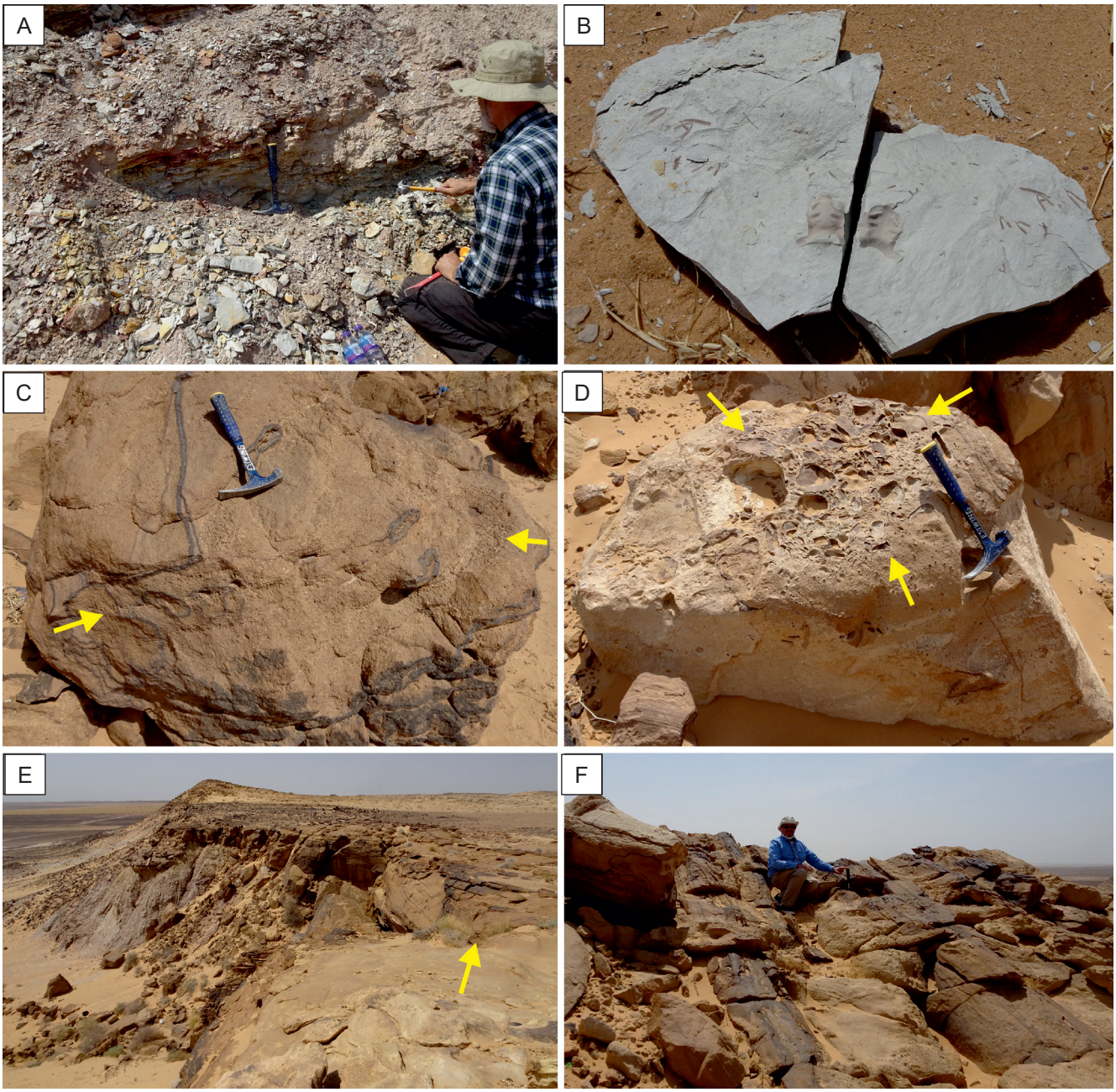



Fig. 5. Geotouristic objects described in the text: A – middle Ordovician shale of the Hanadir Member of the Qasim Formation in a side gully at Locality 1b; B – graptolites and trilobite fragments in shale of the Hanadir Member, Locality 1b; C – boulder of latest Ordovician sandstone of the Sarah Formation showing bands of quartz pebble conglomerate (arrows), Locality 1b; D – boulder of Sarah sandstone showing shale intraclasts (arrows) of the Hanadir Formation, Locality 1c; E – view of the lens-shaped body of sandstone of the Sarah Formation from the top of the cliff (the contact between the grey-coloured sandstone of the Kahfah Formation and sandstone of the Sarah Formation is shown by the arrow), Locality 1c; F – glacial striations and grooves carved by the Gondwanian ice sheet, to the left of the Sarah outcrop at the top of the cliff, Locality 1c. Photo C. Yoder

The sandstone of the Sarah Formation is much coarser grained than the underlying Ordovician marine sandstone. The boulders of sandstone (Sarah Formation) also contain shale intraclasts derived from the underlying shale (Hanadir Member of the Qasim Formation) (Fig. 5D).

A the top of the cliff, the contact between sandstone of the Sarah Formation and the lighter coloured marine sandstones of the Kahfah Member of the Qasim Formation of Late Ordovician age is clearly exposed (Fig. 5E). This is an unconformable contact (an angular unconformity). To the left of the sandstone of the Sarah Formation near the edge of the cliff, we can observe groove marks on the surface of the Ordovician marine sandstone caused by the movement of the Gondwanan ice sheet (Fig. 5F).

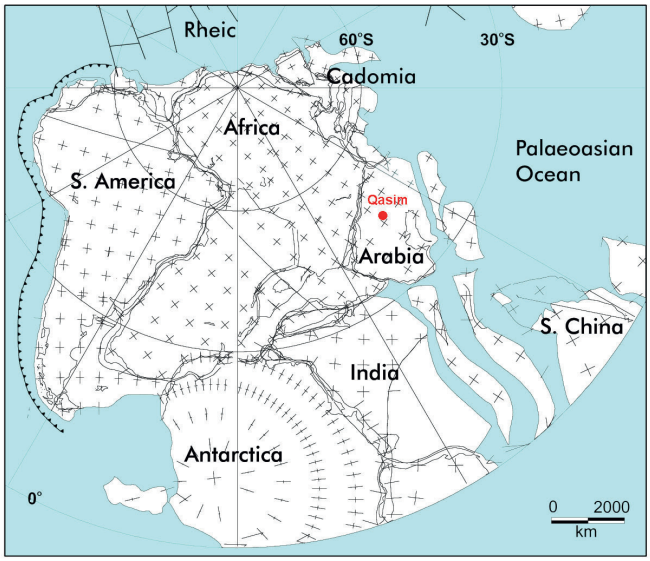



Fig. 6. Palaeogeographical reconstruction of Gondwana during the Late Ordovician, showing the position of the South Pole, and the location of the study area (base map from Golonka, 2012)

*Location 2: Upper Ordovician Kahfah Member (Qasim Formation)*

After visiting sandstones of the Sarah Formation we retrace our route, returning to the Tiraq road. At the top of the Hanadir cliff, the Upper Ordovician (late Sandbian to early Katian age) marine sandstones of the Kahfah Member forms low ledges on the right side of the track. Opposite some farm buildings on the left side of the Tiraq road, there is a small hill about 100 m from the road comprised of the Upper Ordovician sandstone of the Kahfah Member (26°36.1973'N, 43°28.2532'E) (Fig. 7A). This outcrop is known for its trace fossils – *Scolithos*, vertical burrows created by sand worms that live in a very shallow marine environment. Halfway up the hill a sandstone ledge is exposed that is completely bioturbated by the *Scolithos*-producing worms (Fig. 7B). Their circular burrows are highlighted by the differential weathering of the sandstone, with the burrow wall more resistant to erosion.

*Location 3: Upper Cambrian Risha Member of the Saq Formation*

At the intersection of Highway 65 and Road 6280 leading to Uyun Al Jawa, there is an excellent exposure of the thickly bedded Cambrian Risha Member of the Saq Formation. The Risha member is comprised of white quartz sandstone that was deposited in a non-marine setting, probably by braided streams. The sandstone of the Risha Member is the major aquifer in the Al-Qassim Province. At the end of the exit ramp there is a farm road on the right side of Road 6280. About 200 m further on the right side there is an isolated rock tor surrounded by a fence (26°33.0931'N, 43°35.7012'E). This site is known as Antarah's Rock, after the well-known Arabic writer who used to meet with his beloved in the shade of the rock (Fig. 7C). This is another archeological site that preserves ancient graffiti. The weathered surface of the stone shows honeycomb weathering at different scales, caused by slight differences in the cementation of the sandstone. Another standing stone balanced on a narrow pedestal can be seen about 300 m up the dirt track, again surrounded by a chain-link fence (Fig. 7D). In addition to ancient and modern graffiti, this stone preserves some ancient petroglyphs depicting animals such as the oryx, which were once native to the Al Qassim area.

*Location 4: Upper Ordovician (middle Katian) Ra'an Member of the Qasim Formation*

Continuing along Highway 65 in the direction of Buraydah, we reach Exit 519 signposted for Qassim University on the northern outskirts of the city. Proceeding on Road 419 in the direction of the University there is a playa salt flat on the right side of the road. At the traffic light at the top of a gentle hill, we turn right onto Road 6260 in the direction of Al Qara'a. There is a small mosque at the corner. About 700 m from the intersection there is a water tower on the left side of the road (26°23.9032'N, 43°46.3663'E). A dirt track to the left of the tower passes through a rocky field that is subdivided into a grid by white property markers, and ends at a shepherd's encampment at the edge of an escarpment. In the wadi below the escarpment and to the right, we see a cliff and some rounded hills made of grey shale with glittering veins of gypsum (26°23.2760'N, 43°45.6174'E). The campus of Qassim University is visible on the horizon. This locality exposes the shale of the Ra'an Member of Late Ordovician (Katian) age. The sandstones at the top of the cliff are those of the Upper Ordovician Quwarah Member of the Qasim Formation (Fig. 7E).

The shale of the Ra'an Member represents the last maximum flooding horizon of the Late Ordovician before the onset of the Hirnantian glacial event. The shale here is silty, and contains stringers of thinly bedded sandstone. The shale has a greenish colour when fresh, and weathers to medium grey. Graptolites, conodonts, and trilobites have been reported from the shale of the Ra'an Member (Williams *et al.,* 1986), but none have yet been reported at this locality (26°23.2435'N, 43°45.6968'E). The foraminiferal assemblages at this locality have been studied by Kaminski *et al.* (2019) and contain some of the oldest known multichambered agglutinated foraminifera belonging to the hormosinid group (the genera *Reophax* and *Subreophax*). The maximum flooding surface is exposed in a ravine near the base of shale of the Ra'an Member (Fig. 7F). From this level, the shale becomes more silty upsection until it grades into the overlying sandstone of the Quwarah Member of the Qasim Formation. The thin-bedded slabs of sandstone that are strewn on the surface of shale of the Ra'an Member are bioturbated, and specimens of the trilobite trails (*Cruziana*) have been observed. The sandstones contain numerous millimetre- to centimetre-size iron concretions.


Fig. 7. Geotouristic objects described in the text: A – view of the hill of sandstone of the Kahfah Formation at Locality 2, photo taken from the roadside; B – top view of *Scolithos* trace fossils in sandstone of the Kahfah Formation at Locality 2; C – the tor of sandstone of the Saq Formation known as Antarah's Rock at Locality 3 (the surface of the stone displays honeycomb weathering at various scales); D – the tor balanced on a pedestal at Locality 3; E – view of shale of the Ra'an Formation exposure behind Qassim University, Locality 4; F – the O40 maximum flooding surface within shale of the Ra'an Formation at Locality 4 (arrow). Photo T. Garrison

### *Trip 2: Silurian to Permian*

This excursion begins at exit 571 on Highway 65, but this time we turn right onto Road 6280 at the end of the exit ramp in the direction of Quararah. We cross over the new Saudi railroad and enter the town of Quararah, passing the park along the right side of the road and the town center, and continuing to the large roundabout at the bottom of the hill. Just beyond the roundabout there is a rock formation known as the "Saudi Sphynx" (Location 5), made of reddish thickly-bedded sandstone of the Sarah Formation (Fig. 8A). From the roundabout the Qusaiba road passes some farms until it descends through a road cut. At the base of the hill a smaller road enters the Qusaiba Road on the left (Fig. 8B). A line of cliffs rises up on the left side of the side road exposing dark grey shale. This is the Silurian Qusaiba Formation, the most prolific petroleum-producing unit in the Middle East. The whole Paleozoic petroleum system in the Gulf countries is fuelled by hydrocarbons produced from shale of the Qusaiba Formation.

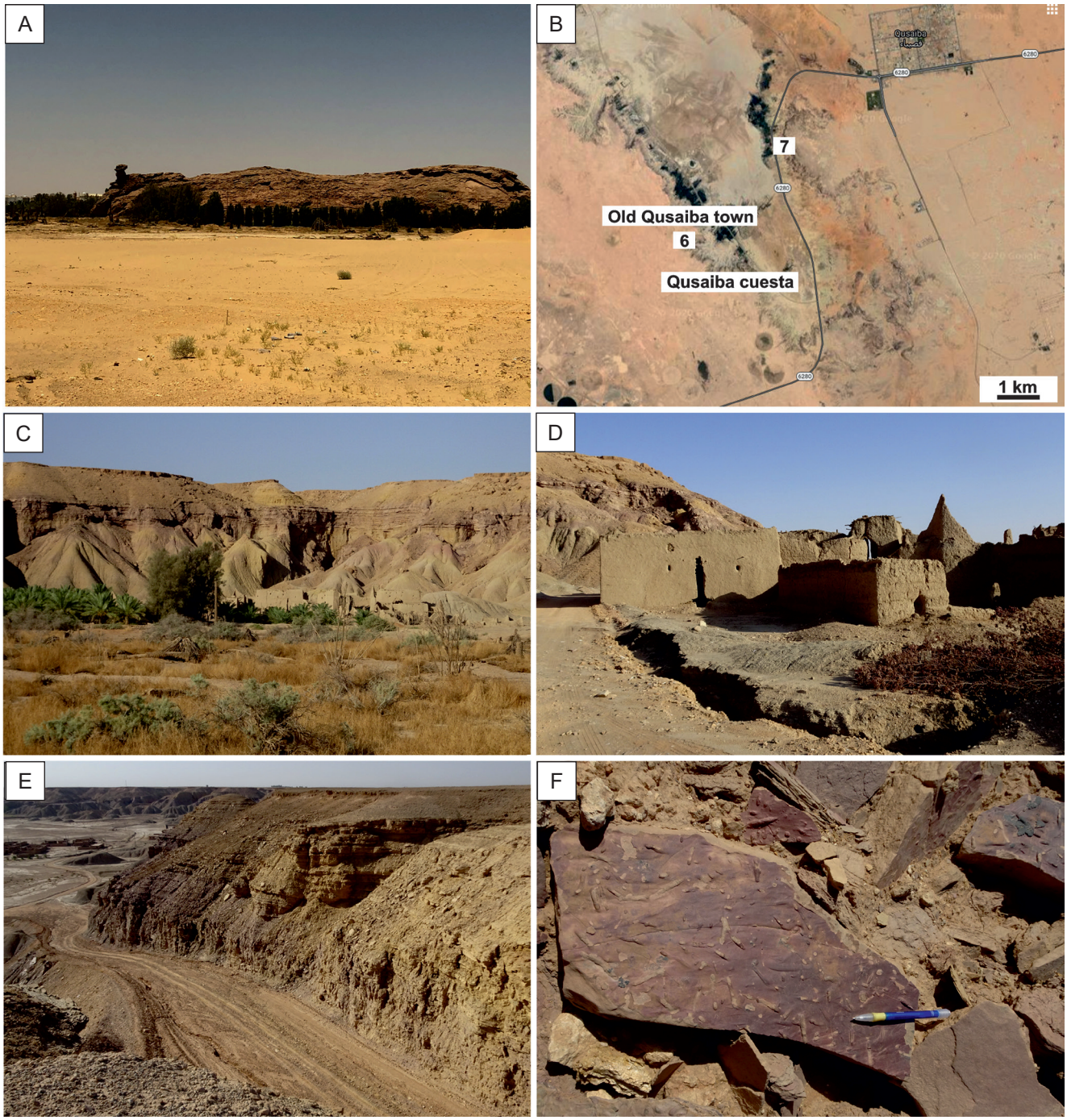



Fig. 8. Geotouristic objects described in the text: A – view of the "Saudi Sphynx", a hill comprised of sandstone of the Sarah Formation in Quwarah town, Locality 5. Photo T. Garrison; B – map showing the position of Localities 6 and 7; C – Old Qusaiba Village with the exposure of shale of the Qusaiba Formation and sandstone of the Sharawra Formation in the background. View from the main road at Locality 6; D – some of the surviving mud-brick structures in Old Qusaiba Village; E– the section of shale of the Qusaiba Formation and sandstone of the Sharawra Formation sampled by Abbas *et al*. (2017) and by Kaminski & Perdana (2017, 2020), viewed from above; F – trace fossils on the upper surfaces of sandstone of the Sharawra Formation, road cut overlooking Old Qusaiba Village

After passing the large date farm enclosed by a cinder block wall, a dirt track on the left leads to the base of the cliff (26°49.8281'N, 43°36.7686'E). A second road branches off to the right and follows the base of the cliff to the abandoned Old Qusaiba village (26°50.8585'N, 43°35.1025'E), a picturesque archeological site consisting of ruins of mud brick structures (Figs. 8C, D). We return along the same road, pass the junction, and proceed along the base of the cuesta several hundred meters to a dirt track that ascends the cliff (Fig. 8E) (26°50.6381'N, 43°35.2163'E).

*Location 6: Lower Silurian shale of the Qusaiba Formation*

At Old Qusaiba village, only the upper half of the Qusaiba Formation is exposed. The lower half is covered by talus all along the base of the cliff. A borehole drilled by Saudi Aramco on top of the cliff recovered a thickness of 32 meters of shale of the Qusaiba Formation at this locality. Graptolites from the Qusaiba-1 core were studied by Zalasiewicz *et al*. (2007), who found assemblages belonging to the Lituigraptus convolutus graptolite Zone of Aeronian age. A total of 14 graptolite species were reported at this locality, mostly the monograptids such as *Lituigraptus*, *Normalograptus*, *Pseudorthograptus* and *Neolagerograptus*, but also including occasional phyllograptids such as *Petalolithus*. The low diversity of the graptolite assemblage points to a continental shelf environment (Zalasiewicz *et al*., 2007), probably mid-shelf, below the wave base. The early Silurian foraminifera from this locality were studied by Kaminski & Perdana (2017, 2020), who reported a diverse assemblage consisting almost entirely of primitive agglutinated foraminifera belonging to the monothalamid and tubothalamid groups. Unexpectedly, Kaminski & Perdana (2017) also discovered some rare specimens of coiled multichambered lituolids, including the oldest known species belonging to the genus *Ammobaculites*. This finding represents the oldest known occurrence of multichambered foraminifera belonging to the lituolid group, and pushes back the known geological history of the coiled multichambered foraminifera by about 40 million years. Previously, the oldest known *Ammobaculites* was reported from the Lower Devonian in the Czech Rebuplic (Holcová, 2002).

The lower part of the Qusaiba Formation found in the subsurface contains the organic-rich "hot shale", which was deposited in anoxic conditions that took hold in the ocean after the melting of the Gondwanan ice sheet (Hayton *et al*., 2017). During the early Silurian, black graptolite-bearing shales were deposited world-wide (Lüning *et al*., 2000).

Along the dirt track that leads to the top of the cliff above Old Qusaiba village, we see the transition to the overlying Sharawra Formation, which is comprised of fine to medium grained subarkosic sandstones interbedded with green claystones (Abbas *et al.*, 2017). Although fine silt layers can be seen in the upper part of shale of the Qusaiba Formation, the boundary with the overlying Sharawra Formation is placed at the lowermost sandstone bed. Thin-bedded sandstones at the base of the formation are micaceous and their upper surfaces display trace fossils created by benthic organisms (Fig. 8F). The thickness and frequency of the sandstone beds increases upsection. The Sharawra Formation was deposited in a lower to upper shoreface environment, with sediment sourced from the Arabian Shield. The maximum thickness of the Sharawra Formation at this locality is 27 m, and the unit thins in the SW direction (Abbas *et al*., 2017). The top of the outcrop is capped by a hard layer of calcareous duricrust. Along the edge of the cliff overlooking the Old Qusaiba village, a series of stone watch towers was constructed by the inhabitants of the village in pre-modern times. Ruins of the watch towers can still be seen near the edge of the cliff (Fig. 8A).

*Location 7–8: Middle Permian Unayzah Formation*

The next locality is along Route 6280 that leads in the direction of the modern Qusaiba township. On the right hand side, we see a cliff comprised of variegated clastic sediments capped by limestone of the Permian Khuff Formation. A dry streambed passes beneath a bridge just before the road curves to the right and ascends to Qusaiba (26°52.2539'N, 43°36.2227'E). We walk upstream until we reach a tributary stream that cuts exposes a red cross-bedded sandstone (Fig. 9B). These are the nonmarine sandstones of the Unayzah Formation, which is also known as the "pre-Khuff clastics" by Saudi Aramco geologists. The unit was formally named the Unayzah Formation by Al-Laboun (1987) and is assigned a middle Permian (Wordian) age based on the occurrence of fossil plants (Lemoigne, 1981; El-Khayal, Wagner, 1985). Pre-Khuff clastic sediments of late Carboniferous to early Permian age are well developed in the subsurface and are subdivided into three informal units by industry geologists.

The sandstone is rippled and cross bedded at a large scale. It forms lenticular bodies, and was likely deposited by a major river. The sandstone at this locality contains large silicified logs of petrified wood that erode out of the sandstone (Fig. 9C). Pieces of petrified wood can be seen among the gravel in the modern-day streambed. Several streams cut through the Unayzah Formation at this locality.

It is possible to return to Buraydah on Route 400, via New Qusaiba town. On the outskirts of Buraydah the road passes a complex of grain silos on the left-hand side of the road, and descends down a line of low cliffs. This cliff again exposes limestone of the Khuff Formation and the underlying clastics of the Unayzah Formation. Location 8 is a protected geological site that was preserved thanks to the efforts of Dr. Abdulaziz Al-Laboun of King Saud University, who worked on the Unayzah Formation in the area (26°26.4929'N, 43°50.2104'E). Enclosed within a chain-link fence on the left-hand side of the road is a large log of petrified wood (Fig. 9D). It is possible to walk along the base of the cliff in the direction of Buraydah and observe fragments of petrified wood that erode out of the formation.

## Cultural sites

For centuries, the Al-Qassim area has been a stopover point for pilgrims travelling to Mecca and Medina. The historical sites in the Al-Qassim region provide an idea of what life was like in a desert oasis in pre-modern times. The petroglyphs preserved on stones indicate that the region has been inhabited since Pre-Islamic times.


Fig. 9. Geotouristic and touristic objects described in the text: A – ruins of a watch tower on top of the bluff overlooking Old Qusaiba village; B – cross-bedded red sandstone of the Unayzah Formation at Locality 7. Photo T. Garrison; C – logs of petrified wood eroding out from the Unayzah at Locality 7. Photo T. Garrison; D – large logs of petrified wood (arrows) in sandstone of the Unayzah Formation at Locality 8. Photo T. Garrison; E – the landmark "golf ball" in the centre of Buraydah, near the convention centre; F – view of the gold market in the souq in Buraydah

Modern-day Buraydah is a rapidly developing regional center with modern facilities, including tourist hotels and many of the well-known chain restaurants. The King Khalid Cultural Center, King Khalid Park, and Buraydah Museum are tourist attractions within walking distance of each other. Also nearby is the Buraydah Water Tower, which is a popular landmark that dominates the local skyline (Fig. 9E). The older downtown district is famous for the Buraydah Date Market and for its souq. The modern souq contains numerous stalls offering items of jewellery fashioned from Saudi gold (Fig. 9F). Another section of the downtown souq contains the spice market, which is well worth an aromatic visit.

## Discussion

### *Geotourism value*

The Paleozoic succession of the Al-Qassim Province has educational value to petroleum geologists interested in the subsurface petroleum system of the Middle East. The outcrops north of Buraydah expose the most important source rocks in Saudi Arabia, as well as some of the subsurface reservoirs. The sandstone of the Sarah Formation has been a target for hydrocarbon exploration in the subsurface in the Rub Al-Khali desert of southern Saudi Arabia. The carbonates of the Khuff Formation are the major gas producer in the world's largest natural gas field in Qatar, and the Unayzah clastics are another reservoir unit in Saudi Arabia. Palaeontologists will be impressed with the trace fossils of the Sajir sandstones, and specialists will be interested in the remains of the oldest microfossils derived from land plants in shale of the Hanadir Member of the Qasim Formation. The Ra'an shale near Qassim University and the Qusaiba shale in Old Qusaiba town contain a diverse assemblage of agglutinated foraminifera that includes some of the oldest known multichambered forms. These discoveries are so important that textbooks will need to be revised based on the recent micropalaeontological and palynological studies.

### *Geotourism infrastructure*

Buraydah is a modern city with all the necessary infrastructure to support geotourism. The city has a wide selection of chain hotels and restaurants. Prince Nayef bin Abdulaziz International Airport (formerly known as the Qassim International Airport) is served by a number of Middle Eastern airlines and has regular connections to all of the major airport hubs in the region. The recently built train line offers passenger service to the capital city Riyadh, with onward connections to Dammam. The city of Buraydah, with its abundant tourist attractions and infrastructure, ranks highly using the geotourism valorisation criteria adopted by Doktor *et al*. (2015).

The Saudi Commission for Tourism and National Heritage is in the process of developing Qusiaba as a geotourist destination (Saudi Gazette, 2018). However, the geological localities described above currently do not have tourism infrastructure, explanatory signs, or tourist information brochures. A 4-wheel drive vehicle is recommended to access some of the localities. Fortunately, the outcrops are well-exposed, and the local structural geology is quite simple. There are small grocery shops and petrol stations in Al Quwarah and Qusaiba where basic items such as cold drinks can be purchased, but the geotourist is advised to pack ample supplies of drinking water. Daytime temperatures during summer months regularly exceed 45ºC, and it is best to visit the localities early in the morning before the temperature becomes uncomfortable. Furthermore, the geotourist will be exposed to the open sun the entire time and is strongly advised to take all necessary precautions for sun protection.

Finally, a visit to Al-Qassim is genuinely a rewarding experience because of the exposure to traditional Saudi culture through date farming, shopping at the souq, and the wonderful Saudi cuisine that can be sampled at traditional restaurants.

## Conclusions

Al-Qassim district of Saudi Arabia has strong potential for geotourism. There are excellent geological sites that are well exposed and easily accessed. Furthermore, the Paleozoic formations are among the most important geological units in terms of natural resources, which drive the economy of the Middle East. Their educational value to geoscience students and specialists ranks highly because they contain unique fossil and microfossil occurrences that give us a new perspective on the evolution of land plants and marine microorganisms on our planet. Furthermore, the stratigraphic units exposed in the Al-Qassim district can be used to explain the history of the Gondwanan continental shelf that includes the latest Ordovician glacial event.

## Acknowledgements

We thank Marco Vecoli (Saudi Aramco), Jan Golonka (AGH), and the journal editors for offering constructive comments on the manuscript, and Justyna Kowal-Kasprzyk (AGH) for help with the figures.

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# Land of Extinct Volcanoes Geopark – geoeducation for everyone

## Geopark Kraina Wygasłych Wulkanów – geoedukacja dla każdego

**Piotr Słomski[1]*, Julia Jankowska[1], Ewelina Rozpędowska[1]**

[1]*The Kaczawskie Association, Mściwojów 45a, 59-407, Poland*
*piotr@kaczawskie.pl, julia@kaczawskie.pl*

* Corresponding Author


Article history:
Received: 13 November 2020
Accepted: 12 December 2020
Available online: 17 February 2021



**Abstract:** *The Kaczawskie Mountains and Foothills – Geopark Land of Extinct Volcanoes is an area with an extremely interesting geological structure and outstanding landscape values. Great geodiversity makes it possible to prepare a geoeducation offer for practically every recipient – from kids, through adults interested in natural sciences, to natural science students.*

*The characteristics of the Kaczawskie Mountains and Foothills enable one to develop a nationally unique form of geotourism and utilization of local natural resources for various geoeducation programs. Despite the small area of the mentioned region, it is possible to raise topics related to volcanic phenomena, the formation of mountain ranges, climate change and the impact of glaciers on the relief of the terrain. Educational activity at the Geopark Land of Extinct Volcanoes do not need to be limited only to geological issues, but may also include environmental issues, waste management or even historical topics.*

*However, apart from the very existence of geotourism attractions, equally important are their uniform promotion and dissemination of knowledge about them. This can be done by describing the most important geopoints in the field, e.g. through a network of educational boards or by organizing promotional field trips. This would increase the knowledge about the geological richness of the described region among tourists and residents. The work of the Kaczawskie Association, which is trying to include the Land of Extinct Volcanoes Geopark in the UNESCO World Geopark Network, is currently heading in this direction. The implementation of this initiative will not only increase the interest in natural sciences and the region, but will also allow it to keep its authentic and unique character. Unfortunately, the process of application to the UNESCO GGN, both the development of the geoeducation and geotourism in the region of the Kaczawskie Mountains and Foothills, has been slowed down by the COVID-19 pandemic.*

**Keywords:** *The Kaczawskie Mountains and Foothills, geoeducation, geotourism*

**Treść:** *Góry i Pogórze Kaczawskie – Geopark Kraina Wygasłych Wulkanów to obszar o niezwykle ciekawej budowie geologicznej oraz nieprzeciętnych walorach krajobrazowych. Duża georóżnorodność umożliwia przygotowanie oferty geoedukacyjnej praktycznie dla każdego odbiorcy – od uczniów szkoły podstawowej, przez osoby dorosłe, aż po studentów kierunków przyrodniczych.*

*Charakterystyka Gór i Pogórza Kaczawskiego umożliwia unikalny w skali Polski rozwój geoturystyki i wykorzystanie lokalnych zasobów przyrodniczych do różnorodnych programów geoedukacyjnych. Na omawianym fragmencie Sudetów Zachodnich (o powierzchni około 1300 km$^2$) możliwe jest poruszanie zagadnień dotyczących m.in. zjawisk wulkanicznych, powstawania łańcuchów górskich, zmian klimatu i wpływu lądolodu na rzeźbę terenu. Tematyka zajęć edukacyjnych w Geoparku Kraina Wygasłych Wulkanów nie musi być jednak ograniczona do zagadnień geologicznych i może również obejmować kwestie ochrony środowiska, gospodarki odpadami, a także nawiązywać do tematów historycznych i kulturowych.*

*Niemniej oprócz samego istnienia walorów geoturystycznych równie istotne jest ich spójne i jednorodne wyeksponowanie i upowszechnianie wiedzy na ich temat. Można tego dokonać, opisując najważniejsze punkty w terenie, np. dzięki sieci tablic edukacyjnych, opracowywaniu i udostępnianiu informacji geoturystycznych w Internecie czy też organizowaniu popularyzatorskich wycieczek terenowych. Pozwoliłoby to na zwiększenie wiedzy na temat bogactwa geologicznego opisywanego regionu wśród turystów i mieszkańców. W takim kierunku zmierzają prace Stowarzyszenia Kaczawskiego, które stara się o włączenie Geoparku Kraina Wygasłych Wulkanów do Światowej Sieci Geoparków UNESCO.*

*Osiągnięcie tego celu przyczyni się nie tylko do wzrostu zainteresowania naukami przyrodniczymi oraz regionem, ale i pozwoli zachować jego autentyczny i wyjątkowy charakter. Niestety zarówno proces aplikacji do Światowej Sieci Geoparków UNESCO, jak i rozwój geoedukacji i geoturystyki w Górach i na Pogórzu Kaczawskim został spowolniony przez pandemię COVID-19.*

**Słowa kluczowe:** *Góry i Pogórze Kaczawskie, geoedukacja, geoturystyka*

# Introduction

The region of the Kaczawskie Mountains and Foothills is also known as Land of Extinct Volcanoes Geopark. This last name is used to promote the unique geological heritage of this part of the Sudetes. The Kaczawskie Mountains and Foothills has an extremely interesting and complicated geological structure and outstanding landscape values. Therefore, this region is ideal for educational activities dedicated to a wide variety of topics in the field of Earth sciences, especially geography and geology.

The great diversity of the geological structure and attractive terrain relief make it possible to prepare a geoeducational offer for every recipient, regardless of age, knowledge, physical condition and experience in tourism.

In the Land of Extinct Volcanoes, even children attending preschool institutions and the first grades of primary school can begin their adventure with natural sciences. Students of higher grades of primary and secondary schools can also develop their knowledge. Adults interested in Earth sciences will be able to find active recreation in the Kaczawskie Mountains and Foothills too. Students of natural sciences such as geography, geology, environmental protection or biology have been attending field exercises for many years in the described region. However, along with the development of the Geopark idea, followed by the preparation and sharing of some less known geopoints, the educational potential of the Kaczawskie Mountains and Foothills will increase and become more diverse.

In this article, we want to present the most important forms of geological and ecological education in the Kaczawskie Mountains and Foothills. We want also to indicate potential directions of development in the field of geoeducation. Special attention will be placed on activities, which are focused on increasing the environmental awareness of tourists and members of local communities, as well as those that can help to preserve the unique character of the region. The activities organized by the Sudetic Educational Centre in Dobków – an educational centre belonging to the Kaczawskie Association, will serve as the examples.

# Short geological characteristic

In the Kaczawskie Mountains and Foothills, over 500 million years of geological history can be traced in the rocks occurring in the region, in a relatively small area. Like the entire Sudetes, the described area has a complicated, even so-called "mosaic" geological structure (Baranowski *et al.*, 1990; Mazur *et al.*, 2006, 2010; Golonka *et al.*, 2018). In a geological sense, the Kaczawskie Mountains and Foothills are located in the area of two large geological units: the Kaczawa Metamorphic Complex (Kaczawa Unit) and the North Sudetic Synclinorium (Fig. 1).

The Kaczawa Metamorphic Complex is built from a sequence of metamorphosed sedimentary and volcanic rocks that have been metamorphosed at the turn of the Devonian and Carboniferous. The mineral composition of metamorphic rocks and the tectonic structures observed in them indicate that this unit is a fragment of the Variscan accretionary prism (Baranowski *et al.*, 1990; Mazur *et al.*, 2010; Golonka *et al.*, 2018).

The mountains, which had been raised during the Variscan orogeny, soon has been subjected to strong erosion and were a source of material for the first sedimentary rocks formed in the depressions of the metamorphic basement (Baranowski *et al.*, 1990). Additionally, during the Permian, strong volcanic activity took place (Awdankiewicz, 2006). Sedimentation has begun at the end of the Carboniferous and continues till today, however, the sedimentary rocks from the Upper Carboniferous, Permian and Mesozoic seem to be most interesting. Aforementioned sedimentary rocks are represented by rocks formed in various environments (land, river, sea) and a changing climate condition (Milewicz, 1985).

The remains of the youngest volcanic episode, Cenozoic basalts ca. 20–30 million years in age (Birkenmajer *et al.*, 2007) belong to the important geotouristic resources of the Land of Extinct Volcanoes Geopark. These rocks belong to the eastern part of the Central European volcanic province. In the area of the former volcanic field Legnica–Złotoryja–Jawor, you can see the relicts of volcanic processes (Cwojdziński & Jodłowski, 1982). It is also worth mentioning the interesting glacial sediments, which were deposited in several places in the described region during the last period of the Pleistocene glaciations.

# Geoeducation in the Land of Extinct Volcanoes

Geoeducation can be defined in at least three different ways (Kubaliková *et al.*, 2016): (1) The National Geographic Society proposes to treat geoeducation as a comprehensive education about the mechanisms of nature and human civilization, on a local, regional and global scale; (2) the second approach is limited to the higher education of students in the field of Geosciences; (3) the most common and intuitive understanding of geoeducation refers to the popularization of

knowledge from various Geosciences among students, tourists and members of local communities. The last approach is the basis of the geoeducational activity of the Kaczawskie Association. Nevertheless, the other two approaches are not neglected, since the Kaczawskie Mountains and Foothills offer geoeducation understood in a holistic way, which make it possible to also see natural sciences in the economic, social and cultural perspective.

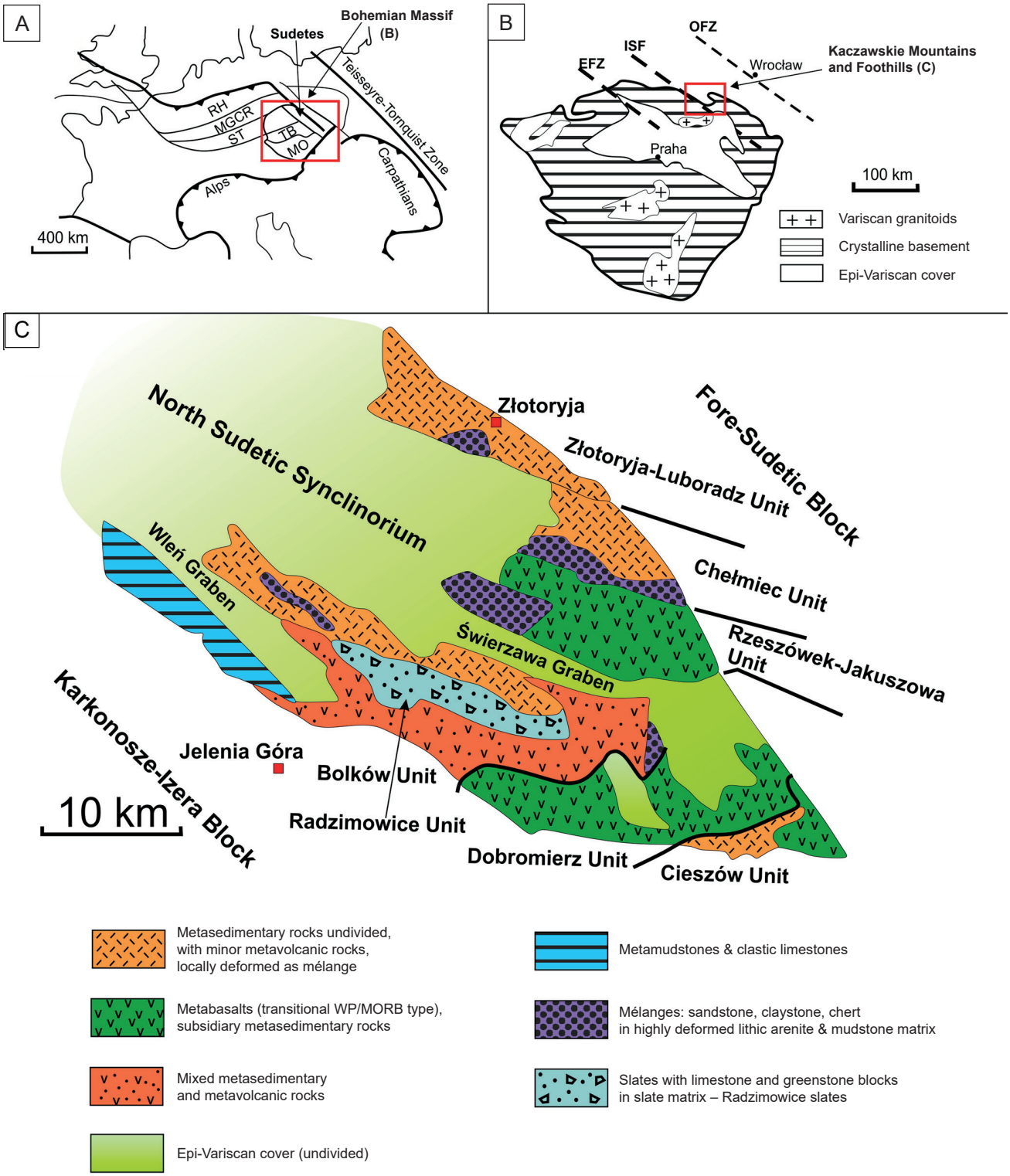


Fig. 1. Location and geological sketch of study area: A – position of the Bohemian Massif and the Sudety Mountains in the framework of main tectonic units of Europe (RH – Rhenohercynian Zone; MGCR – Mid-German Crystalline Rise; ST – Saxothuringian Zone; TB – Tepla-Barrandian Zone; MO – Moldanubian Zone); B – simplified geological map of the Bohemian Massif with the position of the Kaczawskie Mountains and Foothills; C – generalized geological map of the Kaczawskie Mountains and Foothills, after Baranowski *et al.* (1990)

## Examples of geoeducational activity in the Land of Extinct Volcanoes

The valuable and relatively well-preserved diversified natural environment, as well as interesting cultural background of the Kaczawskie Mountains and Foothills make it possible to prepare diverse geotouristic and geoeducational proposals. The topics of conducted educational activities and projects go beyond geology and also concern environmental protection, water management and waste management. Below, we present only selected examples of potential geoeducational activities.

The Ostrzyca hill dominating over the Kaczawskie Foothills is one of the most crucial and recognisable geopoints in the described region (Fig. 2). Sudetic Educational Centre was organising geoeducational trips for children, on the top of Ostrzyca in years 2017–2020. These trips were co-financed by the Lower Silesian Fund for Environmental Protection in Wrocław and were organised in the framework of environmental education programs developed by educators from the Kaczawskie Association.

Ostrzyca is a volcanic neck built of Cenozoic basanites (Szumowska *et al.*, 2013). There is a visible hexagonal (columnar) joint in the rocks on the top of the hill. A trip to Ostrzyca is an opportunity to discuss and learn about the genesis of volcanism, products of volcanic eruptions and potential threats resulting from volcanic eruptions. These issues can be discussed from a broader perspective, global perspective as well as on a local Sudetic scale. It must be mentioned that the educators from the Sudetic Educational Centre adjusted each time the amount of transferred knowledge to the needs and possibilities of participants. Moreover, the slopes of Ostrzyca are partially covered with rock debris, which was formed as a result of weathering processes in the conditions of a periglacial climate during the last ice age, therefore geomorphology and climate change topics can be discussed here too. The area of the hill is covered by the "Ostrzyca Proboszczowicka" reserve, which protects valuable floristic communities. This in turn makes it easy to extend the content of the courses to botanical issues and forms of nature protection.

It is worth mentioning that most often trips to Ostrzyca were combined with a visiting the municipal waste landfill in the nearby village of Jastrzębnik. The landfill was established in 1993 in the basin of the old basalt quarry, in which mining activities ceased (Fig. 3 A and B). Over time, a waste reloading station was also opened at that landfill. The participants of our trips could gain knowledge about the principles of waste segregation, the possibilities of their secondary use, as well as the problems that must be faced in landfills, i.e. dangers of a leachate or the need to burn gases generated from waste. Courses were conducted in cooperation with the employees of the facility. The landfill in Jastrzębnik is an ideal example of reusing a closed quarry. Groups visiting this place can learn that storing waste in an old quarry allows you to avoid the creation of heaps of waste in the local landscape and minimize the risk of a harmful leachate. Last, but not least, the former basalt quarry in Jastrzębnik, compared with numerous geological attractions of the region, does not present any outstanding natural value, which makes it even more suitable for practical uses such as a landfill.

Fig. 2. The Ostrzyca hill – a volcanic neck built of Cenozoic basaltoids (basanites). Photo DE2


Fig. 3. School trip during classes at the landfill and waste sorting plant in the former basalt quarry nearby the village Jastrzębnik: A – group of students above the landfill in the excavation; B – students at the waste sorting point. Photo J. Jankowska

Geoeducational activities can also be conducted in other closed quarries, which are abundant in the area of the Kaczawskie Mountains and Foothills. These places have a very large geotouristic potential, making it possible to prepare an offer for individual tourists, school groups or those conducting didactic courses with students of natural sciences. Examples of such places include: (1) the inactive rhyolite excavation in the slope of the Wielisławka hill, called the Organy Wielisławskie, (2) the melaphyre quarry in Lubiechowa and (3) the Biały Kamień phyllite quarry in Wojcieszów town (Fig. 4A–C).

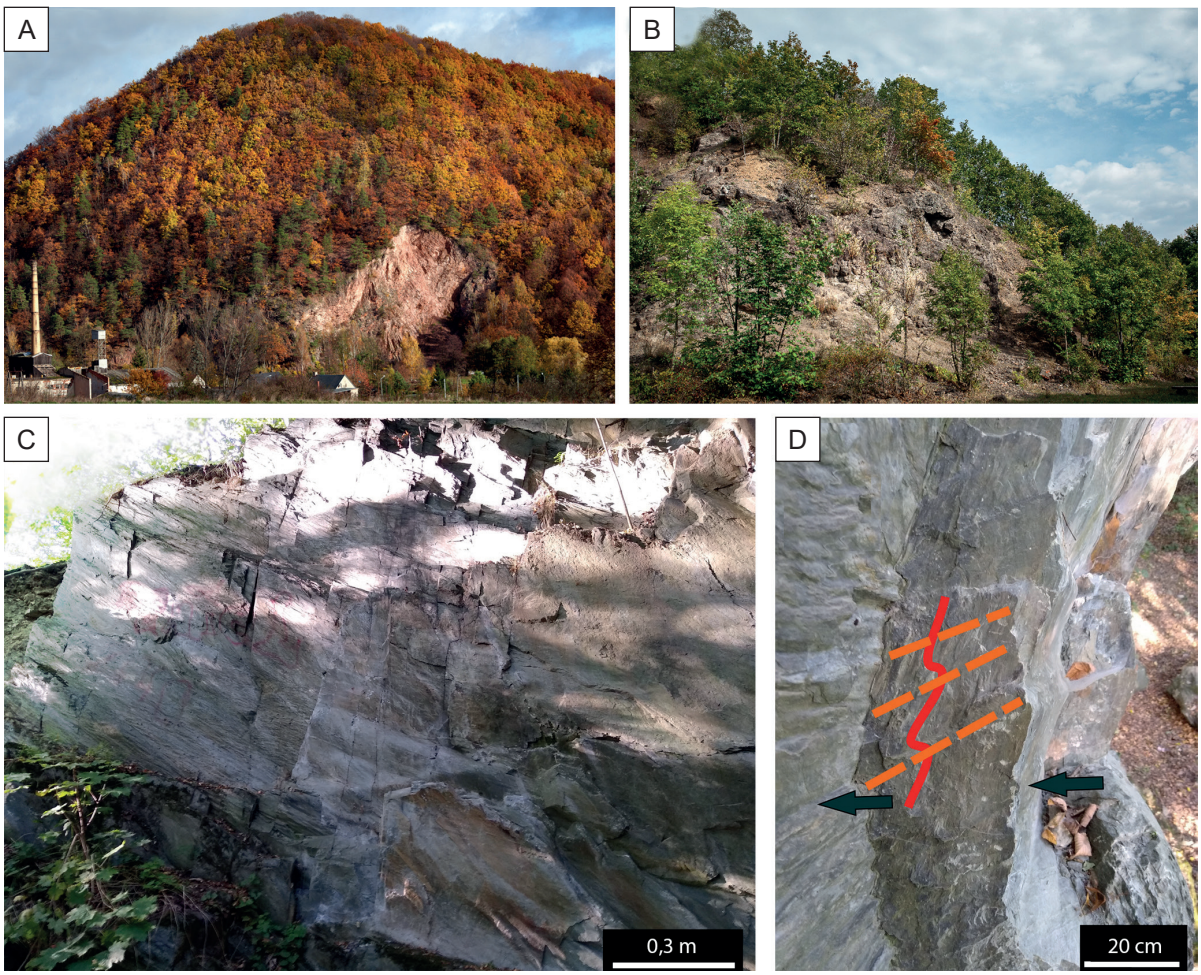


Fig. 4. Selected geological attractions of the Kaczawskie Mountains and Foothills region: A – Wielisławka hill with a visible wall of the Organy Wielisławskie; B – closed melaphyre quarry in the Lubiechowa village; C – northern part of the quarry of phyllites in Wojcieszów town; D – well visible tectonic structures (the surface of the metamorphic foliation is marked with a green arrow, folding – red line, axial plain cleavage – orange lines) in phyllites in Wojcieszów. Photo DE2 (A and B), P. Słomski (C and D)

The Organy Wielisławskie exposure and the quarry in Lubiechowa are convenient places to tell stories about the volcanic past of the region, with particular emphasis on the Permian volcanic rocks visible in both locations. For more advanced groups, including students, longer classes can be planned in the above-mentioned places, including the recognition and full macroscopic description of the visible rocks. Moreover, at the Organy Wielisławskie exposure, an interesting training using geological compass measurements can be made, due to its unique presence of rhyolitic columns (mostly hexagonal and pentagonal), which have there a radial arrangement (Fig. 4A). Both quarries also are impressive in size (the height of the rock wall on the Organy Wielisławskie reaches up to 50 m), which can be visually attractive for all tourists.

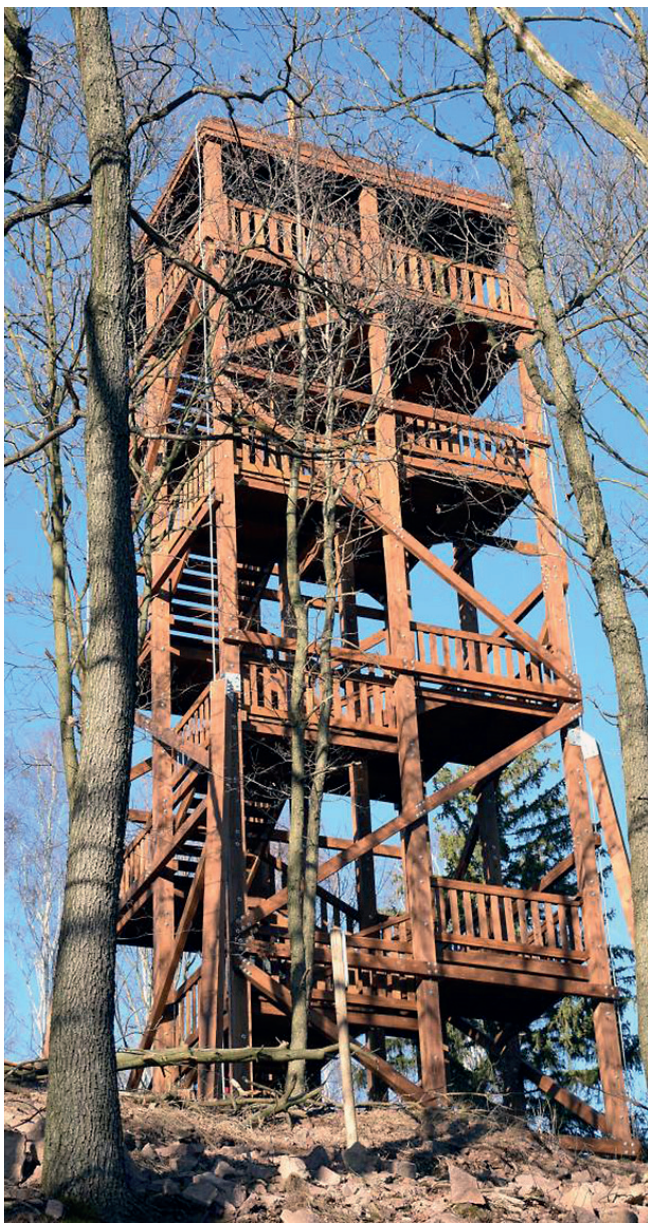

Fig. 5. The viewing tower on the top of the Zawodna Hill. Photo P. Słomski

The Biały Kamień quarry can be a proposal for more inquisitive guests or groups of students. Here you can watch greenstones and phyllites. Particularly interesting is the variety of tectonic structures (folds, metamorphic foliation, and two types of lineation) (Muszer & Muszer, 2017) visible in the northern part of the excavation, within the phyllites (Fig. 4C). The exposure also shows the structure of boudinage, which is the effect of deformation of layers with different mechanical properties. In this particular case, the greenstones are the more rigid and fragile rock, while the phyllites are the more plastic and deformable layers. However, the most distinct fragment of boudinage in this exposure lies at the base of the wall, after it fell off a few years ago. It is necessary to mention that this exposure is currently widely covered by trees and plants. Unfortunately, graffiti on the rock walls and waste under it are also present.

Another proposition for use of the geoeducational potential of the Kaczawskie Mountains and Foothills are trips to the recently constructed observation towers on the Zawodna (Fig. 5) and Dłużek hills. The first one is located nearby Gozdno village, while the second one is near Wojcieszów town. Visiting the observation towers can be an attractive form of activity for organized groups and individual tourists. In the case of schools groups, the aforementioned viewpoints allow one to address issues of the terrain topography and geomorphological processes. Such a visit can be also a stage of a longer geoeducational trip. Interestingly, the observation towers mentioned above, due to the possibility of viewing a wide panorama, additionally make possible a discussing about issues such as the degree of deforestation, land usage, landscape protection, etc. The towers and their neighbourhood can be also a good place to conduct exercises and field games allowing participants to practice their ability to read maps, use of compass or apply their photography skills.

It seems reasonable that each observation tower should have information board with a description of the visible panorama. Such a table exists in Wojcieszów, but the tower on the Zawodna hill does not have this kind of information facilities. A proposed description of the view from the tower in Gozdno, in the most attractive, south-south-west direction (SSW) is shown in figure 6.

In geoeducation, as in many other activities, the best results can be achieved thanks to the cooperation of various, complementary entities. Examples of such activity were trips to the dry flood reservoir in Świerzawa town, organized for school groups by Sudetic Educational Centre in cooperation with the Lower Silesian branch of the National Water Management Authority. These classes were conducted in years 2017–2020 in the framework of the aforementioned educational programs co-financed by the Lower Silesia Fund for Environmental Protection in Wrocław.

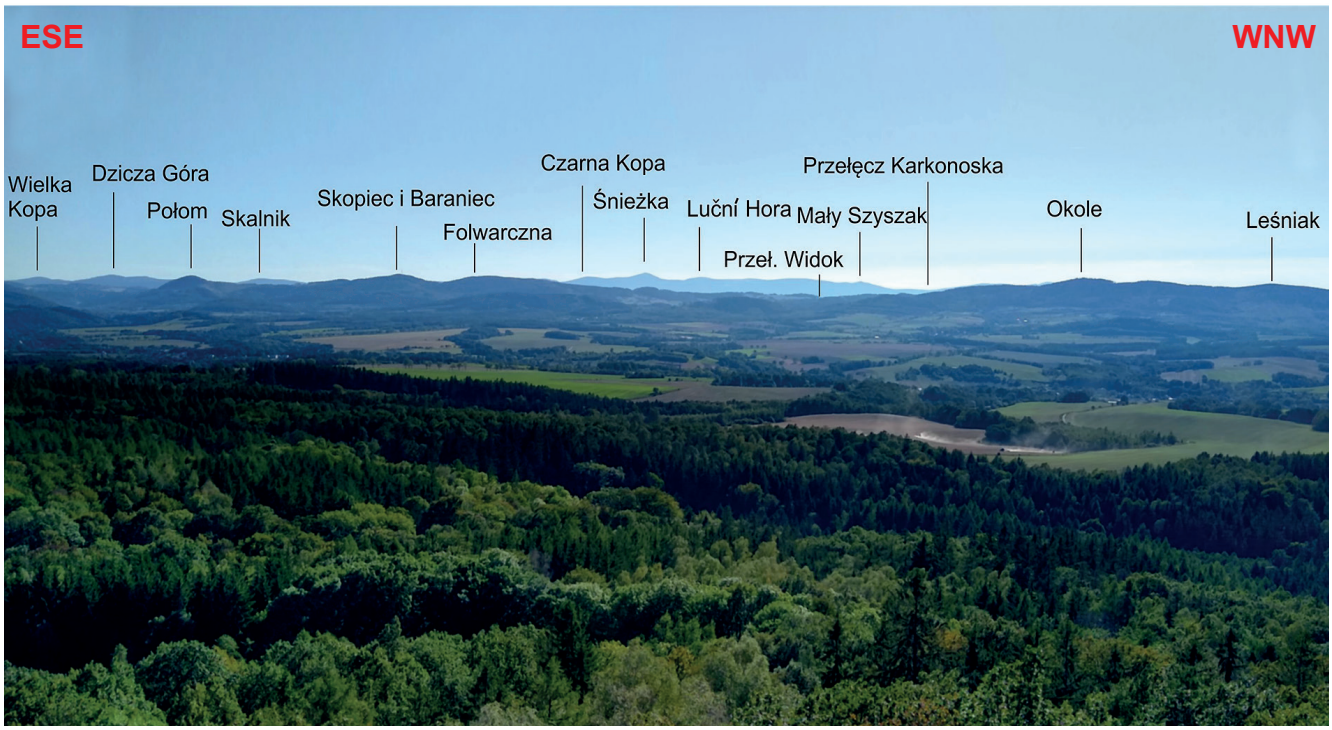


Fig. 6. The panoramic view from the observation tower on the Zawodna hill from ESE to WNW. The described peaks belongs to three mountain ranges: the Rudawy Janowickie, the Karkonosze (Giant Mountains) and the Kaczawskie Mountains. Photo P. Słomski

A walk along the dam in Świerzawa (Fig. 7) allowed the participants to familiarize themselves with the issues of water circulation in nature, water retention, basics of water chemistry and flood prevention. In the case of older age groups, it was also an opportunity to discuss the construction of the dam itself. Moreover, the vicinity of the dam is extremely attractive for geological reasons. On both sides of the Kamiennik stream, especially on its north side, sedimentary rocks from the turn of the Carboniferous and Permian are exposed (Ostromęcki, 1972; Wojewoda & Mastalerz, 1989; Solecki, 2011). These rocks are an effective example of the braided river sediments, which were formed in a dry and hot climate. Since that, the vicinity of the dam in Świerzawa makes of possible to conduct courses dedicated to climate change and the genesis and types of rocks.

This outcrop has been less and less accessible in recent years due to strongly developed vegetation. This situation has changed at the end of 2019, when, thanks to the initiative of the Kaczawskie Association, the authorities of Świerzawa decided to clear this geopoint from excess vegetation (Fig. 8). As a result, the potential of this location can be already better utilised, although this is only the first step. The Kaczawskie Association is currently preparing an educational board, which will highlight the geological and hydrological values of this location.

Fig. 7. The dam on the dry flood reservoir in the Świerzawa town. Photo P. Słomski

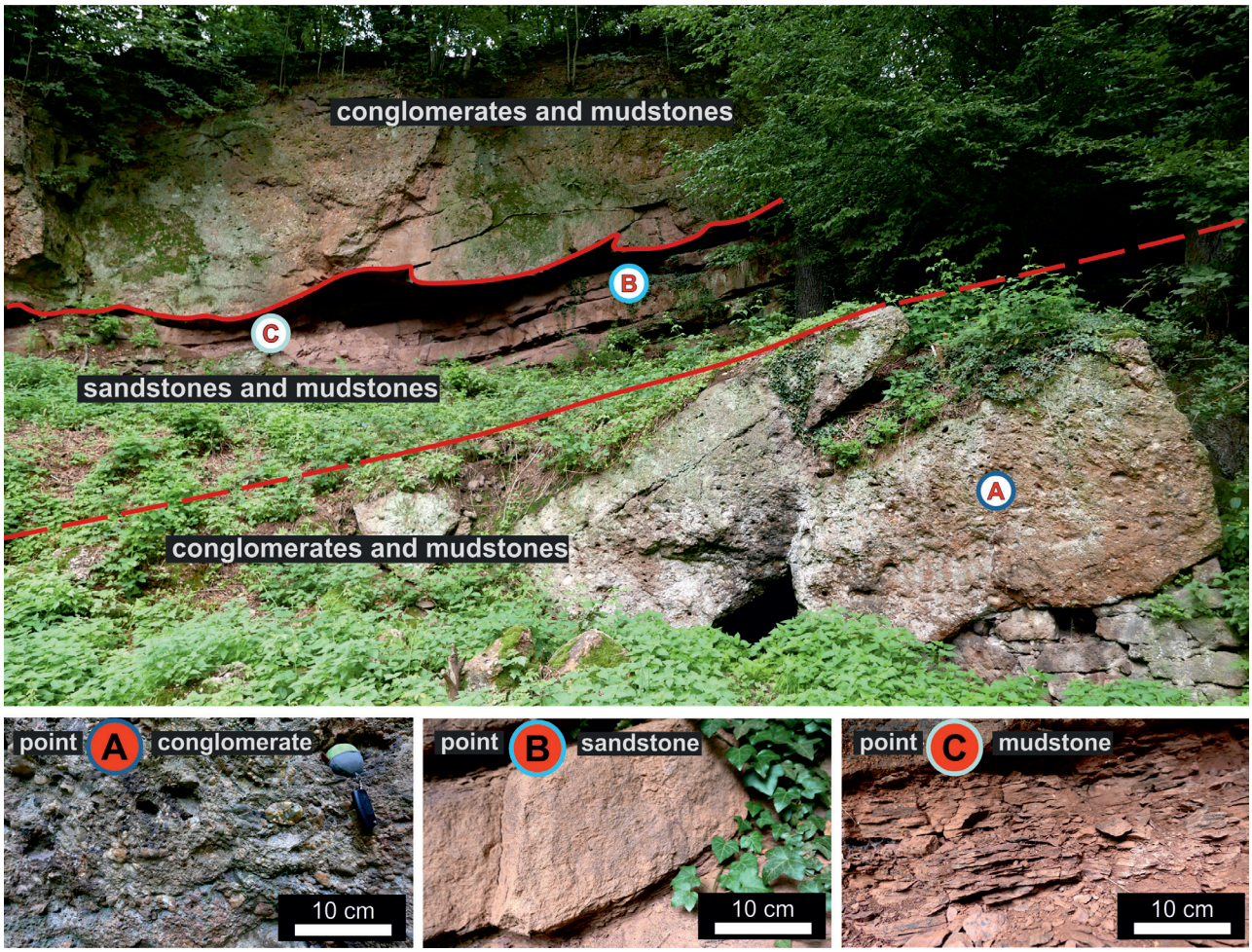


Fig. 8. The sediments of the braided river near the dam on the Kamiennik stream in Świerzawa, cleared of excessive vegetation. Three types of sedimentary rocks are visible in the rock wall: A – conglomerates; B – sandstones; C – mudstones. Photo M. Biernat

## Geoeducational potential of working quarries

In the described region, working quarries continue to exist, such as the Wojcieszów limestone quarry in the Połom Mountain massif in Wojcieszów (Fig. 9A) or the Wilcza Góra Basalt Mine on the Wilkołak Hill near Złotoryja. It is important to already consider if and how these objects can be used in terms of geoeducation and geotourism after the end of exploitation.

In both cases, it would be appropriate to install geoeducational tables, informing about the history of exploitation in a given place and providing the geological context. Moreover, these quarries have the potential for creating short educational paths covering a wider range of issues. Additionally, in the quarry on the Połom Mountain in Wojcieszów, there may be a chance for utilising the industrial infrastructure, i.e. the old lime kiln (Fig. 9B), and turning it into the part of the exposition. The kiln should remain in the quarry as an illustration of the old fashioned limestone processing. It would be even more interesting, if the mentioned furnace could also serve as an observation tower located inside the quarry, as long as its technical condition allows for such use. It is also worth mentioning, that all the Wojcieszów limestone outcrops and exposures are very interesting due to the fact that their Cambrian age was confirmed relatively recently, based on Archaeocyaths fossils (Białek *et al.*, 2007).

In case of the Wilcza Góra Basalt Mine (within the Wilkołak hill), the quarry is expected to operate until the year 2027. The investor has prepared the proposition of terrain reclamation, which would include the installation of educational infrastructure at the bottom of the quarry, creation of a geological garden and establishment of a viewing point, as well as a water reservoir (Marek *et al.*, 2014). Although all these propositions are interesting and seem to be a proper way to give a "second life" to the old quarry, we would like to emphasize the need for cooperation with local citizens and touristic organisation in discussing the details of such enterprises. This is important in particular because this quarry is an extraordinary place for geoeducational activities due to the so-called basalt rose, which is the radial system of basaltic columns visible on the quarry wall (Fig. 10A).

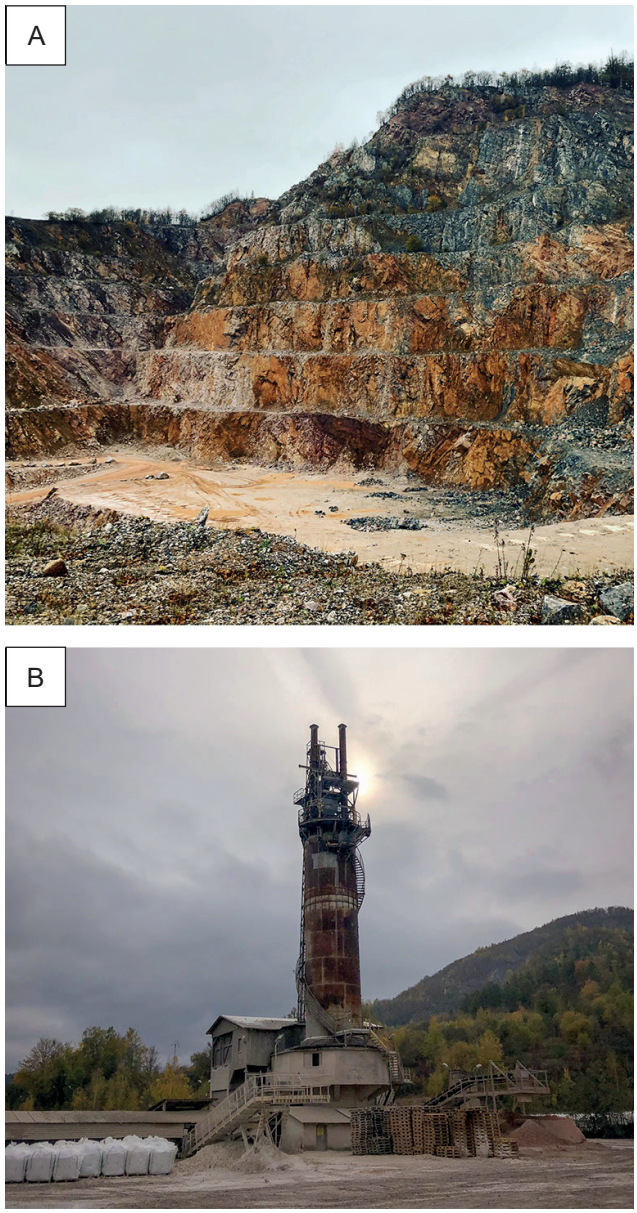


Fig. 9. The quarry of Cambrian Wojcieszów limestones at the slopes of the Połom Mountain in Wojcieszów town: A – a general view of the quarry; B – old lime kiln. Photo J. Jankowska

Another issue for potential discussion may be the location of the viewing point. It is planned to be created on the bottom of the excavation, however, the peak of the hill Wilkołak, due to its isolated character, seems to be a much more attractive location (Fig. 10B). If the top of the hill was cleared of the trees, a 360° panorama would offer views towards the Kaczawskie Mountains and Foothills, the other nearby Sudetes ranges, the Chojnowska and Legnicka Plains. This would be also a rare opportunity to peek into the depths of the former quarry's excavation. Of course, we are aware, that such a setting for a viewing point would demand additional infrastructure like stairs and barriers, etc., and should be preceded by checking if the hill peak is a safe place for tourists.


Fig. 10. The quarry of basalt "Wilcza Góra" on the Wilkołak hill: A – the so-called "basalt rose" visible in the wall of the quarry; B – a view toward Wilkołak hill from south direction. Photo DE2

Interestingly, in the aforementioned quarry, there has been a rockfall in the second half of August 2019, which stopped mining works for some time. According to local media reports, the preliminary findings of the Mining Office in Wrocław suggests that the area of the reserve and its protective pillar were not affected by the rockfall (Kanikowski, 2019). Such events, although rare, at least theoretically may have an impact on further quarry management plans.

## Promotion of the region and sustainable development of tourism

The sustainable development of geotourism requires the cooperation of many entities, groups and citizens on a regional scale. The preparation of the geotouristic and geoeducational offer for the potential customers should be combined with the spreading of knowledge about the valuable geological heritage among the local community. This approach will make it possible to activate the entire region around the common goal of geotourism development.

Another very important thing for geotourism initiatives is the substantive support of the scientific community.

Comprehensive activities for geotourism, and geoeducation development, engaging the local community, have been consistently undertaken in the Kaczawskie Mountains and Foothills for over a dozen years (Pijet-Migoń & Migoń, 2019). In 2002, the Kaczawskie Association, a non-profit organization, was established, and in 2005 the Local Action Group (LAG) "Kaczawskie Partnership" was created. These organizations are acquiring funds and coordinate work on tourist and educational projects in the Kaczawskie Mountains and Foothills region. Thanks to the efforts of the abovementioned entities, the Sudetic Educational Centre was opened in 2015 in the village of Dobków. It is a modern, interactive educational centre, focusing on the geological heritage of the Land of Extinct Volcanoes and education in the field of natural sciences. The Kaczawskie Association is involved in the process of submitting the application for the Land of Extinct Volcanoes Geopark into the UNESCO Global Geoparks Network – GGN. In 2019, a geological inventory of the Kaczawskie Mountains and Foothills was carried out (Inwetaryzacja geopunktów na obszarze Partnerswa Kaczawskiego, 2019) and a system of graphic identification of the region was developed. In December 2019, the Kaczawskie Association submitted a complete application dossier to UNESCO GGN (Land of Extinct Volcanoes Geopark Application Dossier, 2019).

The application to the UNESCO GGN is an example of large-scale activities dedicated to building the prestige of the region, making it possible to protect and promote it internationally. Nevertheless, there are also many local initiatives in the Land of Extinct Volcanoes, aimed to promote the region and encourage tourists to explore it. An example of such an initiative is the program "Passport of the Discoverer of the Land of Extinct Volcanoes", which was launched in 2018. It is both a program of cooperation between local tourist and educational entities and a campaign targeted at tourists. In the Kaczawskie Mountains and Foothills, there are many small family businesses offering workshops prepared for families. Such entities include (apart from Sudetic Educational Centre, which conducts scientific workshops covering mineralogy, climate protection, basic issues of chemistry and physics), numerous ateliers offering creative workshops, e.g. weaving, ceramics, glass engraving, herbalism or gold rinsing. All of the mentioned activities intensely refer to the historical, cultural and natural heritage of the Kaczawskie Mountains and Foothills. Thanks to the cooperation of all educational entities, as well as restaurants and accommodation facilities, before the periods of increased tourist traffic, such as holidays or long weekends, a coherent program of workshops is developed, which is then promoted together. Throughout the year, for participation in each workshop, visitors receive dedicated stamps or stickers for visiting attractive places (volcanic rock outcrops, medieval castles, historic city centres). The stamps entitle them to be awarded with medals created by local artists and craftsmen. This approach mobilizes tourists to explore the Kaczawskie Mountains and Foothills, and at the same time creates an opportunity for establishing contacts with the local community. Importantly, all offered workshops have sufficiently high substantive levels, thanks to the fact that the offered product is both authentic and professional, and also has an educational character.

## The impact of COVID-19 pandemic on geotourism in the region

This paper was planned to be dedicated only to geoeducation, however, in the face of recent months, we think that we should add a short paragraph referring to COVID-19 pandemic and its impact on the geotourism in the Kaczawskie Mountains and Foothills.

We will use the statistical data referring to the number of visitors in the Sudetic Educational Centre as an example. We believe, that this data are, at least to some extent, representative also for other educational entities in the Land of Extinct Volcanoes Geopark, since many groups and tourists visit not only Sudetic Educational Centre, but also other places.

We will present and shortly compare data from 2017 to 2020, each time only from January to September for consistency. During a few recent years, the total number of visitors, who had been visiting Sudetic Educational Centre from January to September, was constantly growing, from ca. 9525 in September 2017 to ca. 13 509 in September 2019 (Fig. 11). Moreover, the share of organised groups was getting bigger in each of these years, from 54% in September 2017 to 65% in September 2019 (Fig. 11).

The year 2020 has brought two important changes. First of all, the number of visitors till September decreased ca. 290% in comparison to the previous year and was equal to ca. 4678. Secondly, individual guests (58%) were prevailing over organised groups (42%). This was caused by the "lockdown" in springtime and the lack of school trips in that time. When we focus only on the holiday months (July and August in Poland) the proportions between individual visitors and groups are similar to the previous years, although the total number of guests was ca. 900 less than in holiday 2019 (−33%). This suggests, that the mobility of potential tourists was reduced due to all the negative effects of the pandemic. Moreover, the assumption that people will spend their holiday in Poland instead of going abroad, was false. Unfortunately, since the end of October 2020, the Sudetic Educational Centre is temporarily closed, which is related to the restrictions during the second wave of the pandemic.

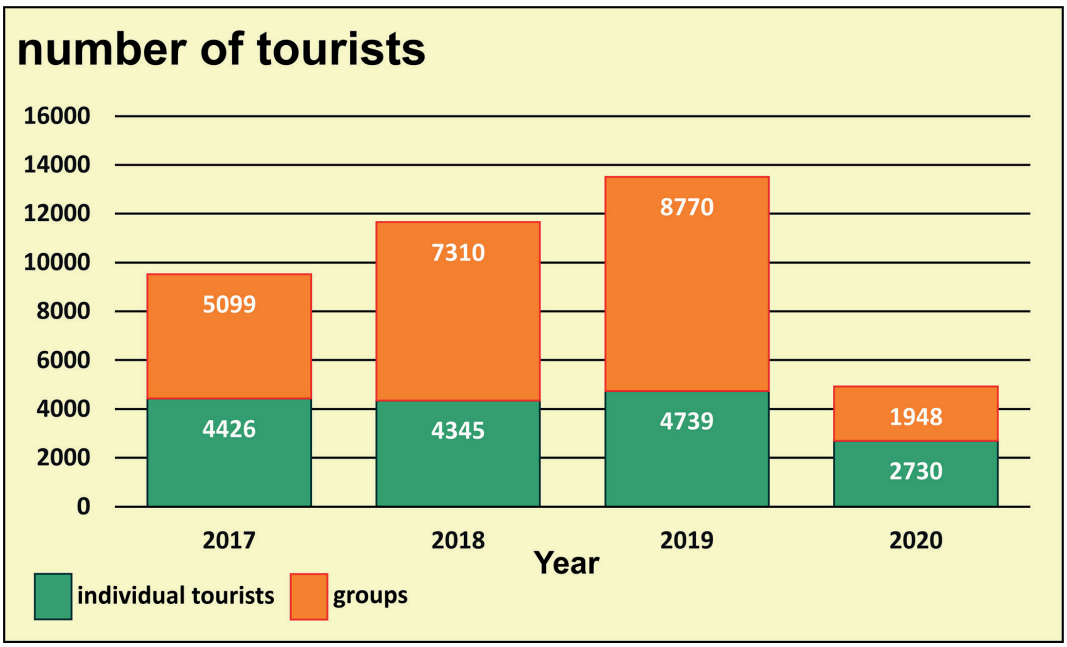


Fig. 11. The number of visitors in Sudetic Educational Centre during last four years (data from January to September for each year)

## Summary

The regions with rich nature and historical heritage are predestined to play an important educational role, both in terms of school education and various forms of non-formal education. Nevertheless, even the greatest tourist attraction will not contribute itself to the increase of ecological awareness of tourists and local communities, unless educational and touristic entities develop a cooperative network. Such a network can guarantee the creation of a valuable educational and geotouristic offer for a vast range of receivers. The educational activities presented in this text provide examples of efforts to strengthen the sustainable development of tourism and geoeducation, taking into account the local specificity of the region.

2020 is a very special year in geotourism and geoeducation in the Kaczawskie Mountains and Foothills. The COVID-19 pandemic changed the volume and structure of the tourist traffic and slowed the process of application to the UNESCO GGN. However, all the local parties, including the Kaczawskie Association, are ready to restart the realisation of their educational enterprises, as soon as it will be possible.

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# Geoproduct potential analysis based on the example of the GEOsfera Ecological and Geological Education Center in Jaworzno

## Analiza potencjału geoproduktu na przykładzie Ośrodka Edukacji Ekologiczno-Geologicznej GEOsfera w Jaworznie

**Barbara Bieniek[1,2,a], Alina Kordysh[1,2,b], Mateusz Mirosławski[1,2,c], Katarzyna Nowak[1,3,d], Kacper Sękowski[1,2,e], Edyta Sierka[1,3,f,*]**

*[1] College of Individual Interdisciplinary Studies of the University of Silesia in Katowice, Bankowa 12, 40-007 Katowice*
*[2] Faculty of Social Sciences, Bankowa 11, 40-007 Katowice*
*[3] Faculty of Natural Sciences, Będzińska 60, 41-205 Sosnowiec; Jagiellońska 28, 40-032 Katowice*
*e-mails: [a]basiabieniek@poczta.fm; [b]alina6521@gmail.com; [c]mmiroslawski@hotmail.com; [d]katarzyna009b@interia.pl; [e]kaspian313@gmail.com; [f]edyta.sierka@us.edu.pl*

*Corresponding Author


Article history:
Received: 28 September 2020
Accepted: 12 December 2020
Available online: 17 February 2021



**Abstract:** *At the time of discovering and exposing the scientific and educational potential of areas where mineral resources were exploited in the past, they have become a significant element in tourism elements. In the presented paper, the potential of the GEOsfera Ecological and Geological Education Centre in Jaworzno as a geoproduct was analysed. In the first part of the study, based on the published works and consultations with experts, the "geoproduct" was defined. Then the area, where the GEOsphere is located, was characterized. Its geology, the natural world, the way of land development and the promotion of geo-attractions located in this area are described. In the next stage, an analysis of the opinions of users regarding their perception of the GEOsphere was carried out. For this purpose, evaluations posted on social media and the collected survey results were used. As shown by the results, the majority of users of the GEOsfera are residents of Jaworzno – 63% of the respondents. The importance of the GEOsphere as an educational centre was indicated by 22% of visitors. About 5% of the respondents mentioned learning and obtaining information from the descriptions placed next to the exhibits in the centre. 93% of respondents recognised the graduation tower as the greatest attraction of the GEOsphere. Over 92% of people noticed the recreational role of the GEOsphere. 81% of users declared that they were satisfied with their visit to the GEOsphere. More than half of the respondents (56%) visited the GEOsfera with their family. A significant part of respondents (42%), pointed to the role of environmental protection, which is extremely important from the point of view of geoproducts' design. The respondents also indicated that the GEOsphere has numerous geological, natural and educational functions and protects and promotes the geological heritage of the region.*

**Keywords:** *geo-attractions, geological education, natural potential, limestone quarry, Jaworznickie Hills*

**Treść:** *W dobie odkrywania i eksponowania potencjału naukowego i edukacyjnego terenów, na których w przeszłości prowadzono eksploatację surowców, stają się one znaczącymi obiektami turystycznymi. W prezentowanej pracy dokonano analizy potencjału Centrum Edukacji Ekologiczno-Geologicznej GEOsfera w Jaworznie, zlokalizowanego na terenie wyrobiska surowców skalnych, jako geoproduktu. W pierwszej części opracowania, opierając się na dostępnych pracach publikowanych i konsultacjach z ekspertami, zdefiniowano „geoprodukt" oraz określono kryteria, jakie powinien spełniać. Następnie opisano teren, na którym zlokalizowana jest GEOsfera, uwzględniając geologię, elementy przyrody ożywionej oraz sposób zagospodarowania terenu i promowania geoatrakcji, które się tam znajdują. Na kolejnym etapie przeprowadzono analizę opinii użytkowników w zakresie postrzegania przez nich GEOsfery. Do tego celu wykorzystano oceny*

*zamieszczone w mediach społecznościowych i zgromadzone wyniki badań ankietowych. Wykazały one, że większość spośród badanych użytkowników GEOsfery to mieszkańcy Jaworzna, którzy stanowili 63% ankietowanych. Znaczenie GEOsfery jako istotnego ośrodka edukacyjnego wskazało 22% odwiedzających. Około 5% pytanych doceniło uczenie się i pozyskiwanie informacji z opisów umieszczonych na tablicach obok eksponatów na terenie ośrodka. Jako największą atrakcję terenu GEOsfery 93% ankietowanych wskazało tężnię solankową. Ponad 92% respondentów dostrzegło rekreacyjną rolę GEOsfery i dogodne warunki do aktywnego spędzania czasu. 81% badanych zadeklarowało zadowolenie z wizyty. Ponad połowa respondentów (56%) odwiedziła GEOsferę z rodziną. Znaczna część ankietowanych (42%) zwróciła uwagę na znaczenie ochrony środowiska w funkcjonowaniu GEOsfery, co jest niezwykle ważną informacją przydatną podczas projektowania geoproduktu. Użytkownicy, którzy wzięli udział w badaniu, wskazali również, że GEOsfera ma liczne walory geologiczne, przyrodnicze i edukacyjne oraz chroni i promuje dziedzictwo geologiczne regionu.*

**Słowa kluczowe:** *geoatrakcje, edukacja geologiczna, potencjał przyrodniczy, kamieniołom wapieni triasowych, Pagóry Jaworznickie*

## Introduction

More and more often, areas where the extraction of raw rock materials has ended are used as tourist attractions, combining education with leisure (Woźniak *et al.*, 2011). The Sadowa Góra quarry in Jaworzno is a good example of such a transformation, where environmental potential has been adapted for the purpose of education, mainly in geology, but also in the field of biological sciences. Post-mining areas, often with a significant potential of preserved natural qualities (fossils, geological formations, etc.), as a result of human industrial activity, can be used to create facilities, which are attractive for tourists and are able to function as commercial entities.

The aim of this study is to analyse the tourism potential of the quarry area turned into Centre for Ecological and Geological Education – GEOsfera, as a geoproduct.

What is a geoproduct? A geoproduct, according to Michał Poros (2014), the director of the Kielce Geopark, is defined as a popularization tool for the product of Earth sciences. It is a post-exploitation area, an artefact of a past state or activity that connects all interested communities, the academics, specialists, experts in the subject, and people involved in the dissemination of knowledge. A geoproduct is correlated with the goals of local governments focused on development and education. In terms of geology, it is the uncovering of an important place in this respect, e.g. a post-mining area, which must, however, be identifiable with a tourism event promoted under a specific name. Contrary to the essence of the geoproduct, it does not have to be related to geology as such. It presupposes a greater contribution from people and history rather than only from the presence of nature in itself. Often, it refers only to historical memory, being attached to a place that builds the identity of the local community.

According to the UNESCO definition (UNESCO Geoparks Programme... 1999), "geoproducts are innovative artisanal products that are associated with geology". In the opinion of Farsani *et al.* (2012), a geoproduct should be made from locally sourced products, while being a symbol of the geological (or geomorphological) heritage of the area. It should be an educational tool, as well as a commercial product. In accordance with the idea of sustainable development, a geoproduct must be environmentally friendly and should combine local traditions with scientific elements.

Dryglas & Miśkiewicz (2014) proposed the classification of geoproducts. The basic groups of geoproducts include:

- objects, e.g. geotouristic guides, handicrafts (geo-cosmetics, geo-jewellery);
- locations, e.g. mining facilities, lapidary workshops;
- events, e.g. mineral exchanges, geological picnics, geo-conferences;
- services, e.g. geo-educational, geo-sales, geo-medical (lithotherapy).

In addition, complex geoproducts such as:

- events, e.g. field games (Geocaching);
- paths, e.g. educational paths;
- areas, e.g. national and UNESCO geoparks, mineral springs.

Based on the information above, a "geoproduct can be defined as any object, institution, or an event aimed at promoting the geological heritage of a specific area, related to the concepts of earth sciences and life sciences, used for commercial and educational purposes, and inherently environmentally friendly". A geoproduct is directly related to geotourism focused on learning about geological facilities and processes. Through direct contract, a geoproduct allows one to experience sensual and aesthetic impressions. Geotourism utilises the results of basic geological research for practical purposes and is closely related to environmental protection (Ścibisz-Kosanowska *et al.*, 2013).

## Study methods and characteristics of the research subject

Material used in the analysis was collected from the available expert studies and published papers. Results were obtained also from questionnaires prepared by the authors.

The Centre for Ecological and Geological Education GEOsfera in Jaworzono was adopted as the research subject.

GEOsfera is the facility with the total 8 ha of the landscaped area, established on the site of a former dolomite quarry (Fig. 1). Located between Jaworzno city centre and the Sand Mountain, on premises Sadowa Góra. During the Triassic Era, 230 million years ago, this area was occupied by a shallow and warm sea, inhabited by a swimming prehistoric lizard – the *Nothosaurus.* With time, some dead remains of bivalves, brachiopods and echinoderms settled on the seabed.


Fig. 1. Localisation of the Centre for Ecological and Geological Education GEOsfera in Jaworzono

Until 1980, limestones and dolomites were mined in this area for the needs of the cement industry. After the raw rock materials were exploited, attempts were made to cover the quarry with waste. However, thanks to the involvement of Jaworzno authorities and experts in the field of geology and zoology, who identified the natural, mainly geological potential of the area, it was decided in 2014 that the GEOsfera will be established in the quarry. Funds were obtained for this purpose from the European Regional Development Fund under the Regional Operational Programme of the Śląskie Voivodeship for the years 2007 – 2013. The current GEOsfera has an extensive infrastructure, i.e. a ripple marks exhibition pavilion, reconstruction of Triassic vertebrate habitats, a graduation tower, a "geological window" and an educational trail with information signs.

The Sadowa Góra quarry is located within the Garb Jaworznicki highland region (Kurek *et al.*, 1994; Jochemczyk *et al.*, 2004; Tokarska-Guzik *et al.*, 2012), which, along with the Garb Ciężkowicki region is a part of the Jaworznickie Pagóry range. The region borders from the East with a Pleistocene denudation plain, which is filled with sands and gravels dating back to the Odra glaciation (Tokarska-Guzik *et al.*, 2012). The hills of Jaworznickie Pagóry are inliers. They consist of monoclinally arranged carbonate Triassic formations (Kurek *et al.*, 1994). Sadowa Góra is an old excavation site where mainly marly conglomerates of the upper Gogolin Formation were excavated (Nita & Bradziński, 2008 after: Woźniak & Krzeczyńska, 2014). The Gogolin Formation developed in the Triassic and is divided into the lower (older) and the upper (younger). The lower Gogolin Formation consists of carbonate rocks: limestones, conglomerates with a carbonate binder and marls. In the lowest part of its profile, the Gogolin Formation consists of: micrite, fine-detritic, medium and thick-bed limestones, containing numerous fragments of crinoids. Their main species is *Dadocrinus kunischi* (Kurek *et al.*, 1994). Crinoids belong to the echinoderms family. Their fully preserved frames, including the crown, are a rare find, because usually the dead flower crumbles. You can find many trochites at the GEOsfera (Woźniak & Krzeczyńska, 2014). They are single rings that build the daylily stem. In their glory days, when they lived static lives, crinoids formed so-called lily meadows. Abundant accumulations of trochites are the building blocks of crinoid limestones. Crinoids fragments are accompanied by numerous bivalves, predominantly the *Pecten discites*, as well as *Plagiostoma striatum* species. Marly limestones with a wavy roof and bottom reside above the crinoid limestones. The lower part of the Gogolin Formation consists of some open sea sediments, associated with the first transgression of this period. Dark yellow dolomitic cellular limestones are at the bottom of the lower part of the Gogolin Formation. They are a relic of evaporites formed as a result of gradual regression of the sea basin (Woźniak *et al.*, 2010).

The upper part of the Gogolin Formation begins with conglomerate and intra-formation limestones, in which we can find pebbles of micrite and marly limestones from the lower layers of the formation. Crinoid limestone containing bivalves (*Lima striata* Goldfuss) is the binder here along with fragments of reptile bones (Kurek *et al.*, 1994). The highest part of the Gogolin Formation consists of micrite and sparite limestones. This layer contains two levels with a wavy texture – that is the 2nd and 3rd wavy limestone. The upper part of the Gogolin Formation displays a record of a sea transgression that caused the emergence of Tethys Ocean fauna in the Germanic Basin (Woźniak *et al.*, 2010). The thickness of the Gogolin Formation ranges from 25 to 30 meters. Above the Gogolin Formation, the *Diplopora*-bearing layers can be found, followed by Tarnowice Beds, which end with middle Muschelkalk limestones. The upper Muschelkalk limestones is composed of the Boruszowice Beds, which, just like the Tarnowice Beds, are made of micrite and oolite dolomites with sandstone interbedding (Kurek *et al.*, 1994; Jochemczyk *et al.*, 2004; Woźniak *et al.*, 2010).

The Szczakowa Cement Plant ended production in Jaworzno in 1999. It was the chief recipient of raw rock materials, so mining stopped as well and excavation site walls were left exposed. One can clearly observe the sequence of rock layers of the Gogolin Formation in the profile of the quarry walls. Beginning with crinoid limestone, 1st wavy limestone occur, then intra- to the formation conglomerate and 2nd wavy limestone occur finally (Markowiak, 2014). In the rocks, we can find numerous fossils, ichnofossils, including the aforementioned crinoid trochites. The wall of the GEOsfera quarry is a record of the Germanic Sea that filled this area 225–210 million years ago. It was an epicontinental sea (with a maximum depth of 100 meters, 50–60 m in today's Jaworzno city limits), well oxygenated, in which predatory reptiles thrived. Reptiles are represented at GEOsfera by the fish-eating *Nothosaurus*, which is classified as a primitive fin-lizard (Markowiak, 2014). The length of their bodies could exceed four meters (Surmik, 2013). Apart from the "false lizard", the ichthyosaurs and posterodontons also probably lived at Sadowa Góra (Woźniak & Krzeczyńska, 2014). The GEOsfera Jaworzno can boast of the presence of mega ripplemarks on its grounds (Fig. 2). These are numerous, regular furrows separated by gutters. These wrinkles flow in the North-South direction. Their size and amplitude (10–35 cm) suggest that they are the result of oscillatory waves in the declining phase of tropical hurricanes (Markowiak, 2014; Woźniak & Krzeczyńska, 2014). In geology, objects of this type are used to reconstruct palaeoenvironments.

The above-mentioned crinoids are examples of living fossils, but only those species that have retained the stem are present.

The area of the centre in question can boast of a unique wealth of Triassic rocks, but also a stunning display of animated nature, i.e. flora and fauna, for which the quarry has provided favourable conditions for development. The walls of the excavation are cliffs and there are numerous depressions and elevations at the bottom. The soil variations are at the stage of initial rendzinas with varying levels of humus, carbonate rocks and moisture.

Diverse habitat conditions allowed for the formation of a mosaic of plant communities in this area, from places covered with vegetation consisting of forests in initial stages of development, through shrubs, grasslands and meadows to typically ruderal areas (Fig. 3). In the quarry itself and in its immediate vicinity, 433 species of vascular plants were found (Szendera *et al.*, 2016). Characteristic elements of this area are thickets of shrubs including blackthorn (*Prunus spinosa*), European buckthorn (*Rhamnus cathartica*) and single-necked hawthorn (*Crataegus monogyna*). Undergrowth and small biogroups of trees are mainly composed of Scots pine (*Pinus sylvestris*) and warty birch trees (*Betula pendula*), species that disseminate thanks to the wind. Slopes with sliding layers of weathered limestone are covered mainly with species of blackberry (*Rubus* sp.), but also with spontaneous growth of light-seeded trees such as Scots pine, silver birch and willow trees.

Fig. 2. Mega ripplemarks. Photo E. Sierka

Fig. 3. Quarry walls with spontaneously encroaching vegetation. Photo E. Sierka

Xerothermic grasslands are an inextricable element of limestone areas at GEOsfera. These thermophilic communities consist of the Carthusian pink (*Dianthus carthusianorum*), the spiny restharrow (*Ononis spinosa*), and many others. In places where the terrain is almost flat, sandy grasslands develop fragmentarily on the sandy ground. At GEOsfera, these communities are mainly formed by dicotyledonous plants, i.e. sand thyme (*Thymus serpyllum*), sea thrift (*Armeria maritima*), and field chickweed (*Cerastium arvense*). Meadow communities also develop spontaneously in moderately humid places. Where the permeability of the substrate is lower, e.g. at ripple marks or depressions, temporary stagnant water gathers, thus eliminating species that do not prefer stagnant water.

Simultaneously vegetation from adjacent areas appears in the fissures where rocks are weathering. On the grounds of the Centre for Ecological and Geological Education, many habitats have been established by man. These include a water reservoir with rush vegetation consisting of lakeshore bulrush (*Schoenoplectus lacustris*), the European water-plantain (*Alisma plantago-aquatica*), and the broadleaf cattail (*Typha latifolia*), as well as submerged vegetation including the spiked water-milfoil (*Myriophylum spicatum*). As part of the "BioGalmany" project, the calamine plants area was created with plant species associated with this very specific habitat. The area also includes sensory gardens that can be perceived with all senses, i.e. sight, smell, touch, hearing and taste.

The resulting wealth of plant species also indicates the diversity of other organisms. The GEOsfera faunal inventory (Inwentaryzacja przyrodnicza... 2017) showed the presence of 282 different species of animals from the groups: annelids (1), molluscs (10), crustaceans (2), trichomonads (13), insects (165), centipedes (3), amphibians (7), reptiles (4), birds (60), mammals (17). The quarry itself is a natural terrain 'trap' for smaller fauna specimens living in its vicinity, integrated into the local landscape. Some animals move to the GEOsfera area or its vicinity, while others are blown over from neighbouring biotopes, open areas and forests, as well as the surrounding Pagóry Jaworznickie hills covered with diverse plant systems. In addition, the semi-open quarry area is located on the route of local animals migrating between various types of biotopes, from near and far in the vicinity, including larger forest complexes (Inwentaryzacja przyrodnicza... 2017). Numerous species of butterflies are associated with limestone areas, such as the chalkhill blue (*Polyommatus coridon*).

A vertebrate species associated with wetland habitats is e.g. the European tree frog (*Hyla arborea*). This species leads a land-water lifestyle. It can climb trees and begins its activity only at dusk. There are also animals only temporarily living at the GEOsfera, e.g. using the quarry area as an ecological corridor in their migration. Within the OEEG GEOsfera, one can find the Field Research Station of the University of Silesia in Katowice – BIOGEO, where students learn about the diversity of life forms in this area.

Closed quarries are experiencing a renaissance nowadays, often adapted for recreational purposes and events for minerals and fossils enthusiasts. As a result, geotourism is on the rise, encouraging tourists to explore in depth the regions they visit and offering them an opportunity to learn about the natural history of our planet. The GEOsfera in Jaworzno is a good example of an attractive geotourism site (Chybiorz & Kowalska, 2017). The main idea behind the creation of GEOsfera is the large-scale promotion of the riches of the natural world. In the extensive sensory park created here, one can see over forty thousand plants. It is a place where, apart from recreation and tourism, the educational offer reaches far beyond the limits of academic theory. The main concepts behind the establishment of the Centre focus on the inextricable bond between all elements of the natural environment, as well as on showing the constant changes in the plant and animal world. One of the main goals of the Centre is nature education, based on acquiring knowledge and skills through experience and shaping desirable environmental attitudes.

Installations at GEOsfera with an especially large potential in terms of geotourism include, among others, reconstructions of the Triassic four-legged land animals. At GEOsfera a small pavilion was built for the purpose of showcasing ripple marks, which were most probably created as a result of a gigantic tsunami caused by an earthquake. Right next to the pavilion, there are mega ripplemarks, i.e. huge fossilized wave marks (Fig. 3). The geological history information has been placed on educational billboards and is presented at numerous exhibitions that bring the history of the Triassic period to life. In addition, currently the centre organizes nearly thirty different thematic activities available for free to groups of tourists.

In addition to being an educational space, the GEOsfera also offers recreational facilities. Walking routes, viewpoints, a graduation tower, a barbecue site, a small amphitheatre, a playground, a didactic room, a pond, a seasonal clock, a weather station, a moorland and a sensory garden are all located on an area of 20 acres.

Admission to the premises is free, and lighting available 24 hours allows guests to visit without time restraints. The direct safety measures at the facility include a video surveillance system. There is a small car park for guests arriving by car. Public transport to and from the city centre is also available. The GEOsfera is a place for those who are interested in history and excavations, as well as for those who seek peace and relaxation, which is extremely important in the densely populated Silesian conurbation.

## Results

The GEOsfera is present in social media via Facebook and Trip Advisor. Since the creation of the profile in 2014, 9161 people have liked the GEOsfera page on Facebook, which is a moderate result when you consider that the GEOsfera has about 10,000 visitors annually. Announcements about site modernisation, educational events, etc. are published via Facebook. The popularity of posts published for two months (May–June 2019) ranged from 5 to 322 likes per post.

The average rating of the facility, out of 200 opinions expressed on Facebook, is 4.7 on a five-point scale. In addition, 60 people posted comments to GEOsfera, in which they indicated the following advantages of the facility presenting in Fig. 4.

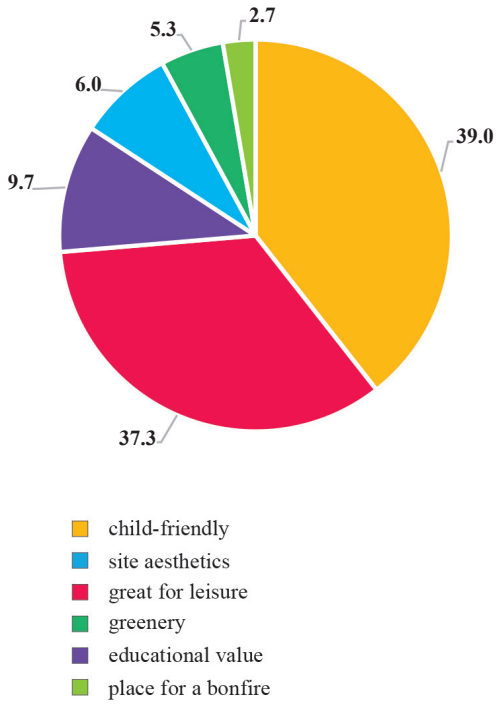


Fig. 4. Opinions evaluating GEOsfera park in Jaworzno on basis of Facebook portal

The centre in Jaworzno also has a profile on Trip Advisor, where the average rating from 31 user ratings is 4/5. Written opinions were expressed by 26 users, in which they indicated the following advantages of the facility in Figure 5.

Opinions expressed by internet users show that GEOsfera is primarily perceived as a place for relaxation, where you can go for walks with children. On Facebook, only a small (6.7%) group of visitors mentioned the educational or natural value of the facility. Almost a quarter of commenting users (23%) emphasized the value of these elements on Trip Advisor, but still most (65%) visitors considered the GEOsfera primarily as a good place to visit with children.

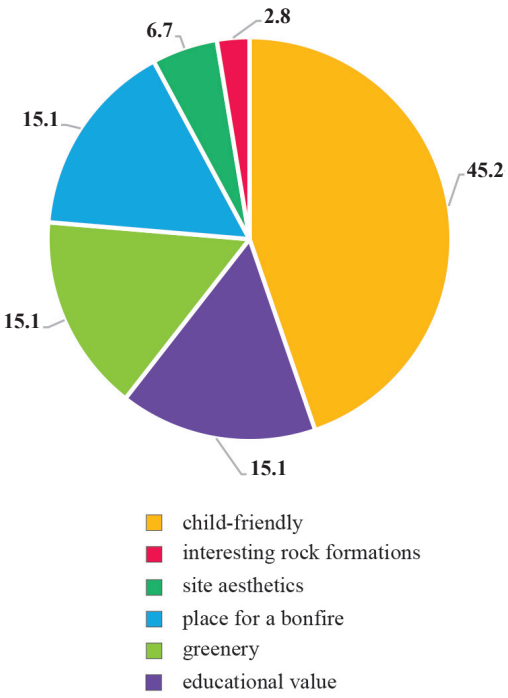


Fig. 5. Opinions evaluating GEOsfera park in Jaworzno on basis of Trip Advisor portal

A poll consisting of 13 questions in a questionnaire was conducted on a sample of 100 people (61 women, 39 men) at the centre. The results show that:

- Most respondents (63%) were residents of the city Jaworzno. Of the remaining 37%, four people declared that they live in the countryside.
- Most of GEOsfera visitors found out about it from friends (53%) or learned about it on the Internet (26%). Only 5% of visitors found information about the GEOsfera in the press. This observation most probably indicates that the GEOsfera is not present nearly enough in either traditional or social media. Only 8% of respondents came upon the facility while driving or walking by, and 2% of the respondents found out about it from regional television.
- The most frequently declared purpose of visiting the GEOsfera was taking a walk in the open air (71% of respondents). The second most frequent purpose of a visit to GEOsfera was leisure (55%), and the third – providing children with something engaging and fun (30%). Education was mentioned by only 22% of visitors. Only 2% of people declared taking advantage of the graduation tower as the purpose of their visit. At the very bottom of the list, 1% of visitors indicated their professional duties as a reason to visit, tied with "curiosity", also at 1%.
- In response to an open-ended question about activities undertaken in the park, 90% of people mentioned walking, 21% inhalation, 5% viewing the objects (especially dinosaur reconstructions). Only 5% of people also mentioned learning and obtaining information from descriptions next to the exhibits, and 2% of people indicated cycling.
- The brine graduation tower was considered the most attractive facility at the GEOsfera (as many as 93% of respondents considered this facility as exceptionally attractive). The sensory garden was second (45%). In turn, 33% of people found the dinosaur reconstructions very appealing, 23% mentioned the bonfire place, and only 15% came to visit to see the calamine plants. The playground was mentioned in a few answers.
- Almost half, i.e. 44% of the respondents, declared that they spent 31-60 minutes at the GEOsfera, while 25% spent 61–120 minutes, 23% spent over two hours, and only 8% spent no more than 30 minutes at GEOsfera.
- Over 92% of respondents recognise the recreational role of the GEOsfera, which is in line with the most frequently declared purpose of visits to the GEOsfera – walking and leisure. Interestingly, the educational role was in second place (81%), although only 22% of respondents declared education as the purpose of their visit. This points to the fact that the educational role of the GEOsfera is widely recognised, but it can be better utilised to build the potential of the GEOsfera as geoproduct. As many as 71% of respondents believe that the GEOsfera effectively promotes the region, and 42% see its contribution to environmental protection. The health role was also emphasised, i.e. supporting the healing process for patients (2%).
- 81% of respondents declared they were satisfied with their visit to GEOsfera, 15% were not fully satisfied, and 4% were undecided on the matter.
- In the surveyed group, 37% of respondents believe GEOsfera could benefit from a number of improvements, and the suggestions were as follows: four people pointed to the lack of places to eat, two people did not like the gravel paths, two visitors indicated the need to take better care of the vegetation, and another two recommended building a fountain. Some expressed the need for more activities for children, including multimedia. Some pointed out that the area could be cleaner or that the dinosaur models could be bigger.
- More than half of the respondents (56%) visited the GEOsfera with their families, 26% came with friends, and 16% with a partner. 5% visited the GEOsfera on a school trip, and 4% came alone. The results show that the GEOsfera is a family establishment. This is important in the context of possible changes that may be introduced (e.g. making it more attractive to children).

In general, the GEOsfera is viewed positively by visitors. However, knowledge about the GEOsfera is distributed mainly through word of mouth, less so through the media. This indicates the need for better publicity at the centre. Some aspects of the GEOsfera, when defined as a geoproduct, are noticed and perceived as important by visitors, especially

its educational role. Several hypotheses can be made about this state of affairs. One of them is the low appeal of educational objects, which was indicated by respondents in the open question. A significant number of respondents (42%) noticed the environmental protection role, which is extremely important from the point of view designing a geoproduct. Perhaps the environmental role was not emphasised strongly enough by the exhibits and their descriptions in the park. A facility of great importance for the GEOsfera is the brine graduation tower, which draws visitors who are not interested in geology, nature or the educational offer of the Centre, but in improving their health.

GEOsfera as a geoproduct. In light of the definition of a geoproducts proposed by Dryglas & Miśkiewicz (2014), the GEOsfera in Jaworzno offers its visitors numerous geo-attractions, which are geoproducts. The facility hosts mineral exchanges that fall under the "events" category. There are also "facilities" on the site: a lapidarium, a graduation tower, a sensory garden and reconstructed mining facilities. It is important to remember that the Centre itself used to be a mining facility. In the "services" category, geoeducation is at the top of the list. Moreover, the GEOsfera offers more complex geoproducts: recreational games such as Geocaching and educational trails.

After analysing the GEOsfera Centre in terms of the definition of a geoproduct adopted for the purposes of this work, it was established that the GEOsfera fulfils all the requirements to be categorized as such. This is achieved thanks to:

- the development of the area for the purposes of tourism and education protecting the geological heritage of the region;
- promotional activities provide publicity for the region and its heritage;
- exhibitions, events and educational trails at the GEOsfera fulfil its educational role;
- thanks to its aesthetic merits and facilities such as the graduation tower, the GEOsfera is developing its commercial and geotouristic potential;
- the growing number of visitors (only 40% are not residents of Jaworzno) proves the need for such facilities;
- the commercial aspect resulting from the definition of a geoproduct is not fully realised at the GEOsfera. Rather it relies on the durability of the project, as part of which the GEOsfera was created.

## Recommendations and summary

The GEOsfera Ecological and Geological Education Centre in Jaworzno meets the criteria of a geoproduct, meaning that it fulfills both the aesthetic and didactic expectations and is of value to the citizens of Jaworzno and tourists.

However, in order to strengthen its rank, it is worth considering:

- increasing the number and visibility of signs indicating the location of the GEOsfera;
- taking into account the presence of disabled people – e.g. modifying fragments of gravel paths that make it difficult to move around on bikes or wheelchairs;
- better display of fossils and *Nothosaurus* models (Fig. 6), whose information boards should be larger and in a more visible places.


Fig. 6. *Nothosaurus* models at GEOsfera. Photo E. Sierka

The centre, despite the huge local and even national potential (as evidenced by the top award of the Ministry of the Environment "Geology 2018") and the multiple elements that emerged during and after its exploitation, does not meet the criteria of being a geopark. The Jaworzno facility rather fits into the idea of geosites (Chybiorz *et al.*, 2015) and is included in the Central Register of Geosites run by the PGI-NRI (Polish Geological Institute – National Research Institute).

The GEOsfera as a cultural and ecological institution appears to be a well-run project, created thanks to people involved in strengthening the tourist appeal of the local natural environment. A product has been created that is a family-friendly, allowing for better contact with nature, surrounded by the remains of a historic quarry with geological formations. It is also a very important area for the integration of Jaworzno residents.

## Acknowledgments

The authors of this paper would like to thank:

Mrs. Agnieszka Chećko, director of the Centre for Ecological and Geological Education GEOsfera in Jaworzno, and Mr. Paweł Woźniak from PGI-NRI Sosnowiec Branch, for consultations and substantive support.

The project was realised as a part of the module for finding solutions to heterogeneous problems and was financed by the College of Individual Interdisciplinary Studies of the University of Silesia in Katowice in 2019.

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