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Acta Geoturistica volume 9 (2018), number 1, **1-8**
doi: 10.1515/agta-2018-0001

Stone in architecture and sculpture – source material for reconstruction

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ABSTRACT
Stone is the oldest, natural material, which was (and still is) used as both building and sculptural material. The most commonly used for these purposes are: granites, marbles, limestones and sandstones, representing the three main genetic groups of igneous, metamorphic and sedimentary rocks. All of them are permanently being destroyed in result as well of natural weathering as microbiological activity and anthropogenic pollution of atmosphere, known as deterioration. The speed of such decay depends on both environmental conditions and mineral composition of the stone and it can lead to such intensive destruction that conservation may require partial replacement. Smaller damages are refilled with appropriate mineral masses, whereas in case of bigger damages refilling with natural stone is necessary. Professional conservation practice demands the selection and use of the same rock or the rock that is, in so far as is possible, identical to that originally used. It can be done only after previous detailed petrographical studies of the original material. Only then the stone material used for reconstruction will be appropriate and stonework performed properly will not (or almost not) leave marks. In many cases the ancient quarries do not exist and original source material is not available. Then petrographical studies of numerous rock-samples, which are recently available from other existing and/or working quarries, will allow the indication the most similar material. In many cases, unfortunately, the stone used for replacement is not identical to the original but only macroscopically similar. In such a case results might be visible sooner or later. These will be differences in colour, differences in structure and in some cases even crystallization of secondary minerals in the newly inserted fragments.

Keywords: stone, architecture, sculpture, deterioration, petrography, reconstruction.

INTRODUCTION

Stone is a natural material accompanying a man since the dawn of time. In different climatic zones, people lived in caves which are natural karst formations developing in some types of rocks; and where there were no caves, people hid under great rock masses or overhangs. Later on, they collected loose rock debris and used it as a building material for different walls and simple habitable structures. What is more, appropriately processed fragments of some types of stone were materials used to produce simple tools and weapons. And this has not changed in many places all around the world. Apart from its protective and utility applications, stone was also used for decorative purposes which is best proven by not only various design elements but also, and most of all, numerous sculptures originating from different periods of the history.

Although stone in general is relatively durable material, its different types are characterised with different reactions to weather conditions, undergoing more or less advanced destruction over time. The most often, sharp edges become blunt and all tiny details fade away so that artistic expression is gradually dying away. Stone features located within great urban and industrial areas are especially exposed to destructive conditions, where natural weathering processes are intensified with the impact of deterioration related to anthropogenic pollution of atmosphere and poor ventilation of urban areas. The modern conservation techniques enable one to stop further destructive processes; however, in some cases, visible destructions require refilling in order to restore a sculpture or architectural structure to its original state (this also concerns mechanical damages). In this case one should aim at obtaining such a stone material which will not differ from the original material of the reconstructed feature, and the close petrographical analysis proves to be very useful here.

TYPE OF STONE

With regard to its durability and weather resistance, the best stone material is a vast group of crystalline rocks, commonly known as "granites" when, in fact, it includes igneous rocks of different mineral compositions, starting with gabbro and diorite, through tonalite, monzodiorite and syenite, and ending with proper granite. All these are hard rocks with a wide range of colours, from black to white, through all shades of brown, red, yellow and even green and blue. Their mineral composition is various and their chemical structure is dependent on proportional content of such major minerals as quartz (SiO_2), potassium-feldspar ($KAlSi_3O_8$) and plagioclase (a continuous series of minerals from sodium albite $NaAlSi_3O_8$ to calcium anorthite $CaAl_2Si_2O_8$). Furthermore, in relation to technical and chemical parameters, of considerable significance is the percentage of other rock-forming minerals as pyroxenes, amphibole and micas which are chemically complex iron and magnesium alluminumsilicate. The universal character of this vast group stems from their crystal structure and relatively high hardness (Lorenc, 2004; Lorenc & Mazurek, 2007).

The group with the commercial name of "granites" often includes equally nice, hard and crystalline rocks of totally different origin. The most often, these are different types of gneiss and some quartzites which are metamorphic rocks formed as the result of mineral, structure and texture transformations of, among others, sandstone and granite.

A second group of rocks widely applied in architecture and arts are sandstones which occur in equally wide range of colours as in the case of the above-mentioned "granites". These are rocks of sedimentary origin, composed of single grains of sand joined with mineral binding material which composition determines the basic physical qualities of these rocks. If the binding material is silica (SiO_2), these types of sandstones are the most durable and weather resistant. There are also sandstones of calcite ($CaCO_3$) or clay matrix which have relatively low chemical resistance; thus, rarely used in the stone industry. Apart from quartz sandstones of silica matrix, other types are quite susceptible to weathering and deterioration. The details concerning a type of sandstones' grain framework and binding material may be determined only during petrographical analysis. It should be emphasised that all sandstones are porous rocks which makes them absorbents of water and moisture - the major factors facilitating decomposition and/or disintegration of a stone.

Commonly used stone materials are carbonate rocks which, with regard to their genetics, represent two completely different groups. One of them are limestones which are sedimentary rocks of organic or chemical origin, almost entirely composed of calcium carbonate ($CaCO_3$). Here, this mineral does not have a crystal structure. The other group includes marbles of metamorphic origin, coming from limestones transformed in high pressure and temperature conditions. Here, calcium carbonate takes a crystal form and this causes that a stone has slightly different physical properties than a limestone. A disadvantage of all carbonate rocks is the fact that, as practically monomineralic rocks (composed almost exclusively of calcite), they are much softer in comparison with granites and sandstones.

DETERIORATION

Airborne aggressive dusts and gases cause considerable damages to stone features, especially, in a poorly ventilated compact urban development. Sulphur dioxide (SO_2) and nitric oxides (NO_x), mostly anthropogenic, are especially dangerous in this scope, which, when joined with water vapour, transform into very aggressive acids. Reaction with some rock minerals, especially those of porous nature, results in the acids causing crystallization of new salts changing the chemical composition, technical parameters and appearance of a stone to a great extent. In the case of some salts, a significant role is played by their force of crystallization having a mechanical impact on the rocks, that is, similarly to water in the process of freezing, causing bursting and crumbling of a stone while growing in volume. One should also bear in mind that porous and cracked surfaces of rocks are much more susceptible to destructive forces than smooth surfaces.

External indications of aggressive substances' influence on stone products are various. In the case of dark types of limestones, these are, the most often, discolorations, and in the case of multicoloured types – changes in colour contrast. In all rocks containing calcium carbonate, one may observe a quite common crystallization of gypsum efflorescence. This process has influence not only on the appearance but also internal structure of a rock due to rinsing calcium carbonate ($CaCO_3$) out from a binding agent and replacing it with insoluble gypsum ($CaSO_4$ x $2H_2O$).

What is more, rock materials undergo destruction because of bacteria, algae, lichens and fungi, that is the process of biodeterioration. One of the metabolism products of these microorganisms are organic acids which, in reaction with some minerals, cause precipitation of new salts, depending on the rock porosity, even 2-3 cm deep under an external surface. Other indications of stone destruction as the result of the influence of microorganisms are changes in original colouring, and new colourful stain and discoloration. Another indications of biodeterioration is stone spalling and dilapidating due to fungous activity (Lorenc, 2003; Lorenc & Mazurek, 2007). Methods of stone conservation in order to protect it against further destruction have long been applied and the details concerning these activities may be found in many reference books (among others, Haber et al., 1988; Domasłowski, 2011; Wilczyńska-Michalik & Michalik, 1995; Pavia & Bolton, 2000; 2001; Rembiś & Smoleńska, 2008).

STONE SELECTION

Degradation, weathering and deterioration often cause such considerable stone cavities that conservation requires application of proper refilling. Similar requirements concern features damaged mechanically for different reasons. Small cavities are refilled with relevant mineral pulps, while in the case of bigger damages, natural stone replacement is the only solution. Scrutinising the stone historic monuments, both architectural structures and sculptures, enables one to notice that, in some cases, the former renovation works were limited to refilling the cavity with cement or well-fitted fragment of a stone but only resembling the original. After a while, this kind of action results in different colouring and structure of the fillers which obviously reduces aesthetic value of the feature (Fig. 1). In some cases, if the fragments were stones of only similar colour but different mineral composition, less weather-resistant than the original stone, after several years they will differ in, for instance, the presence of secondary mineral crystallization (Fig. 2).

Fig. 1 The application of improper kind of sandstone

Fig. 2 The application of improper kind of sandstone

Undoubtedly, the best solution is selection of such a stone which will be as similar to the original as possible; and when there is such a possibility, using exactly the same stone (Figs. 3, 4). Although it is often impossible for different reasons, the possibility is always worth verifying (Lorenc, 2005; 2014).

In all above-mentioned groups of stones, there are macroscopically similar types; however, the hidden catch is that these are often very different rocks with regard to their genetics. In this case, visual similarity is very delusive - mineral (chemical) compositions of these rocks are so different that a possible refilling with the use of this material will come into play after a while with a clear distinction. In order to rule out such a mistake, first of all, one should conduct detailed analysis. Selecting a proper stone is only possible following the close petrographical analysis - both macro- and microscopic - enabling one to unequivocally determine a type of stone used to refill the cavity. In this case, the general determination of type of rock is insufficient as granites, marbles, limestones or sandstones may have extremely diverse mineral composition (Figs. 5-8). Their structures and colours may also differ. Many sandstones are similar to each other with regard to their macroscopic features, have similar grain size distribution and, especially, colours. Only the thorough petrographic analysis, apart from the type of a rock, enables one to determine the kind and type of grain framework and a nature of binding material. These are the factors determining crucial qualities of a stone as: hardness, abrasiveness, porosity, absorbability etc. that is resistance to aggressive chemical factors.

Fig. 3 The application of a proper kind of limestone

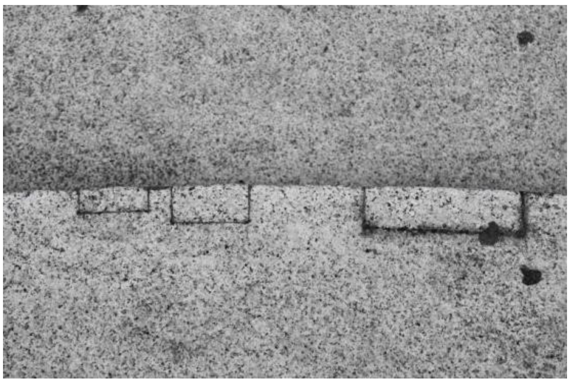

Fig. 4 The application of proper kind of granite

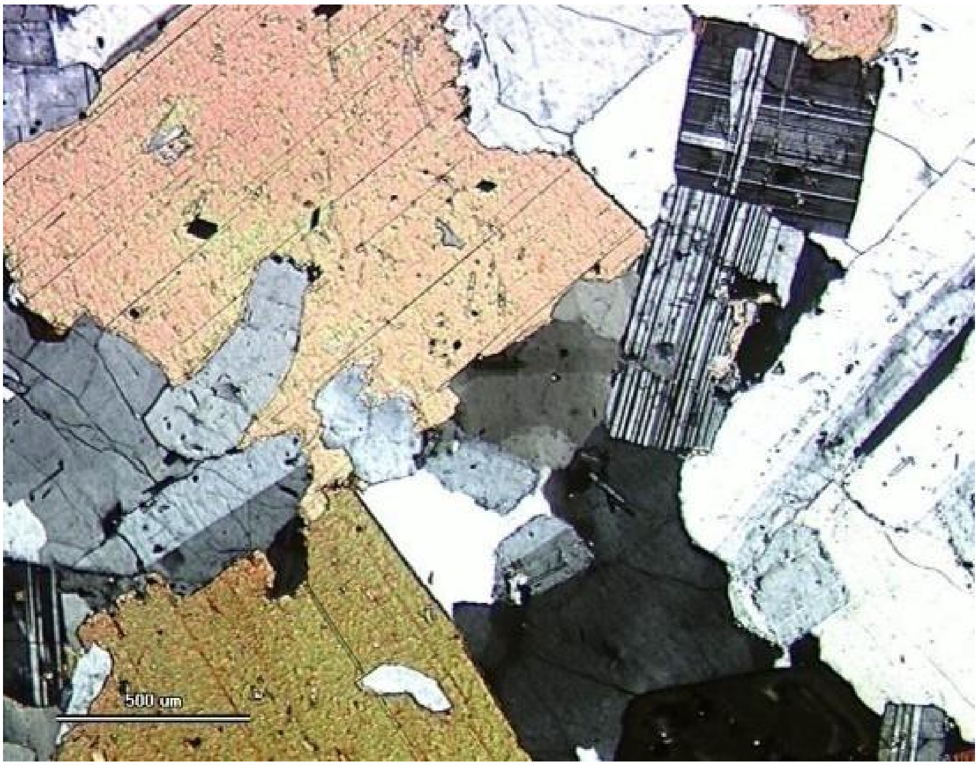

Fig. 5 The structure of granite. Polarized light, bar. 0.1 mm

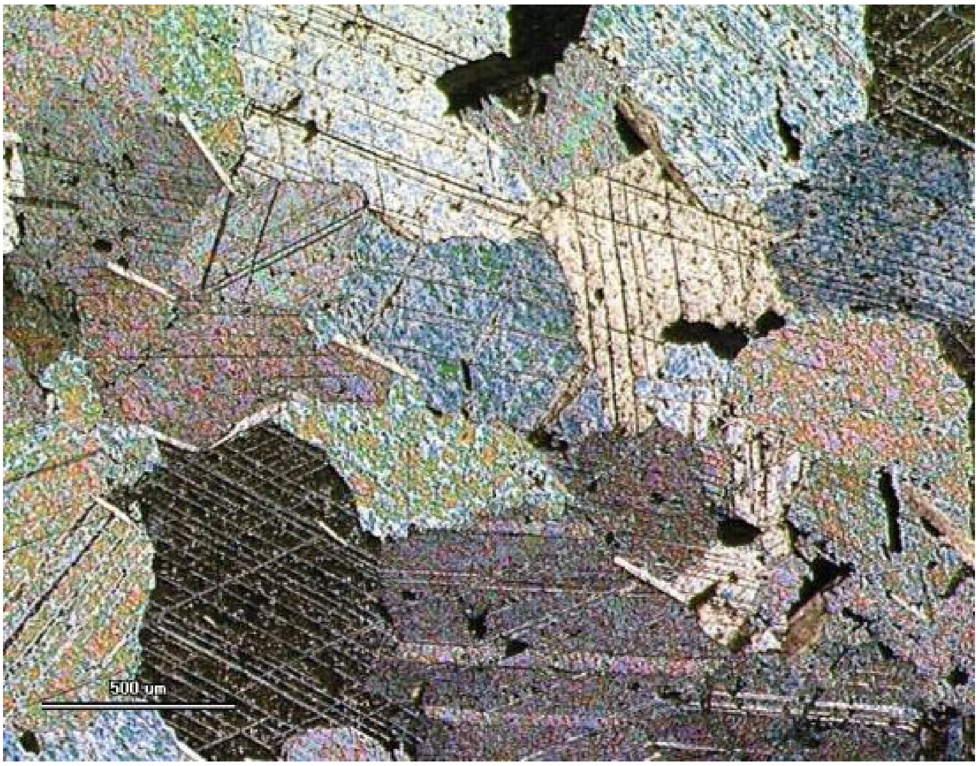

Fig. 6 The structure of marble. Polarized light, bar. 0.1 mm

The mineral composition of the particular types of rocks constitutes their distinctive feature, often specific for a particular type of mineral extracted in a specific place. In some cases, a detailed petrographical study enables one to show a deposit or even

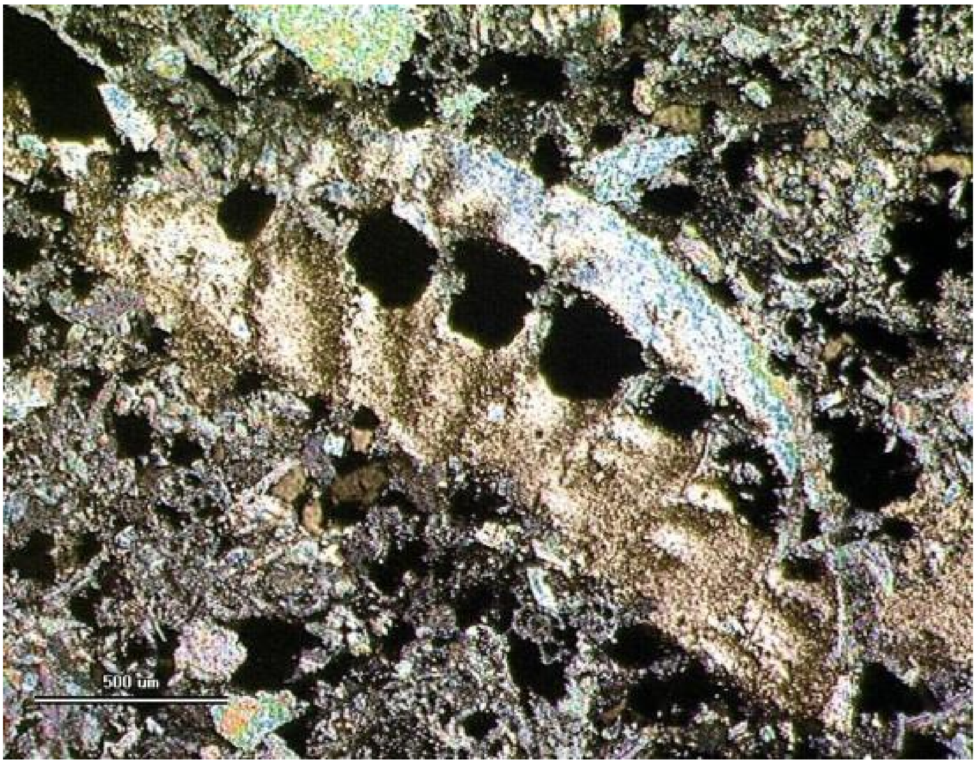

Fig. 7 The structure of limestone. Polarized light, bar. 0.1 mm

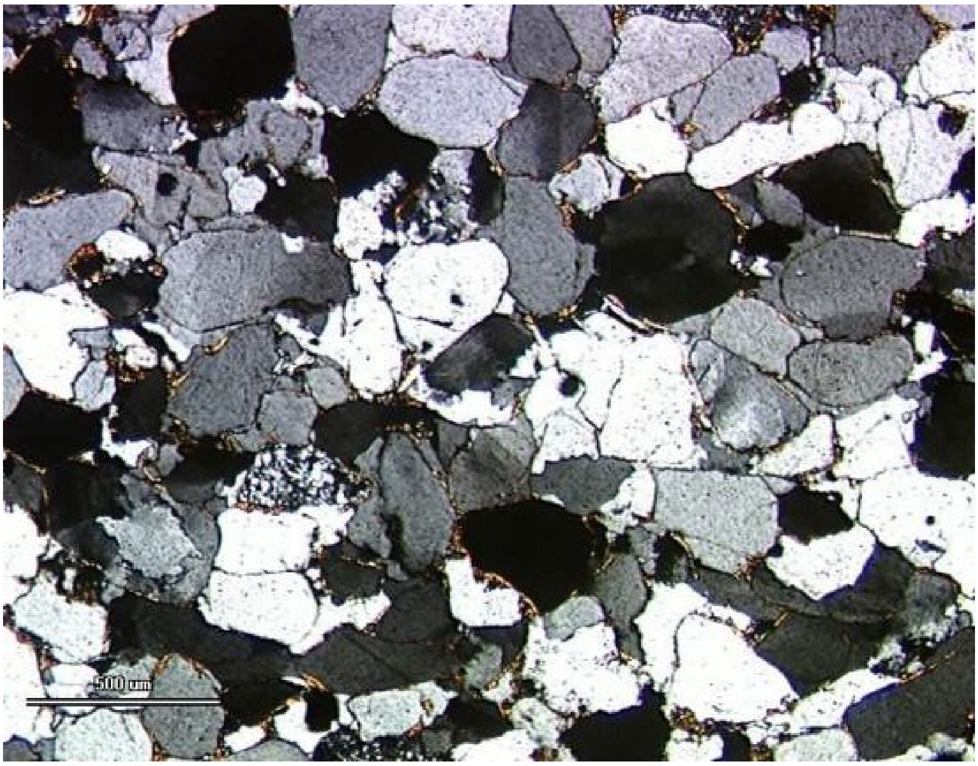

Fig. 8 The structure of sandstone. Polarized light, bar. 0.1 mm

quarry from which the material for a reconstructed feature originated. If the material is properly and unequivocally identified than the access to the "source" is conditioned only by its physical existence. In this case, stone material extracted for refilling or reconstructing will be the best possible. In the case of impossibility of finding the original, historic quarry, one should match a type of stone which would be the most similar to the original with regard to qualitative and quantitative mineral composition as well as structure and colour. Only then, the proper stonework will not leave a visible trace or this trace will be inconsiderable and doing no harm to the feature.

The procedure should be as follows: if there is documentation of the feature unequivocally indicating its material than the petrographical analysis is not necessary; the material for refilling is extracted from the place mentioned in the documentation. However, if there is no documentation or no mention of the source material, in order to identify the material used to make a historic monument requiring reconstruction, one should take a sample from the feature and prepare a microscopic thin-section which would be the basis for the above-mentioned petrographical analysis. The remaining part of the sample will be used for macroscopic structural descriptions. The result of such analysis enable one to correlate the stone material used to build a certain feature with a proper comparative source material existing in the database or extracted in the field. If necessary, scanning is done with the use of an electron microscope to reveal and determine changes in the structure of the analysed stones, the existence of neogenic phases as well as qualitative and quantitative changes in their chemical composition. These analyses enable one to determine the state of preservation of stone sample extracted from the feature and the possible existence of secondary products occurring as the result of the reaction of rock's original mineral substance with aggressive components of polluted atmosphere or organic components. Synthesis of data obtained at the particular stages of petrographical analyses of the sample taken from the investigated historic monument will enable one to determine its condition as well as intensity and level of its damage (Lorenc, 2005; 2009).

CONCLUSIONS

While it is true that the above-mentioned procedure of analysis is quite arduous, it may lead one to finding and obtaining the original material used to create a reconstructed stone historic monument. The alternative here is selection of material at least the most similar to the original. Incomplete satisfaction, even in the case of identifying the historic quarry from which the original stone material has been derived, most often results from the fact that qualitative changes in stone occurring over time are different in a historic monument most often located in a city, compared to a monolithic wall of a quarry located in the natural environment, often away from a specific urban atmosphere. A material properly selected for reconstruction remains unnoticed in the reconstructed feature with regard to quality, only with a shape of used filler visible. In the case of selecting the material only on the basis of colour, with no petrographical study, the negative effects will appear over time resulting, among others, from different level of weather resistance of the original and the filler. In the case of reconstructing features made of porous stones, one has to clean a monument before refilling and apply proper protection of moisture (hydrofobization) after the required reconstructions. Only then, the colour of the monument and refilled fragments will remain similar for a long time and the reconstruction will be discrete.

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Acta Geoturistica volume 9 (2018), number 1, **9-22**
doi: 10.1515/agta-2018-0002

Geotourism and Mining Heritage: a Potential Gold Mine for Central Nigeria

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ABSTRACT
The potential for geotourism and mining heritage of some landscapes in parts of Kaduna, Plateau, Nasarawa and Kwara states in central Nigeria were studied and compiled. The result show that geological endowments range from insalbergs, flood basalts and dome structures, which presents natural landscape for tourism. The quartzite ridges of the Oreke area in Ilorin host the Owu Falls of 120m cascading waters, the Kafanchan flood basalts that flowed extensively from the Kagoro hills with extensive columnar jointing creating the prestigious water falls of over 30m all present versed potential for geotourism. Mining activity around the Jos Plateau (Bassa, Jos, Bukuru, Barakin Ladi and Bokkos areas), southern Kaduna (Godogodo and Jagindi) create landscapes that if properly beautified can become tourist landmarks. Adopting and harnessing these landscapes can boost and provide alternative revenue for the affected central.

Keywords: geotourism, mining heritage, potential, development, central Nigeria.

INTRODUCTION

Geotourism, with proper management has been fingered as a powerful tool for sustainable development (Newsome et al., 2012). Traditionally it has been seen as a form of tourism which is principally exploiting geological attributes. Increasingly, wider definitions has been included to cover archeological, educational and more recently for economic purposes. The interest in this now established field has increased around the world (see e.g. Dowling, 2011; Hose, 2012; Newsome & Dowling, 2010). Ngwira, (2015) identified Geotourism and Geoparks in Africa as having Prospects for Sustainable Rural Development and Poverty Alleviation.

Nigeria is the populous nation in Africa with a human population of at least 160 million. It is located in equatorial west Africa with versed arable land which prior to the discovery of oil in the 1940s was largely dependent on Agriculture and solid mineral resources both for local and export earnings. Nigeria over decades has been driving her tourism potentials as an alternative revenue earner. This has made the Tourism Board to identify five major gateways in order to drive this all important sector (Fig. 1). These gateways were identified based on factors like existing airports and sea ports to serve as transport routes as well as population.

The Sahara gateway is exploiting the Kano airport as well as the proximity to land boarder cultural prospects from Niger and other Sahara trade routes. The Atlantic and Southeast gateways are to depend on the availability of seaports as major promoting determinants. The Abuja gateway is the capital city stimulant because of the traffic into the fast developing Federal Capital, while the Scenic Cluster depends heavily on the natural scenic endowments of the belt such as the highest spot heights in the country, tin mining and the cold climatic conditions.

The scenic cluster therefore strictly speaking is the geotourism niche of the country because of its geological

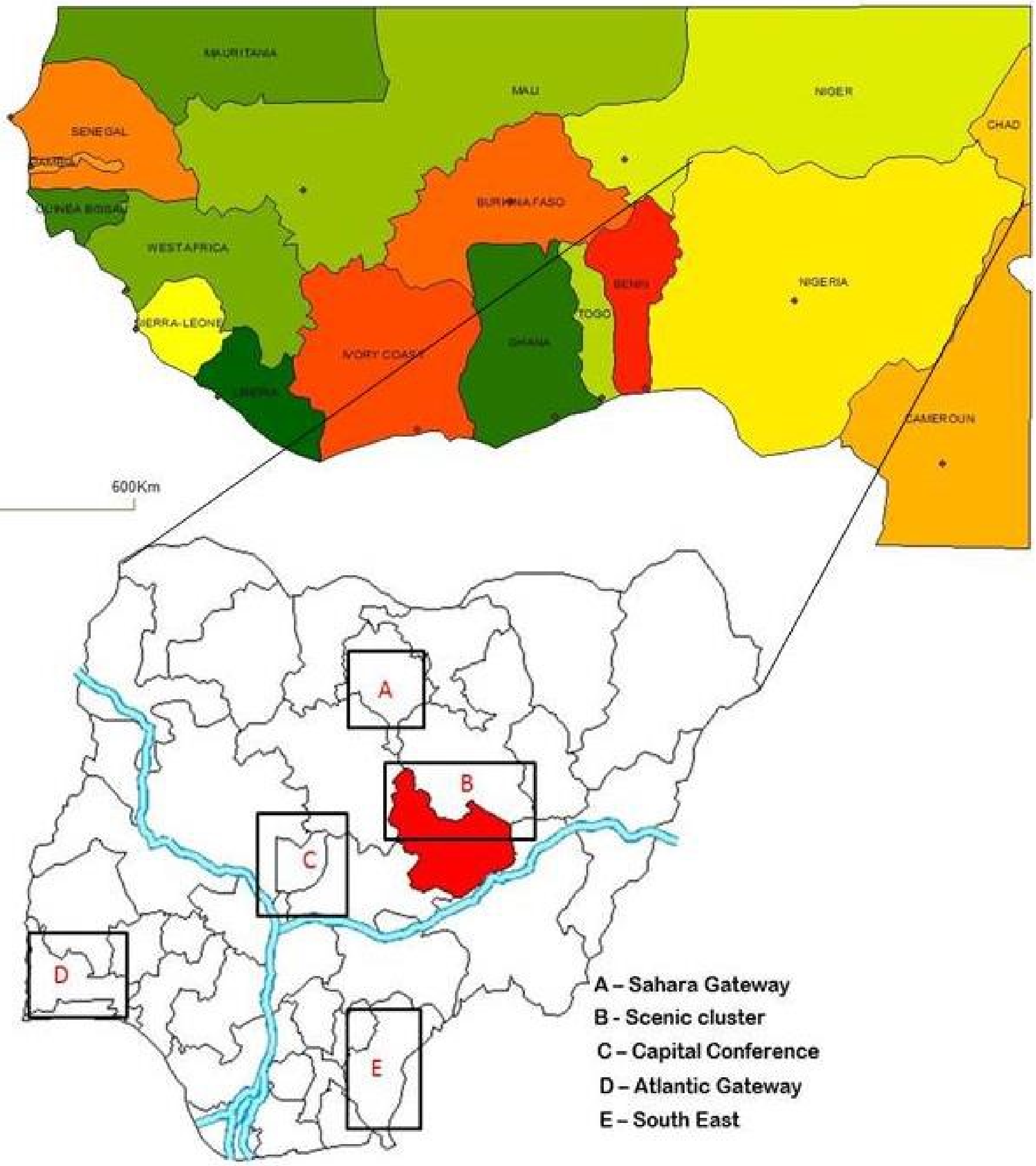

Fig. 1 Map of Nigeria showing the tourism clusters, location of Plateau state an in set West Africa (Goki at al., 2016)

endowments. The Central Nigerian Belt (Fig. 2) coincides with the Rivers Benue and Niger with a scenic confluence in Lokoja, the very first capital of Nigeria, itself another geotourist landmark feature.

These river basins therefore provided the requisite depressions into which most of the upland areas that transcends the valleys flow into justifying the location of waterfalls stretching from Farin Ruwa Falls (Wamba), arguably the highest in west Africa; the Kurra and Assop falls all of which are falling from the Upland rocks of the Jos Plateau. Other examples on the Plateau have been reported by Ogezi et al. (2010) and Iyakwari and Lar (2012). Then to the Owu Falls in Kwara State.

Central Nigeria is therefore a stretch endowed with extensive geosites.

MATERIALS AND METHODS

This work is a preliminary compilation of all the geosites and mining heritage sites in central Nigeria. The work involves visiting and snapping the sites, assessing the accessibility to such sites and subsequently compiling the investment potentials in those areas as well as watching the possibility of

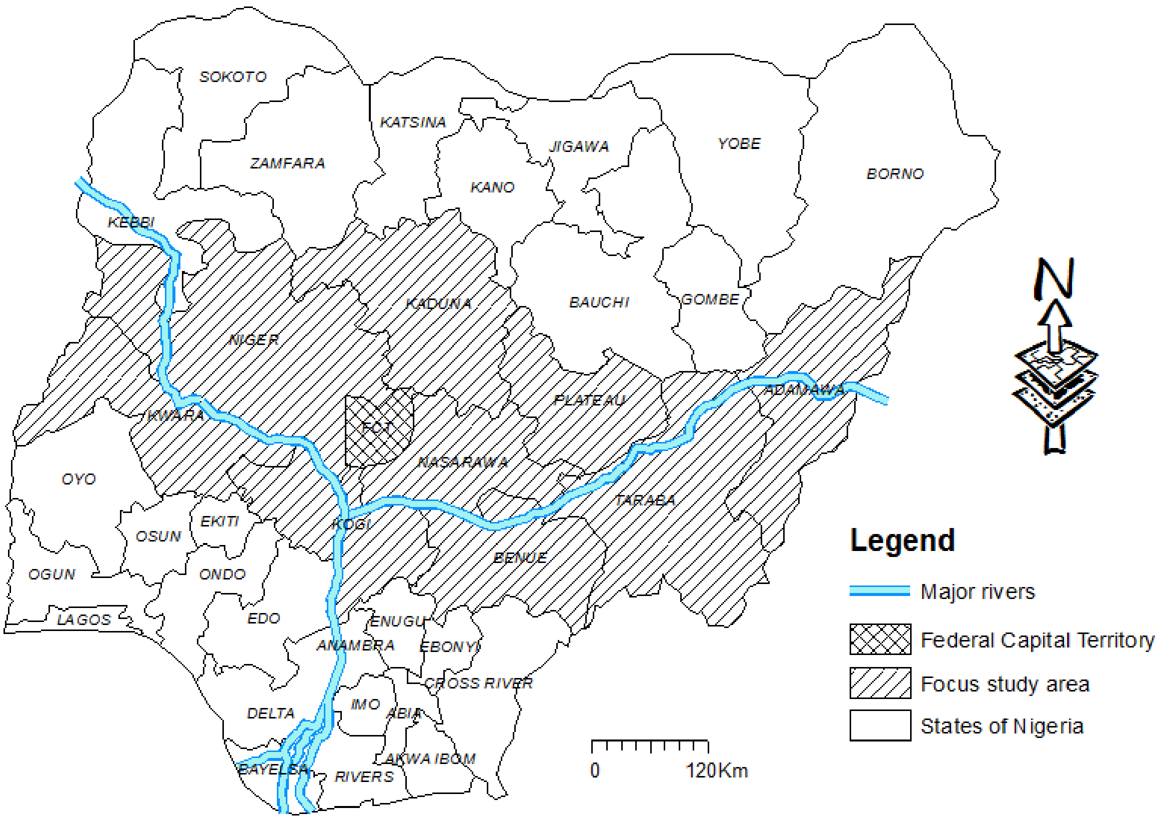

Fig. 2 Map of Nigeria showing the central Nigerian area – the study focus

revenue generation for the local as well as national economies as an alternative for revenue generation in a challenged economy like Nigeria. Some of these geosites have been reported by other others (Ogezi et al., 2010), but this paper attempts to expand their coverage over a wider belt of central Nigeria.

RESULTS

Figure 3 gives a generalized map which at the present scale cannot capture all, but some of the major geosites and mining heritage sites. They range from falls in Kwara, Kaduna, Plateau and Nasarawa states as the first categories. It will suffice to say that depending on accessibility and size, some are more developed than the others. However, such descriptions are relative because generally, those geosites have the capacity to attract other facilities like camps, resorts and hotels. The geosite size in itself may not be the determinant but a stimulator.

Water Falls

Beautiful water Falls are also abundant and a few have been presented (Figure 4, 5, 6) including those that have not been presented such the Farin Ruwa Falls Wamba (Fig. 2).

The Kafanchan falls (Fig. 4) represents a water fall plunging some twenty meters over extensive basalt flows stretching for some tens of kilometres through the sleepy central Nigerian town that boarder the south-western Plateau Younger Granites hosted historical tin fields. The flood basalts themselves display columnar jointing which provides geological attraction for holiday makers.

The recreational ecstasy provided by the dissected quartzite ridge which forms part of an extensive Okegbala – Oreke quartzite ridge exposed at different road cuts at both the Lokoja north-eastern exit and the south-eastern exit respectively, exposing its anticlinoral axial planes. This regional

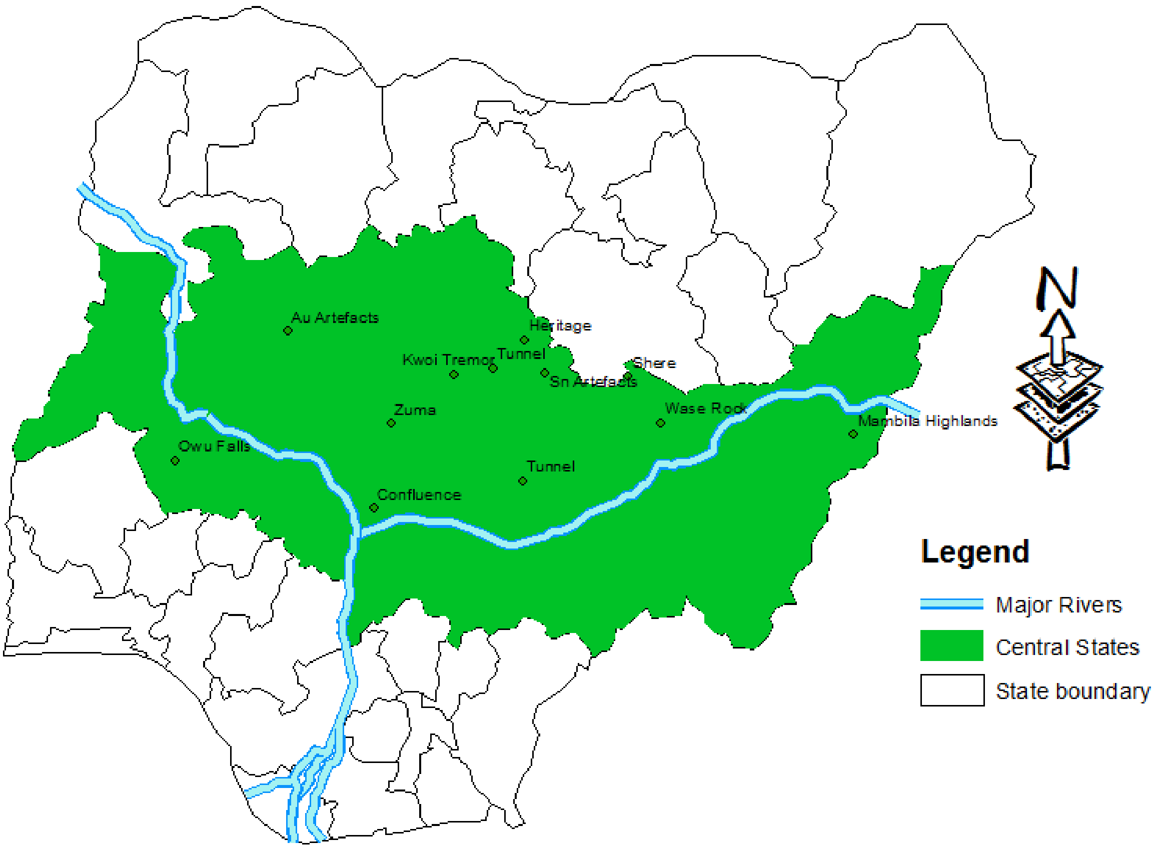

Fig. 3 Map of Nigeria showing some major landscape geosites in central Nigeria

Fig. 4 Falls over the basalt flows of Kafanchan

structure created the over 120m high Owu Falls (Fig. 5). The three-step cascading waters has been a major attraction with attempts made by the Kwara State Tourism Board to make it a tourism landmark.

Fig. 5 Owu Falls Kwara State, a 120 m cascading water fall over the Oreke quartzite ridge.

The Kurra falls (Fig. 6) with elevation of about 1150 m above sea level located some 77 km southeast of Jos is ideal for recreational activities such as boating, rock climbing and picnics.

Rock and Hill Attraction

The next category is geological in nature. Here, the main attraction stem from high landscape that are mainly used for mountain climbing, geological fieldwork and the scenic ecstasy that they give tourists.

The Wase hill (Fig. 7) rises for nearly 150 m above its base with a monolithic structure and can be sighted 40km away. Continuous weathering led to a pile of rubble at its base. Caves within the plug which historically served as hiding place during war, now houses wild animals.

The beautifully arranged Riyom rock formation (Fig. 8) situated along the Jos Abuja road and which was historically used as a hiding place in ancient times is a beautiful landmark feature that is often celebrated among the Berom cultural group on the Plateau. The rocks, just like the Shere Hills (Fig. 9) forms part of the Nigerian tin-rich Younger Granite Complexes. The Shere Hills has been used for decades as a leadership training centre because of its height of 1 829 m, presumed to be the highest in the country.

Another major region with geotourist potential is the Pankshin Wulmi Hills (Fig. 10) which forms part of the Sara-Fier Younger Granite Complex. The area around these hills prides itself as the coolest region in Nigeria with historical records of mild snow falls in the past. Extensive hill chains with cable line rides abound in such scenic geomorphological terrain.

The Gahweng columnar Tertiary basalts (Fig. 11) which extends for several kilometres along the Bachit River in Riyom area with its distinctive and impressive straight sides and edges is another major geosite in central Nigeria. This can attract tourists in large numbers if properly developed.

The Jibang bridge (Fig. 12) abuts another extensive basalt flow sourced probably form the volcanic flows associated with the uplands of the Pankshin Hills. The bridge itself is one of the tallest in height and has attracted a lot of tourist attraction with a possibility of complimenting such a potential with the underlying basaltic base.

Mining Heritage sites

Extensive tin mining activity and other minerals have occurred over the century in this belt. Artefacts dot the landscape

Fig. 6 Kurra Falls in Riyom, south east of Jos, central Nigeria

Fig. 7 Wase rock (trachytic plug) with a dry season background with no beautification and landscaping

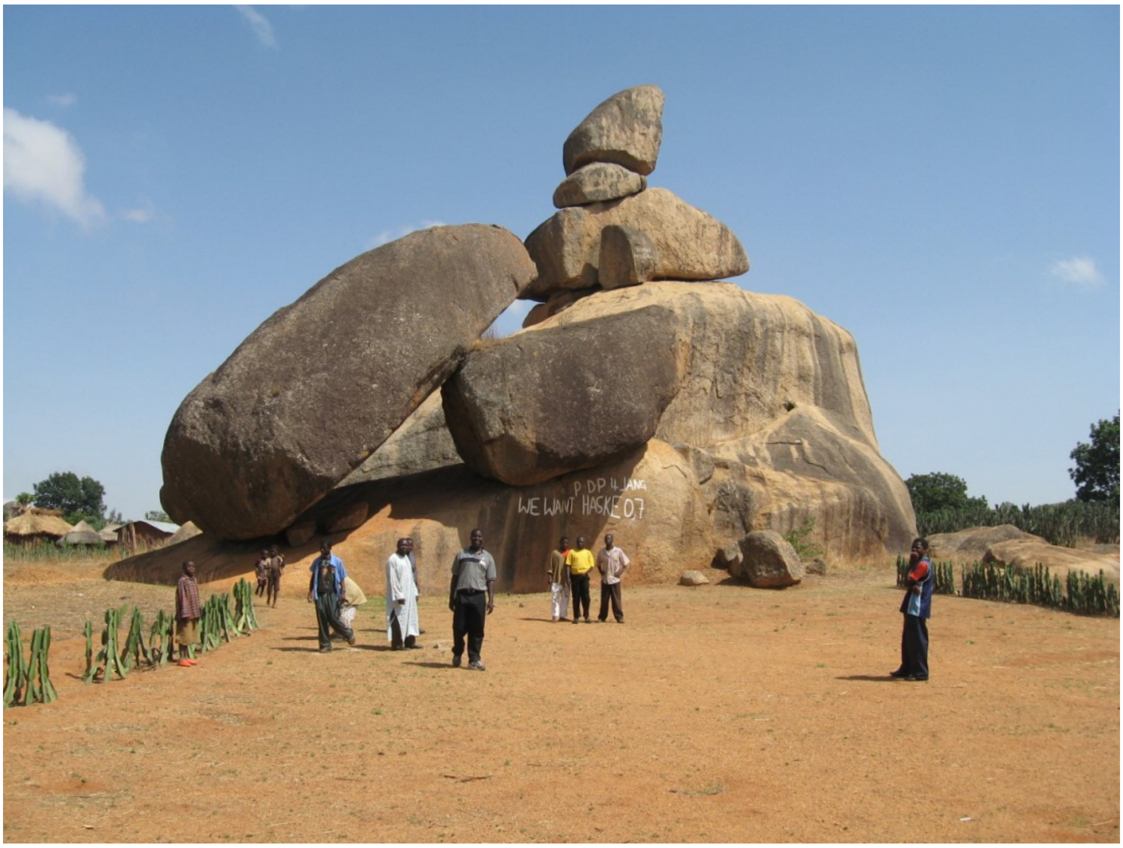

Fig. 8 Riyom rocks along the Abuja – Jos highway with a natural arrangement

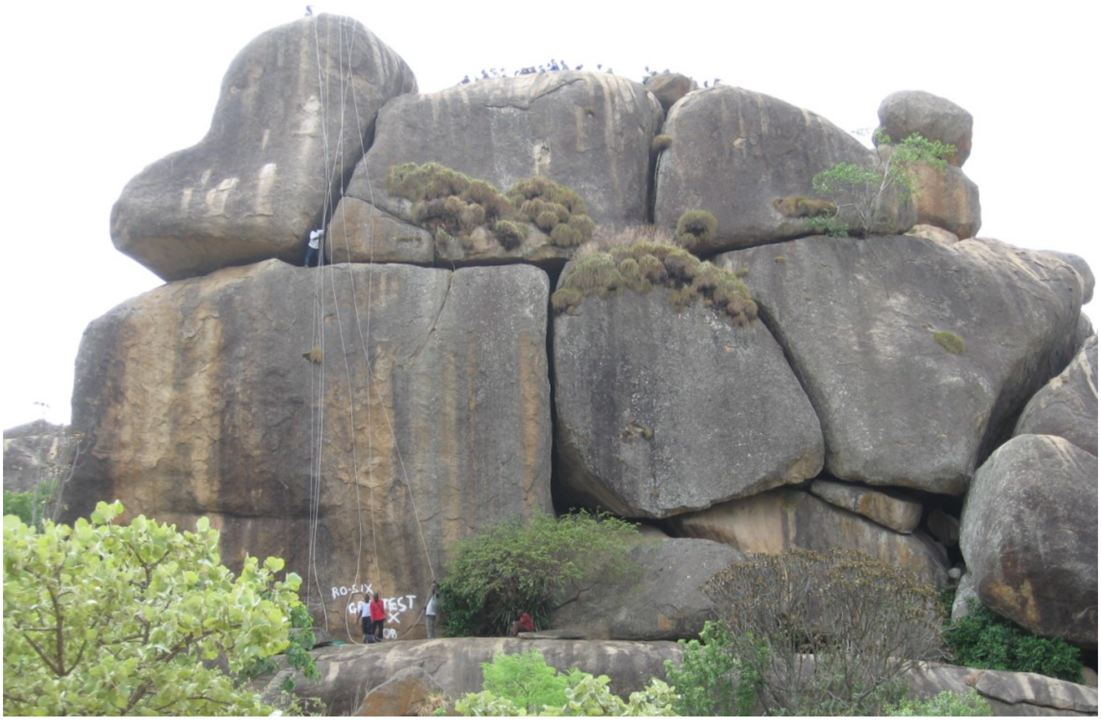

Fig. 9 Shere hill used as leadership training facility since the 1960s located east of Jos, central Nigeria

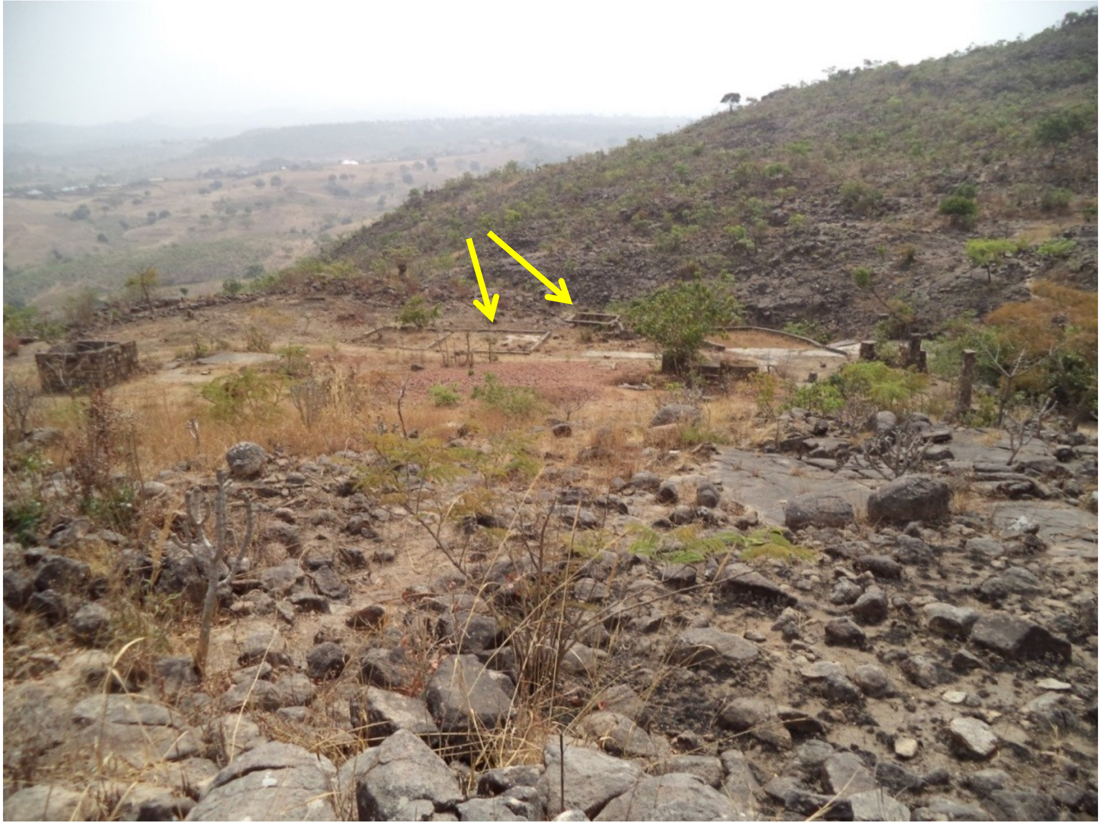

Fig. 10 Hilltop scenery of the Pankshin uplands designed for mountain climber's lovers (indicated by arrows)

Fig. 11 Gahweng Columnar basalts, central Nigeria

Fig. 12 Jibang Bridge, Quan Pan abutting basalt flows from the Pankshin Hills Central Nigeria

ranging from equipment and other landmarks that present extensive history and which can be harnessed for tourism. Draglines in and around Jos mining town (Fig. 13), tunnels used by ancient miners (Figs. 14 - 17) whose history are gradually wearing out are abundant. It is difficult to completely isolate and develop such sites as observed by Conesa (2010), partly because urban development has caught up with mining areas, and partly because of the apathy created by the exploitative mining companies of the past thereby creating stiff opposition from present attempts to gain confidence of the indigenous local inhabitants.

Mining Ponds

The most visible evidence of mining in this region is the ponds (Figs. 18 and 19) now filled with water. So many are used for agricultural purposes while some are used for recreational purposes. So many of the ponds can be utilized for recreation without much hazards (Goki et al., 2016).

DISSCUSSION AND CONCLUSION

The geology of Nigeria trisects the country into three stable platforms with the largest in the north while the two other major upland areas form the cores of western and eastern Nigeria. Sandwiched between these platforms are the major drainage systems, River Niger to the west and Benue valley to the east. The connection in Lokoja of these river systems coincides with the E-W central region which geologically also stretches from the upper Benue, Middle Benue and the Nupe/Bida intracratonic troughs. These region has also been geopolitically coined North Central Nigeria, also referred to as middle belt by a group of people who have been geographically, ethno-politically and socio-economically yearning for identity.

In Nigeria, the sharing of resources is based on such parameters in addition to what that region brings to the national purse. Lately, there is even increasing call for true federalism where each region

Fig. 13 Dragline used dated near a century used by the early tin miners on the Plateau

Fig. 14 Tin mining Tunnel site in Godogodo, southern Kaduna

Fig. 15 Naturally stabilized abandoned molybdenite mined out shaft in Kigom Younger Granite Complex, Jos

Fig. 16 Step bench work for Tin mining since the early 19th century being destroyed by artisanal activity (Goki et al., 2016)

Fig. 17 Gold mining artefact from Niger central Nigeria

Fig. 18 Google image showing an example of mining ponds in one of the mining towns around the Jos Plateau

Fig. 19 A beautifully landscape pond by mining along Barkin Ladi – Bokkos road

controls its resources and only contributes a little percentage to the central government. These geotourist endowments are therefore a strong option in the present modern Nigerian context.

The trisect architecture of Nigeria is not only a stratigraphic classification but geomorphological strato-step down for most of the Falls in the country. The steep gradients provided by the anorogenic uplift that form the Jos Plateau and the domal uplifts of the Pan-African intrusions in the north, east and west of the country which also remotely influenced deformation of the sediments within these basins are also significant. This geological observation makes the middle belt to be very rich in terms of geosites. Even the mining activities in the states named are also direct consequences of alluvial mining activity that accumulates in the valleys adjoining the hills that boarder the escarpments. Southern Kaduna and Nasarawa mining and heritage sites are as a result of mining of alluvial tin sourced from the Plateau area.

The authors believe that central Nigeria, if well explored for geosites as alternative sustainable development venture is a potential gold mine.

Additionally, this cosmopolitan belt has been populated by immigrants from other regions of Nigeria, western Africa and Europe because of the mining history at the turn of the century, including early colonial explorers and missionaries both from the West and the Arabs through the trans-Saharan trade routes. Hospitality therefore is not a major challenge. In fact, until recently, Jos Plateau State was the tourist Headquarters of Nigeria coupled with its cold climate prompting the now botched Super Eagles training camp in Kuru, a nearby suburban centre in Jos.

Even in religious history, this central region either houses the headquarters or was a founding centre for about ten well spread churches in Nigeria (ECWA, COCIN, ERCC, Winners Chapel to mention a few). The headquarters of the Nigerian Mining and Geosciences Society is in the same central Nigerian city of Jos (now gradually relocating to the central city of Abuja). The implications for this are that tourism which is usually an essential part of most conventions around this area will always not lack geotouristic patronage.

It is the opinion of the authors that central Nigeria holds great potential for geotourism and some form of mining heritage.

Geotourism for sustainable development of this region is achievable and can therefore be pursued.

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Acta Geoturistica volume 9 (2018), number 1, **23-29**
doi: 10.1515/agta-2018-0003

Geological Tourism Development In The Finnish-Russian Borderland: The Case Of The Cross-Border Geological Route "Mining Road"

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ABSTRACT
The Finnish-Russian borderland has a unique geological potential for geological tourism development. Creating new tourist attractions based on geoheritage, design and development of the cross-border tourist routes open new opportunities for tourism development on both sides of the border. The article presents the cross-border geological tourist route "Mining Road" as a tool of activation of tourist activity in the Finnish-Russian borderland. This article explores the practical aspects of the project "Mining Road" development for tourism industry. It is proven the significance of cross-border route "Mining road" for preservation, popularization and reproduction of the natural, cultural and historical potential of the borderland.

Keywords: geotourism, cross-border geological route, "Mining Road", Finland, Republic of Karelia.

INTRODUCTION

With the growing significance of environment protection and sustainable development the geological tourism is considered as a new perspective direction of the nature based tourism which can contribute to geoheritage conservation and stimulate the economic activities in the regions (Dowling, 2010; Dowling, 2013; Hose et al., 2011). The importance of creating a new tourist centers and development of the destinations is increasing in the conditions of competition between countries, regions and companies for tourists and investment. The geology provides wide opportunities for creating new tourist attractions on its base. The borderland has a unique geographical position that gives an extra opportunity for the protection and promotion of the geological heritage within international cooperation in tourism sphere.

The relevance of our research is caused by two factors. On the one side, the Finnish-Russian borderland has unique geological resources which can be used not only in mining industry but also as a potential for regional development based on sustainable tourism development. On the other side, design and development of a cross-border tourist route increases opportunities for promotion of unique geoheritage of the territory, enhancing business activity along the route on both side of the border and cohesion tourist space of the border regions.

The aim of this paper is to present the geological tourist route "Mining road" as a tool of stimulating tourist activity for regional development in the Finnish-Russian borderland based on geological tourism.

GEOLOGICAL TOURISM DEVELOPMENT IN THE BORDERLAND

Since the first definition of a geotourism by Thomas Hose in 1995 this phenomena is stabily developing and getting niche form of sustainable tourism in the world (Hose et al., 2011). There are four major approaches to definitions of a geotourism in geological sense (Goki et al., 2016):

1. a tourism where the major attraction is the geological heritage, the promoting of its leads to the development of the Earth Sciences;
2. a knowledge-based tourism;
3. a form of nature based tourism focused on landscape and geology;
4. the provision of interpretative and service facilities for geosites and geomorphosites.

The development of geological knowledge up to recent years has focused on the exploitation of earth resources for mans well-being. Conscious efforts need to be made to ensure continued preservation of an important geological heritage while developing these geological resources at the same time. In this case geotourism has close connection to ecotourism, the latter balances between leisure and nature conservation. Moreover, geotourism having high educational value promotes knowledge about the Earth's surface and interiors, its Past, Present, and Future, as well as about common geological processes and spectacular phenomena (Nenonen & Portaankorva, 2009).

Geotourism comprises the geological heritage combined with the components of tourism including attractions, accommodation, tours, activities, interpretation as well as planning and management. There are five key principles which are fundamental to geotourism: geologically based, sustainable, geologically informative, locally beneficial and tourist satisfaction (Dowling, 2010). One of the important questions determined the geotourism development: who is a geotourist? According to C. Grant six types of visitors to geosites exist, ranging from unaware visitors to geo-experts (Grant, 2010). A key issue is the examining of the correlation of the geological tourism development to the interests of tourists who look for new experiences and new impressions (Kotrla et al., 2016).

Nowadays the geotourism is growing rapidly with travel and appreciation of natural landscapes and geological phenomena continuing to grow as a new form of the global tourism industry (Dowling, 2010; Dowling, 2013; Hose et al., 2011). The part of geotourism development studies is devoted to opportunities of promotion of a unique geological, geomorphological and mining potential as tourist attraction (Vukojević, 2011; Goki et al., 2011; Madziarz, 2013; Rozycki & Dryglas, 2016). Special attention deserve researches that assess the tourist value of the geological and geomorphological sites (Pralong, 2005; Štrba & Rybár, 2015; Tamara & Milica, 2016). The practical result of this evaluation is the base for promotion and including sites in the tourist sphere of the regional economy (Albă. 2016).

The geographical position of the borderland opens an extra opportunity for the protection, popularization and promotion of the geological sites within cross-border cooperation. Nowadays the transnational UNESCO Global Geoparks have been established in the borderlands where geosites and landscapes have international geological significance (today there are four in the world) (UNESCO).

One of the tools of promotion of the border geological and mining sites is design and development of the geological routes which significance has increased in recent years with the growth of interest to the nature based tourism. The opportunities of the including these sites into the tourist and recreational activity promote expansion of regional tourism products and improve competitiveness of the destinations. The impact of different kinds of the cross-border tourist routes development on local economy and protection, conservation and promotion of natural, cultural and historical potential of territory has been investigated particularly in European border regions, including regions bordering Russia (Kovács & Nagy, 2013; Kropinova & Anokhin, 2014). The circular route uniting Norway, Finland and Russia (Kola Peninsula) that can be started from any point is a good example of presentation and promotion of geological potential of the northern Fennoscandia (Johansson et al., 2014). The other example is design and development of the cross-border tourist route "Mining road" in the Finnish-Russian borderland.

THE CROSS-BORDER GEOLOGICAL ROUTE "MINING ROAD"

The cross-border tourist route "Mining Road" (about 400 km.) was elaborated out within KA334 «Mining Road» project (total budget about 800 thousand euro) funded by the Karelia ENPI CBC Programme. The project was developed during 2012-2014 years in collaboration with Finish partners (Geological Survey of Finland, Outokumpu Mining Museum) and Russian partners (Institute of Geology of Karelian Research Centre of the Russian Academy of Sciences as a Leading Partner, Administration of Pryazha National Municipal District of the Republic of Karelia, Karelian Regional State Museum, Ministry of Education of the Republic of Karelia). Besides nine associate partners took part in the project activities (Mining).

The route conects geological, mining and industrial heritage of the Finnish-Russian borderland along the international tourist road "Blue road" from city of Petrozavodsk (the Republic of Karelia, Russia) to city of Outokumpu (North Karelia, Finland) (Fig. 1.).

Totally the cross-border route unites about 20 main objects associated with the industrial geological and mining history of the Finnish-Russian borderland (Table 1.). A pilot tour of the tourist company "Karelika" in August 2014 can be considered the opening of the cross-border tourist route "Mining road" for visitors.

Under the project implementation were reconstructed and the improved number of facilities along the route new tourist attractions based on the geological and mining heritage of the territory were created.

The examples of a new impulse of the tourist attractions development are the "Mining Park Ruskeala" (the Republic of Karelia) and the Outokumpu Mining museum (the North Karelia). According to historical aspects transformation of the old Marble quarry to a new tourist attraction Mining Park "Ruskeala" started in 1998.

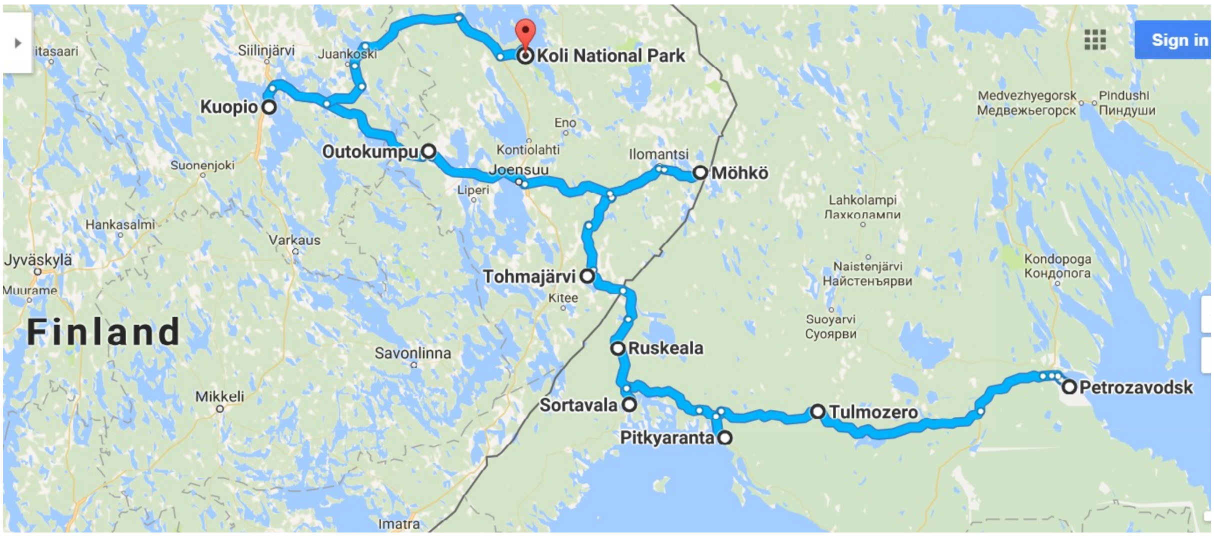

Fig. 1 The cross-border tourist route "Mining Road" (compiled by the authors using Google Maps)

Tab. 1 The main and extra geological, mining, and industrial objects of the cross-border tourist route “Mining Road”

location	objects
the Russian part of the route – the Republic of Karelia	
Petrozavodsk	— the Museum of Precambrian Geology of the Institute of Geology of Karelian Research Centre of the Russian Academy of Sciences — the National Museum of the Republic of Karelia
Tulmozero	— the Mining Park “Tulmozere”
Pitkyaranta	— Kitelskoe field of garnets — Pitkyaranta's mines — Salmi Rapakivi granites
Sortavala	— the Mining Park “Ruskeala” — the North Ladoga Republican Museum
the Finnish part of the route – the North Karelia	
Tohmajärvi	— Tohmajärvi Volcanic complex
Outokumpu	— the Outokumpu Mining museum — the Keretti old mine tower — the old asbestos and chroma-diopside quarries
Möhkö	— the Möhkö Ironworks museum — the Ptkeljärvi National Park
Koli – Juuka	— the Koli National Park — the Visitor Centre Ukko — the Finnish stone Center, Juuka — the Soapstone quarry, Juuka
Kuopio	— the Geological Survey of Finland — the Puijo tower

The expansion of the range of all-season tourist services and the development of modern tourist infrastructure as well as the inclusion the object to the cross-border tourist route “Mining road” determined a rapid growth of visitor’s number to the mining Park “Ruskeala” during 2011-2016 (more than by 6 times, Fig. 2). For example the largest growth in the number of Mining Park ‘Ruskeala” visitors comparing to the previous year was in 2015 (91.3%). For the first time in the Republic of Karelia the number of visitors to the “Ruskeala” Mining Park (194.2 thousand people) exceeded the number of Kizhi visitors (168.3 thousand people) known as open-air museum of wooden architecture in 2015. In 2016 of the “Ruskeala” Mining Park visitors exceeded the number of Kizhi visitors by 1.74 times.

The amount of the Outokumpu Mining museum visitors increased after its renovation (2010), the creation of a new mineral exhibition tunnel as well as a children mine and the playing space for children and teenagers in 2014 (Fig. 3.). Thus the growth of the number of visitors to the Outokumpu Mining museum in 2014 increased by 2.2 times comparing to the previous year

The significant practical result of the project “Mining road” implementation is the creation of a new tourist attraction Mining Park “Tulmozere” on the place of the mining plant ruins (XIX-XX centuries). The area of modern Mining Park is 3 hectares with an adjacent zone 8 hectares, where a excursion and a recreational zones have created within the project. Since the opening of a new tourist attraction based on mining industrial heritage the number of visitors to the Mining Park “Tulmozere” is slowly growing (Tab. 2). At present, the Mining Park “Tulmozere” is considered as a perspective tourist attraction, the annual number of visitors of which is expected to

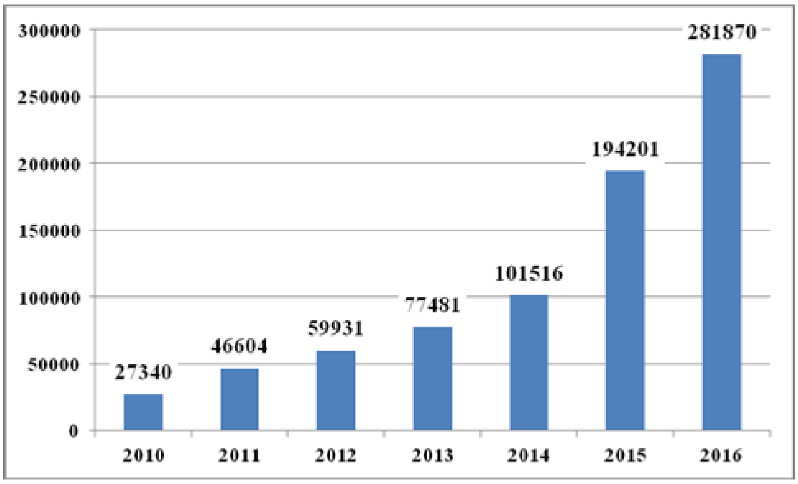

Fig. 2 The number of visitors of the Mining Park “Ruskeala”, people

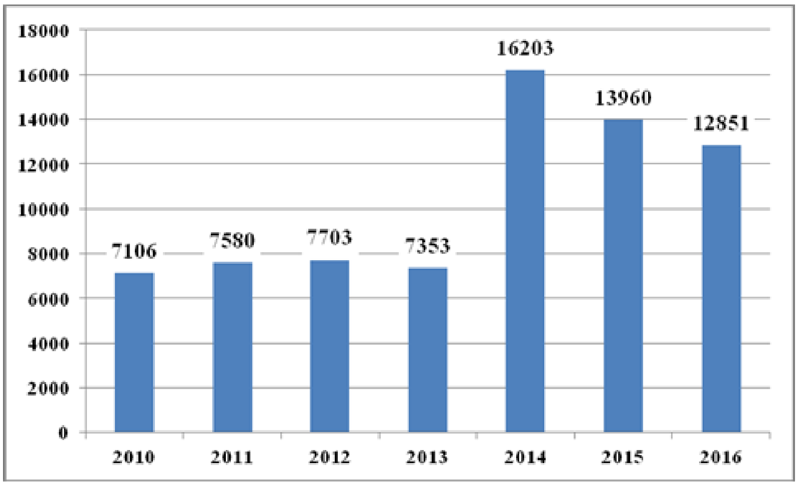

Fig. 3 The number of visitors of the Outokumpu Mining Museum, people

Tab. 2 The number of visitors of the Mining Park “Tulmozere”

Year	2013	2014	2015	2016
the number of visitors of the Mining Park “Tulmozere”, people	1030	1580	2300	2380

be 20-30 thousand people.

Within the framework of the project, a series of GPS excursions (audio guides) and 3D-panoramas were developed, which allows tourists to visit the sights of the route without guide. Also guidelines for guides about Mining Park “Tulmozere” in Russian and English have been developed (Mining).

The positive influence of the project can be noticed also in the Möhkö Ironworks museum and in the Koli National park that can be proved by increasing of the visitor’s numbers. Annually the average number of visitors in Möhkö has been around 3600 and it has been slightly increasing from year 2012 being in 2016 — 4200 peoples. In the Koli National Park the number of visits has been increasing yearly. In 2016 the increase of the visitors flow to the Koli National Park grew 24 % (167 300 visits) comparing the 2014. The reason for this has been local events, good co-operation and renewed exhibition in the information center Ukko. The financial input to the local economy was 17,7 mln. Euros in 2016 (Metsähallitus). Besides the “Mining Road” project has positive influence characterized by transferring the knowledge about the site.

DISCUSSION ON GEOLOGICAL TOURISM DEVELOPMENT IN THE FINNISH-RUSSIAN BORDERLAND

Nowadays development of tourism appears as an instrument for regional development which can stimulate new economic activities. Considering high symbolism of national borders for tourists' interest the Finnish-Russian borderland has an essential competitive advantage among other territories (Stepanova, 2017). The border geographic position largely predetermines possibilities for transforming the geological potential of the Finnish-Russian borderland into a new tourist attraction.

At the same time the opportunities of the geological tourism development in the Finnish-Russian borderland are challenged by territorial disparities in the tourism infrastructure availability, organizational and institutional problems.

An important prerequisite for a full inclusion of the geological potential in regional tourism practices is awareness of territorial unique potential, new tourist products development and wise marketing policy. The creation of tourist attractions and destinations based on the geological potential and promotion of geological tourism requires joint efforts and collaboration of authorities, business and local communities (Dowling, 2013).

With the increasing role of information technology in the modern life a crucial significance is paid at promotion of the tourist potential in Internet including design of the interactive tourist maps (Hurčíková & Molčíková, 2014.). An effective promotion of the geoheritage makes a process of choosing the destination by tourists more simple (Tamara & Milica, 2016). A content quality about geoheritage along the cross-border geological routes creates conditions to choose these routes (or several geosites) by tourists according to their needs, opportunities and desires.

The following measures for promoting the inclusion of the geological potential and geosites in the practices of the regional tourism development can be offered:

- compilation of geosites register that can be visited either individually or in groups, including the descriptions of the objects and the creation of the maps;
- information support and the promotion of the unique geological potential of territories, including the development of roadside signs, info boards, thematic guidebooks;
- placemaking of unique geosites and surrounding areas available for different categories of tourists including children;
- working out of new tourist routes and new products based on the geological potential;
- choosing geological sites with a tourist value and the development of the strategy for the creating and the transforming these unique objects into a new tourist attractions;
- etc.

CONCLUSIONS

Design and development of geological tourist routes play a significant role in the popularization of the geological heritage and in the geological tourism development. The starting point for attracting tourist flows based on the geological tourism is recognition of the value of a geological and a mining sites, the interest for new understanding of geology and of geological history.

The significance of the cross-border route "Mining Road" is determined by business activity along the route, preservation, popularization and reproduction of the natural, cultural and historical potential of the borderland.

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Acta Geoturistica volume 9 (2018), number 1, **30-35**
doi: 10.1515/agta-2018-0004

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Kaczawa Klippen Belt – geotouristic attraction in the Sudety Mountains, SW Poland

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ABSTRACT
In the paper authors present some geological sites from Kaczawa Unit, Sudetes, Poland, and their interpretation in a geotectonic context. All described geosites are important for understanding the evolution of so called Kaczawa Accretionary Prism as well as whole Sudetes. Presented outcrops are easily accessible, well exposed and exhibits high education value. Special attention was given to the Wojcieszów Limestones and their relationship to the surrounding rocks

Keywords: geoturism, geotectonic, Sudetes, Kaczawa Unit, olistolith.

INTRODUCTION AND OBJECTIVES

Noticeable increase of different geoturistic initiatives have been recently recognized in Poland. Few geoparks and geoeducational centers have been already established and some more are in the project phase. Numerous geological sites have been described and prepared for tourism and numerous publications an geoturistic maps are available. However, it has been noticed that not enough attention is given to processes which are responsible for rock formation. Also an information about geotectonical environment in which given rock had been formed are usually not presented in proper and understandable way. It is stipulated, that besides the ability how to recognize different rocks or minerals, it is also, or even more important, to understand the geotectonic position of a given rock. It is believed, that such a knowledge will help in understanding the whole earth as a one system.

In this paper authors would like to focus on the lower part of the Kaczawa Unit lithostratigraphic profile and present some valuable outcrops with geotectonical interpretation in the context of the plate tectonic theory and Wilson Cycle, with special attention given to the Wojcieszów Limestones.

GEOLOGICAL SETTINGS

Geographically, the Kaczawa Unit is located in the south western part of Poland. Geologically, it belongs to the Western Sudetes and occupies most external, northeastern part of the Bohemian Massif. From the south - west the Kaczawa Unit is bordered by the Karkonosze Massif, which is consider as a eastern part of the Saxothuringian Terrane. The stratigraphic profile of the Kaczawa Unit comprises two distinct parts. The lower one of Cambrian to Lower Carboniferous age is interpreted as a accretionary prism formed during the final stage of the Variscian orogeny, while the upper part is represented by Upper Carboniferous and Lower Permian postorogenic sediments (Aleksandrowski et al., 2002).

The lower part of the Kaczawa Succesion starts probably from the Gackowa Sandstone of tentative age of deposition. Based on recent investigations, both Late Proterozoic or Early Paleozoic ages are equally probable (Kryza at al., 2008a).

Those sandstones, known from several outcrops near Wojcieszów, are immature and exhibits typical shallow water structures like hummocky cross stratification. The Cambrian period is represented by pillow lavas and volcano-sedimentary succession. The Wojcieszów Limestone of Middle Cambrian age intercalated by metavolcanoclastic rocks are interpreted as a shallow water reefal limestone (Lorenc, 1983). The Radzimowice Slates exhibits characteristic features of turbiditc currents deposits. Previously they were interpreted as a trench fill (Baranowski, 1988), but recently considered as a deep water sequence deposited in the extensional settings (Kryza et al., 2008b). The Ordovician part of the litostratigraphic profile of the Kaczawa Unit consists different kind of metavolcanoclastic deposits and mixed, acidic and mafic volcanic rocks (e.g. Lubrza Trachytes) (Kryza at al., 2008a) . Above them slightly metamorphosed pillow lavas of Silurian age are present. They are covered by black Devonian siliceous shales, while Lower Carboniferous is build of melanges and flysch like sediments resembling culm facies.

GEOTURISTIC SITES

The Okole Hill is famous for Cambrian pillow lavas which can be found on the summit of the Okole Hill as well as on the northern and south-western slopes of the hill. The pillow structures sometimes are not fully preserved due to the metamorphic processes, however usually well visible.

The Wojcieszów Limestone oucrop in the narrow, west – east trending belt from Podgórki to Mysłów. Those limestones are usually mapped as a different size bodies, ranging from kilometres to meters, which occurre between slates or schists of Lower Palaeozoic age, mainly Radzimowice Slates (Fig. 1).

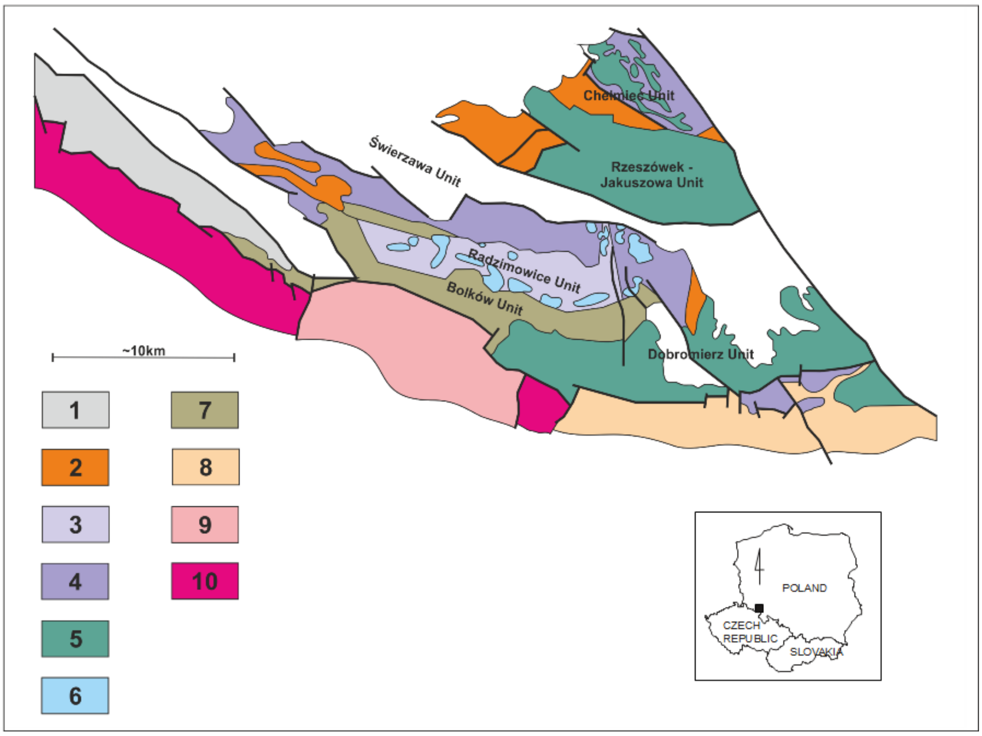

Fig. 1 Simplified geological map of the Kaczawa Uni (after Białek et al., 2007, with changes). 1 – limestones and metasedimentary rocks, 2 – chaotic complexes (melanges), 3 – Radzimowice Slates, 4 – metasedimentary and metavolcanic rocks (undivided), 5 – metabasalts, 6 – Wojcieszów Limestones, 7 - metavolcanic and metasedimentary rocks of the Bolków Unit, 8 – sedimentary rocks of the Intrasudetic Basin, 9 – Karkonosze granite, 10 – mica schists and gneisses

The most spectacular and outcrop of the Wojcieszów Limestone is located in the abandoned quarry in Wojcieszów in the southern slope of the Bielec Hill. In the western part of the outcrop a non-sedimentary contact between crystalline limestones and Radzimowice Slates can be directly observed. The character of the contact suggest that the body of the Wojcieszów Limestone forms a large scale olistolith between Radzimowice Slate (Fig. 2). Similar observation can be made in the western part of the Podgórki village, where smaller block of the Wojcieszów Limestone was also excavated (Fig. 3), as well as in other outcrops near Mysłów. As a more resistant to erosion the bodies of Wojcieszów Limestone form a characteristic klippens in the landscape locally obscured by the vegetation.

The picturesque Lipa Gorge is located in Rzeszówek – Jakuszowa Unit in the northern part of the Kaczawa Unit. It is one of several gorges located in this unit. On the both sides of the gorge slightly metamorphosed Silurian - Devonian

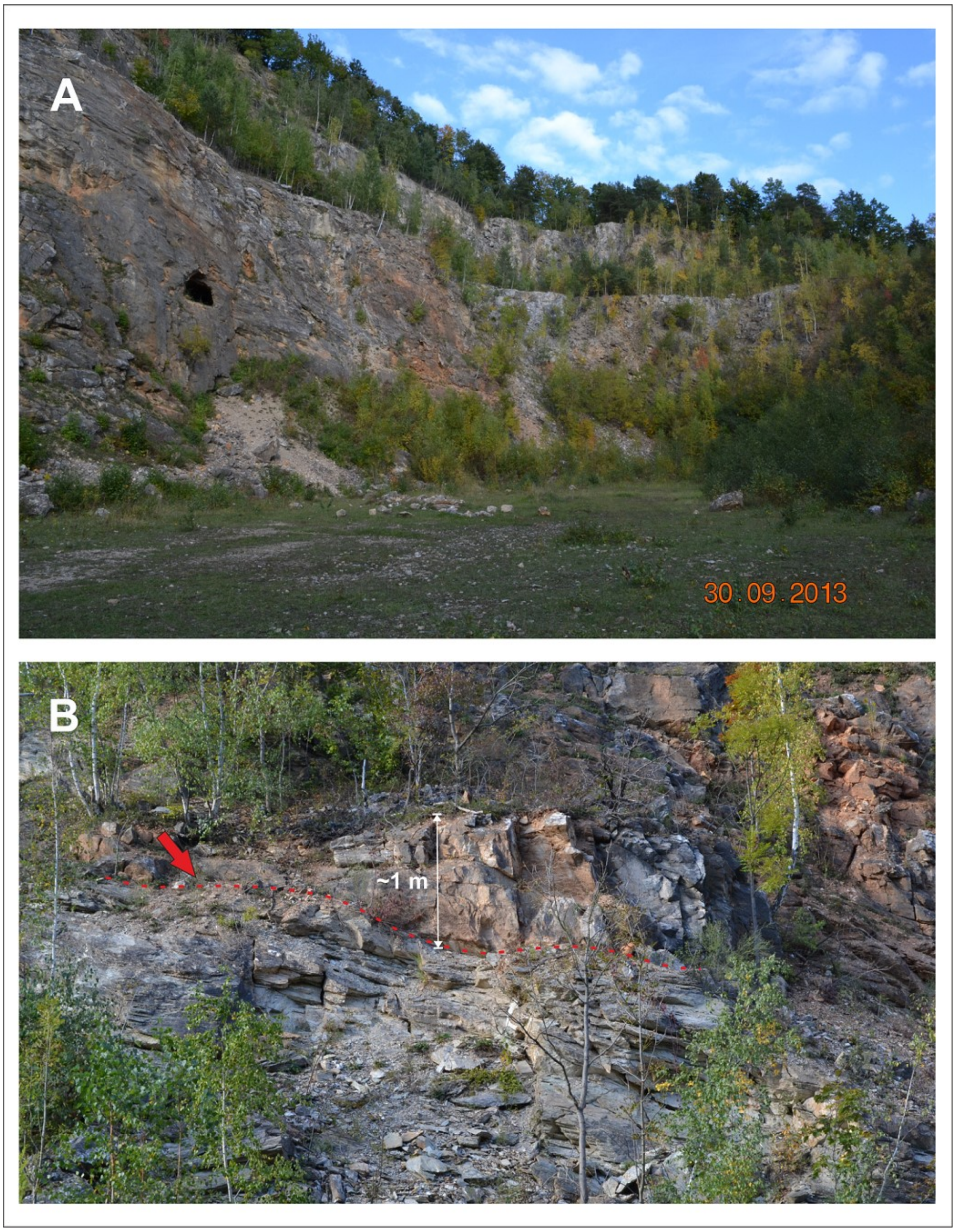

Fig. 2 The Gruszka Quarry. A – generall view on the north wall of the quarry, B – nonsedimenatry contact between Wojcieszów Limestone and Radzimowice Slates (marked with dashed red line)

Fig. 3 Medium sized olistolith of the Wojcieszów Limestone. Abandoned quarry in the western part of the Podgórki village.

Fig. 4 Silurian – Devonian pillow lavas of the Lipa Gorge.

MORB basalts with characteristic and well preserved pillow structures can be observed (Fig. 4).

The outcrop of Lower Carboniferous culm-like facies and chaotic complex can be found in the Rzeszówek village. In the central part of the village in the right bank of the stream a black and brown, intensively fractured shales are visible. In the upper part of the stream, in the northern part of the village, bellow the black shales the so called "Rzeszówek Melanges" complex is clearly visible. This complex is composed of deformed fragments of differentiated rocks (e. g. limestones, sandstones) within a shally matrix.

INTERPRETATION IN THE CONTEXT OF PLATE TECTONICS AND WILSON CYCLE

The lowermost part of the Kaczawa Unit is interpreted as a typical sequence of early rifting stage, which led to the open of the Rheic Ocean (Kryza et al., 2008a). The pillow basalts found in the Okole Hill represents the early oceanic crust of the Rheic Ocean, while Wojcieszów Limestone and Radzimowice Slates are interpreted as a sedimentary fill of the basin. According to the published information (Lorenc, 1983) the Wojcieszów Limestones were deposited in the shallow- to very shallow water environment, however in the great distance from the coast, which may suggest a volcanic ridge settings. The Radzimowice Slates, as mentioned before, exhibits features characteristic for turbidites, thus may be interpreted as deep-water sediments. The emplacement of different size fragments of the Wojcieszów Limestone within Radzimowice Slates should be connected with submarine mass movements like slides or slumps, which are typically considered as processes responsible for olistolith formation (Fig. 5). The Ordovician bimodal volcanic sequence exhibits typical for early rift stage (Kryza at al., 2008a). The Silurian - Devonian MORB basalts of the Lipa Gorge represents remnants of the back arc ocean which had opened during closure of the Rheic Ocean and are interpreted as a equivalent of the

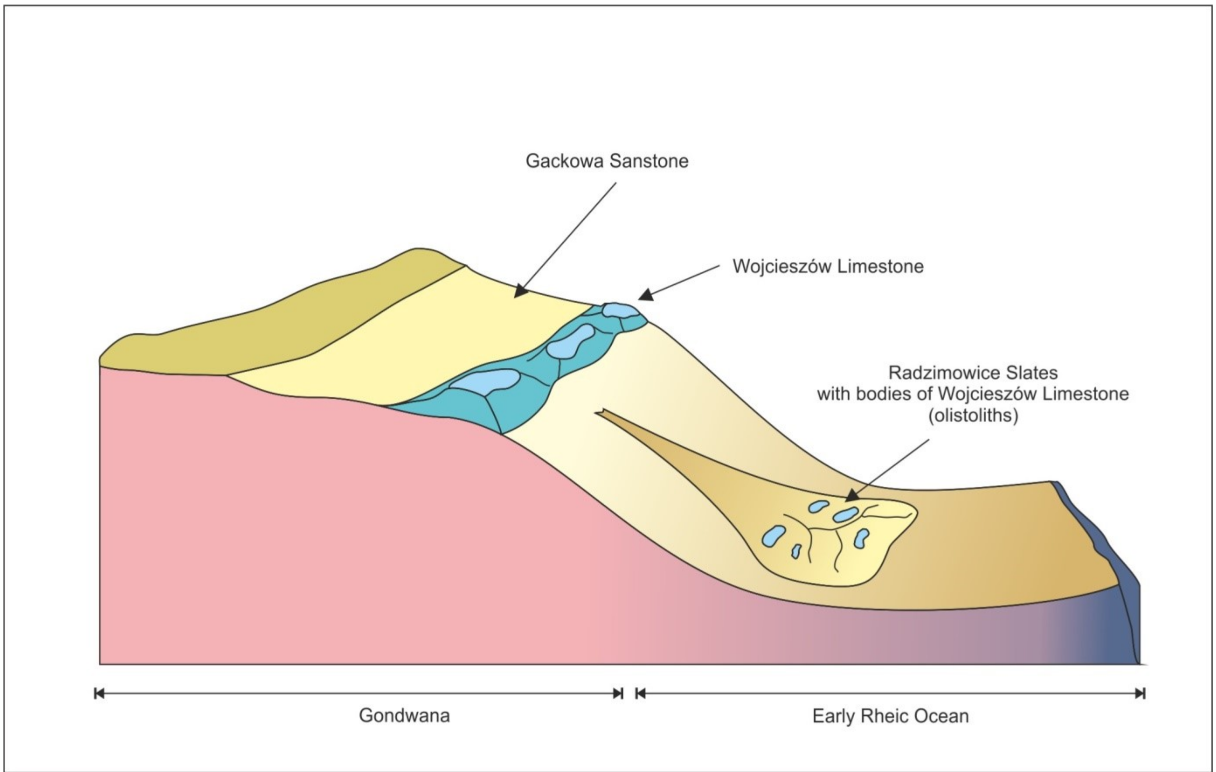

Fig. 5 Schematic model of Gackowa Sandstone, Wojcieszów Limestone and Radzimowice Slates sedimentation during Cambrian – Ordovician period.

Intrasudetic Ophiolite. The stage of Variscian accretionary prism building is represented by the “Rzeszówek Melanges”.

CONCLUSION

Because of the striking resemblance to the Pieniny Klippen Belt, especially in the context of recent advances in the interpretation of its formation (Golonka et al., 2014), it is stated that klippens formed by Wojcieszów Limestone should be named as a Kaczawa Klippen Belt. All mentioned above geoturistic sites displayed high educational values. The presented simplified interpretation covers only the geotectonic aspect. It is believed that many more geological subjects can be supported by those geosites. Authors suggest that all outcrops mentioned above should be precisely described and examined, so they can play a significant role in the education process.

Acknowledgement

This research has been financially supported by AGH University of Science and Technology in Krakow grant no. 15.11.140.388.

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