ProGEO NEWS

ProGEO 2020

the european association for the conservation of the geological heritage n.2

Oxford Geoheritage Virtual Conference

Bringing Our Community Together During a Global Pandemic

by: **Jack J. Matthews**

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As Coronavirus spread across the world in early 2020, one of the impacts was the necessary cancellation or postponement of conferences. For the geoheritage community this was most apparent in the moving of 10th International ProGEO Symposium to 2021. Recognising the often dispersed nature of workers within our field, and therefore the vital role meetings play, a small group of early career researchers came together to organise the Oxford Geoheritage Virtual Conference, 25-29th May 2020.

Back in September of 2018, no one would have predicted how different daily life would be just 18 months later, and yet the foundations of one response to coronavirus were laid back then. The University of Minho, Portugal, was hosting an EGU training school on Geoheritage Management – a wonderful meeting that not only taught attendees a great deal, both in the lecture theatre and the field, but also fostered lasting connections between them. The stage was therefore set for late March that Dr Helena Tukiainen (University of Oulu, Finland), Dr Taha Younes Arrad (Chouaïb Doukkali University, Morocco), Dr Lucie Kubalikova (Institute of Geonics of the Czech Academy of Sciences, Czech Republic), Dr Lubomir Strba (Technical University of Kosice, Slovakia), and myself had the existing connections to each other, to come together and organise the first major virtual conference on geoheritage.

Following our launch across social media on April 1st, we were nervous about how the idea would be received – hopefully not as an April Fool's prank! Our fears were allayed as it only took 2 days for the first 100 delegates to register, a number that would eventually increase to over 600 from 60 different countries. We are grateful to groups such as the Geological Association, the Quaternary Research Association, the English Geodiversity Forum, and ProGEO for all they did in supporting the event, and advertising the opportunities to be involved to their members.

We were also pleased to receive 86 abstract submissions. Even after taking the decision to extend the conference by an extra day, we were still only able to accommodate 60 of these, in both standard talk (15 minutes) and flash talk (5 minutes, 3 slides) formats. If you missed the conference, a number of talks have been uploaded to the OxGVC Youtube Channel. The OxGVC organisers are also indebted to our 3 keynote speakers:

Prof. José Brilha - Director of the Centre for Applied Research in Earth Sciences, University of Minho. Geoethical principles in geoconservation

Prof. Murray Gray - Honorary Professor of Geography, Queen Mary University of London. Geodiversity: redundant term or evolving, multi-faceted, geoscience paradigm?

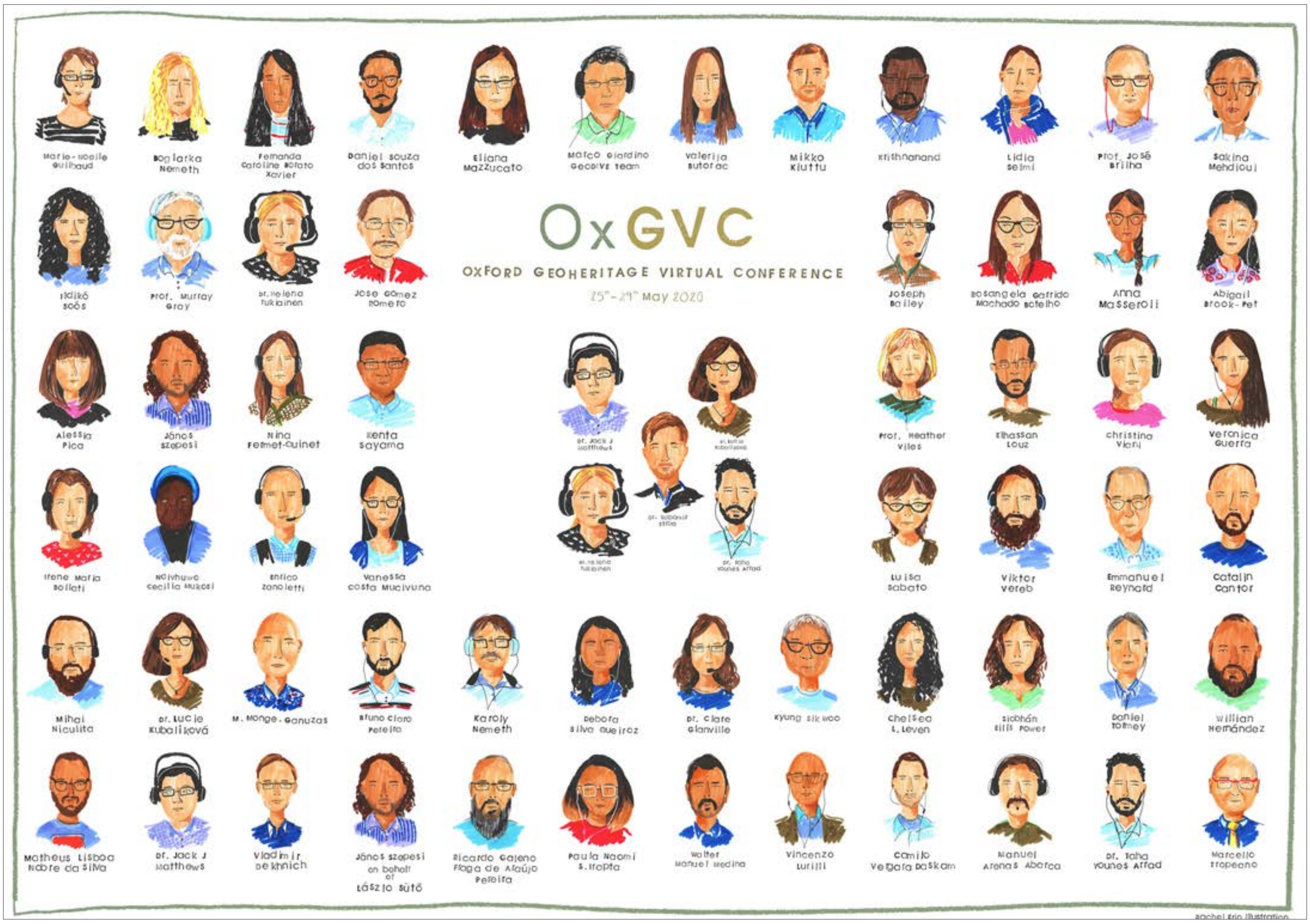
Prof. Heather Viles - Professor of Biogeomorphology and Heritage Conservation, University of Oxford. Integrating the conservation of geological, biological and cultural heritage: challenges and prospects.

The meeting was run over the WebinarJam system, which had a number of benefits. Firstly both attendees and presenters were able to access the system through their web-browser, without downloading software. Also all the slides were uploaded in advance ready for presentation, meaning those with a poor internet connection did not have to use their limited bandwidth for data-hungry screen sharing. Presenters were able to give their talk using webcam and microphone alongside their slides, in real time, and then respond to questions attendees asked in the lecture room chat. It was great to see how the chat allowed attendees not only to engage with the speakers, but also with each other, exchanging papers, contacts, and ideas.

OxGVC benefitted from the fact that the Webinarjam online platform to run the conference had already been paid for to assist a research project, and therefore the conference itself could be provided to delegates for free. We therefore recognise financial support from the Higher Education Innovation Fund, through the Oxford Policy Engagement Network. The fact that OxGVC was free to attend, and accessible online anywhere in the world was no doubt an important factor in the high attendance in general, but also the relative high turnout from specific groups, such as undergraduate students, and those from developing countries. A questionnaire sent to attendees revealed that 52% had never previously attended an international geoheritage conference.

Further discussion around the topics raised in the conference sessions was facilitated through a conference facebook group, which also hosted informal drinks between attendees at the end of each day. There were also a number of unexpected outcomes from the meeting. We were very lucky to have Rachel Simpson attending the conference, a recent graduate of the University of Plymouth's degree in Illustration, who is always keen to apply her skills to anything geological. As well as the delight of illustrations inspired by talks being posted on social media throughout the week, attendees were treated to a montage of illustrated portraits of all the presenting authors at the end of the conference. It was a wonderful addition to the meeting and was greatly appreciated by presenters and attendees alike.

Illustrated portraits of OxGVC Presenting Authors by Rachel Simpson (hyperlink to https://www.rachelerinillustration.co.uk/)



The other major unexpected outcome was a declaration from the meeting. Following a number of inspiring talks on the topic of geodiversity, we were contacted by Professors Brilha, Gray, and Zwoliński suggesting we use the conference to start a campaign to establish an International Geodiversity Day. Conference attendees have been signing a declaration, and the Professors and I have been contacting national and international organisations seeking their support – expect to hear more on this soon!

Face to face meetings will continue to play an important and necessary role in our discourse on geoheritage, but we have also shown that virtual meetings can be an effective way to convey knowledge and also engage groups who have previously been excluded. The OxGVC team and I hope to publish a more complete analysis of the conference organization and outcomes in a proposed article to Geoheritage, which we hope will support others looking to run virtual conferences. Thank you so much to all those who were a part of this meeting, and who knows, maybe we will have another one some time!

ProGEO

A strongly biased view of nature
by the European Union

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The European Commission just recently approved the EU Biodiversity Strategy for 2030 (hereinafter: EUBd2030; COM (2020) 380). I am writing this note with deep concern after observing that this strategy, which is supposed to represent a major step for nature conservation in Europe, actually has a very limited perspective regarding the concept of nature. Why do I say this? In 2012, the General Assembly of the International Union for the Conservation of Nature (IUCN) approved resolution 5.048 (WCC 2012-Res 048; https://portals.iucn.org/library/node/44015). In its operational guidelines, this resolution establishes that, to refer to nature in general, preference should be given to the use of inclusive terms such as "nature", "natural diversity" or "natural heritage", so that geodiversity and geological heritage are not excluded.


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COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

EU Biodiversity Strategy for 2030

Bringing nature back into our lives

EN EN

All the current 27 countries of the European Union are members of IUCN, so all of them are obliged to comply with this resolution, as well as their representing bodies. Needless to say, the logics of the aforementioned resolution's statement is quite obvious: whenever we want to refer to all the components, we should use inclusive terms. However, the EUBd2030 makes direct mention of nature as one of its objectives (for example, as indicated by the subtitle: "Bringing nature back to our lives"), but it never mentions other components of nature, such as geodiversity or geological heritage. A simple word count allows to visualize this issue. In the 27 pages of the PDF of the EUBd2030 (COM(2020)380), the word biodiversity is mentioned 136 times, the word nature 92 times, the word species 40 times, the word natural 16 times, the word ecosystems 14 times, and the words geodiversity or geological heritage are mentioned a total of 0 times (none). Nobody would question the need to mention terms such as species, ecosystem and particularly biodiversity in a document dedicated to a biodiversity strategy. However, no official document on nature conservation, including any strategy in that sense, should use the term nature to refer only to biodiversity.

Of course, it is good that we finally have the EUBd2030. However, it is not proper that this strategy manipulates the discourse by attempting to make people believe that nature is only biodiversity. We know that biodiversity does not include all of nature, and we know that nature does include other elements, processes and services besides those of biodiversity. Thanks to the geological record of Earth we know how climates and life evolved in the past, and how the atmosphere, oceans and continents were formed. And what is more important: thanks to the geodiversity resulting from this evolution of millions of years, we have biodiversity. As stated in several IUCN resolutions, geodiversity underpins biodiversity, geological heritage is part of natural heritage, and geodiversity is part of natural diversity. By ignoring geological heritage and geodiversity, we also ignore the geosystemic services provided by the abiotic nature, as have already been described by Gray (2011a and 2011b), van Ree et al. (2017), and Brilha et al. (2018).


ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm

To conclude, the ideal would be to have an EU Nature Conservation Strategy for 2030 that considers all nature, all natural heritage, and all natural diversity. The EUBd2030 sets an action plan towards this broader objective, but it is only one more step in that direction, and should not lead us to believe that only by conserving biodiversity we are conserving nature.

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Note: This opinion article is a translation of the one to be published in Spanish by Europarc-Spain in June 2020.

Abstract submitted to the X ProGEO Symposium

Enthusiasts, scientists, Franciscans and geoheritage – One story of success

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Keywords: Neogene, proboscideans, geoheritage, Tomislavgrad, Franciscan Museum.

The aim of "One story of success" is to emphasize the important role of local enthusiasts and the local friars in the protection of geological heritage in a particular region of Bosnia and Herzegovina. Most of us, members of ProGEO, once in a while meet an enthusiastic collector of geological heritage, most frequently fossils or minerals. They either love hiking and accidentally find something, or they intentionally go fossil or mineral hunting. The proper ending of such a search takes place when a finder turns the samples to a scientist instead of to the market. The personal perception that found specimens are valuable for the scientific community and also for the public must be appreciated and respected, and even rewarded if possible.

In the historical Tomislavgrad region of Bosnia and Herzegovina there is a well known Franciscan Museum. The current director of the Museum, the Franciscan Monastery Guardian, played a key role in the "One story of success", expressing an outstanding interest to protect and display a valuable fossil collection in his Museum. This is also the story of an excellent painter and sculptor, a layman in geology and palaeontology, who provided a unique final touch to a museum exhibition.

Nearly ten years passed since the local enthusiast and nature lover walked into the large stone quarry of Cebara, near the small town of Tomislavgrad. Always looking around and below his feet, he found a fossil here, a fossil there, nearly everywhere in the active quarry. The fossil material was being washed out from the unconsolidated Neogene sediments that used to completely fill in a large cavern in Jurassic limestones, which had been quarried for many years (Figures 1a and 1b). The founder collected fossils rather frequently, and he still does (Figure 1c). His collection grew and he decided to contact a palaeontologist from the Institute for Quaternary Palaeontology and Geology in Zagreb for palaeontological analyses and determination of his findings. At the same time, the Franciscan Guardian saw other fossil collections and got extremely interested in setting up a specialized exhibition in their Museum to protect such valuable geological heritage from his home region. This was the beginning of the "One story of success". He gathered a team of specialists: geologists from the Geological Survey of Bosnia and Herzegovina, a geologist and palaeontologist from the Natural History Museum in Vienna, a palaeontologist and a geologist from the Institute for Quaternary Palaeontology and Geology of the Croatian Academy of Sciences and Arts, laymen and artists from Tomislavgrad, and the Franciscan Monastery Guardian himself as the project leader.

Figure 1 - Active quarry of Cebara, near Tomislavgrad (A); location of fossil site at the quarry, with in situ Neogene sediments, and talus scree cone with fossil material beneath it (B); specimens from talus scree deposits (C); display of the Museum booklet during preparation of the exhibition (D).

The fossil collection, amounting to almost 1000 pieces, includes well-preserved teeth, abundant fragmented (rarely-complete) bones of proboscideans, as well as the teeth and bones of other animals like sabre-toothed cats, tapirs, hyenas, rhinoceros, beavers, cervids, bovids, smaller mammals, birds, fish, molluscs etc.

The fossil site of the quarry has no interest for further development, but is frequently subject to erosion by rain water and rockfall from adjacent cliff faces, resulting in small talus scree cones with a lot of washed-out fossils. The frequent visits to collect washed-out material have greatly enlarged the collection. Even further focused collecting is planed with members of the local community to save as much fossil material as possible to be safeguarded in the Museum for further research and display. The geological map of the region and the results of a detailed sedimentological study of these fossil-rich Neogene sediments provided additional data on the palaeoenvironmental reconstruction for the Museum display.

Fossil specimens of proboscideans were also sent to the Natural History Museum in Vienna for additional determination by a specialist. In the meantime, the preparations for the exhibition were carried on (Figure 1d) aiming to set up an extraordinary permanent display of this regionally-unique palaeontological collection: the fossil remains of Anancus arvernensis (Mastodon of Auvergne). The Museum director engaged local people, including an artist (painter and sculptor) to create a diorama that would show Anancus in its living environment back in the Neogene. An outstanding job was done, and now one can really "travel" millions of years into the geological past, into the lakes and swamps of the Tomislavgrad region during the Pliocene Epoch, and read about it in the exhibition booklet authored by all project participants (Figure 1d; booklets in other languages are in preparation). Nearly 5000 visitors have registered at the exhibition since its opening in July 2019. "One story of success" documents the excellent collaboration between local enthusiasts, geologists and palaeontologists. It is also a message to scientists to respect local enthusiasts, to help them learn and keep on the right track along with science, explaining the value of geoheritage and the importance of protection for the benefit of their own local community, as well as for scientists – and in this case, palaeontologists in particular.

Palaeontological determination of the extremely-rich fossil collection is in progress and the results about this fossil fauna association will be published in the future. Furthermore, a need to protect the Cebara site from any possible destruction is also in progress, in collaboration with the owner of the stone quarry.

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From Island Arc to resources for humankind

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Keywords: geoheritage, mining heritage, quarries, island arc

Introduction

Where are the boundaries between geoheritage and cultural heritage? This question haunts some of the practical discussions regarding geoheritage. Partly, the debate centers around the legislations and division of responsibilities between different public entities. The walls between cultural and natural heritage authorities are traditionally tall in many countries, and few agencies want to mess around in another's garden. Although the general view in the geoscience community is that a geological resource, important for humankind at some stage, qualifies as geoheritage, one may face opposition. For example, which entity should be the "owner" of value assessment?

In this paper, we argue for "turning down the walls" and call for collaboration. In the light of the European Landscape Convention and other modern and multidisciplinary approaches to the merging of humans, landscape and its resources in a holistic, Anthropocenic view.

An island arc in the service of man

The Sunnhordland Geopark (Stautland 2019), SW Norway, can be described as a significant meeting between geological resources and man through 11.000 years. The Geopark displays parts of an Ordovician island arc system developed in the Iapetus Ocean (Pedersen and Dunning 1997), emplaced from the original position in the Caledonian Orogeny and through later uplift and erosion events (Figure 1). During human occupation in the area, since the last glacial stage 11.000 years ago, virtually every part of this island arc system has been exploited as a geological resource.

Figure 1 - Left: lava breccias, and right: pillow lavas.

The volcanic rocks were target for the Mesolithic and Neolithic tool industries (basalt (Fig. 2), jasper and rhyolite). During the Iron Age and through the Medieval period, soapstone, connected to fragments of mantle rocks, were produced to a large extent. Meta-tuffites became a significant raw material for Medieval baking slabs and building-stone. In the 16th and 17th centuries and up to early/mid-20th, the hydrothermal, ore-forming event systems in the island arc were mined for copper and pyrite (Figure 2) Marble from the area was employed in building the royal Copenhagen in the 18th century (Jansen and Heldal 2003), and later employed for lime production. Gold mines in the late 19th century exploited quartz veins formed by orogenic, hydrothermal processes. The granitoid batholiths in the northern part of the area became the latest addition to the resource pool, delivering huge quantities of granite to the modern industrial age construction activities in the city of Bergen.

The exploitation of these resources left a large number of quarries and mines, many of them extremely well preserved in their geological, historic and pre-historic context. And, collectively, they describe the composition of an island arc.

Discussion

The collective employment of an island arc system as a geological resource system, where the resource types changes through ages, makes Sunnhordland a significant, and perhaps globally unique micro-cosmos for viewing the history of human interactions with geological resources through deep time.

From a strict geological perspective, it is not certain that the island arc in Sunnhordland may display global significance of island arc systems. From a cultural heritage perspective, the Neolithic sites in the area may have values of global significance, but later ones may not. However, combined, geological and cultural values may together display stories of geology linked to human evolution that are globally significant.

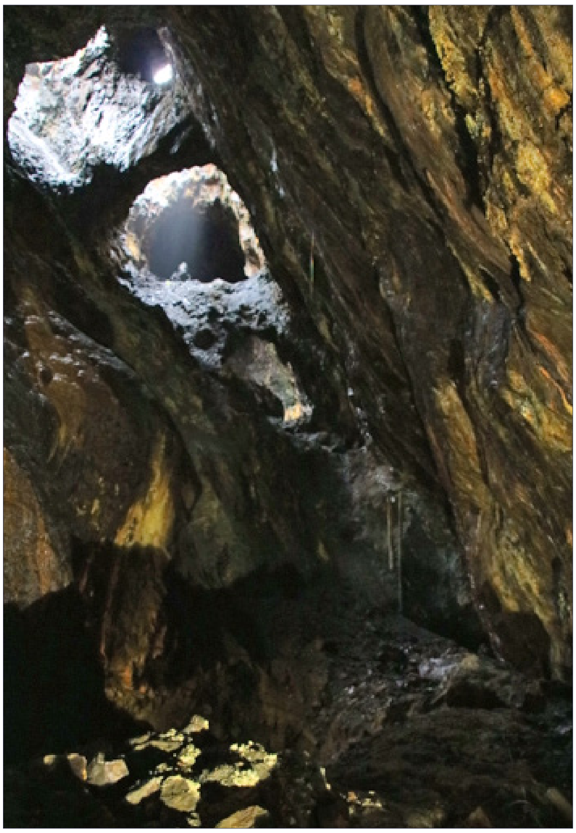

Figure 2- Left: Mesolithic to Neolithic stone axe quarry (sole of quarry lifted 4 metres by glacial rebound) and Right: pyrite ore imprint of exploited ore body in the Litlabø historic mine. lava breccias, and right: pillow lavas.

Conclusion

The Sunnhordland Geopark is an example of how geoheritage and cultural heritage can be combined and collectively create sites of global value. Whether we call these site "geosites" or "cultural heritage sites" is really not very important, because both perspectives are important to their value assessment. Such "combined " values should be addressed.

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Abstract submitted to the X ProGEO Symposium

The Norwegian Red List for Ecosystems and Habitat types 2018. Geological implications

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Keywords: Landform, Management, Norway Red-listing, Vulnerability

The IUCN Red list for species was established in 1964 and has evolved into the most acknowledged system of information on the global extinction risk status of animal, fungus and plant species (https://www.iucnredlist.org/about/background-history). It has later been followed up by a system of red-listing ecosystems (https://www.iucn.org/resources/conservation-tools/iucn-red-list-ecosystems). The ecosystem approach is relevant in a geological setting because geology is the main supporting ecosystem service for all life and embedded in the term ecosystem ("A system that includes all living organisms (biotic factors) in an area as well as its physical environment (abiotic factors) functioning together as a unit" - https://www.biologyonline.com/dictionary/ecosystem). However the red list for ecosystems or habitats tend to be very bio-centred. We see that this has resulted in red listing of several ecosystem of geoscientific origin like gullies in marine clay, earth pyramids and caves in the first red list for Norway (Lindgaard & Henriksen, 2011) as well as caves, ice caps and glaciers and limestone pavements in the red list from Europe (Jansen et al., 2016).

Figure 1 - Earth pyramids, kettle holes, gullies in marine clays and raised beach ridges are all red listed landforms in the Norwegian red list for nature types.for nature types.

The first version of the list was published in 2011. The nature description system of Norway (Nature Types in Norway (NiN, (https://www.biodiversity.no/Pages/135563/Nature_Types_in_Norway_classification) was used as the baseline for assessment. In the first version of the red list, the landforms were included as a special attribute to the habitat classification. When the list was open for revision in 2018, however, it was decided that the landforms figuring in the descriptions system of NiN should be assessed in their own right. For geologists this is interesting because for the first time we were able to include geo-elements in the red list system not only as a supporting variable to biodiversity.

Assessing landforms after the IUCN criteria including their rareness, robustness, threats to their destruction and development of the last 50 years as well as probable development the next 50 years was a challenge that was solved through a combination quantitative and qualitative methods (Erikstad et. al. 2018). The methods use unbiased information such as published and unpublished geological maps and databases (e.g at the survey's website www.ngu.no) as well as research articles and popular science (e.g. Ramberg et.al. 2008).

The Norwegian biodiversity information centre (Artsdatabanken) supervised the revision and appointed expert committees to conduct the reviews. The preferred IUCN methodology encourages the use of quantifiable methods. In the events of lacking quantifiable data, qualitative expert reflection took place.

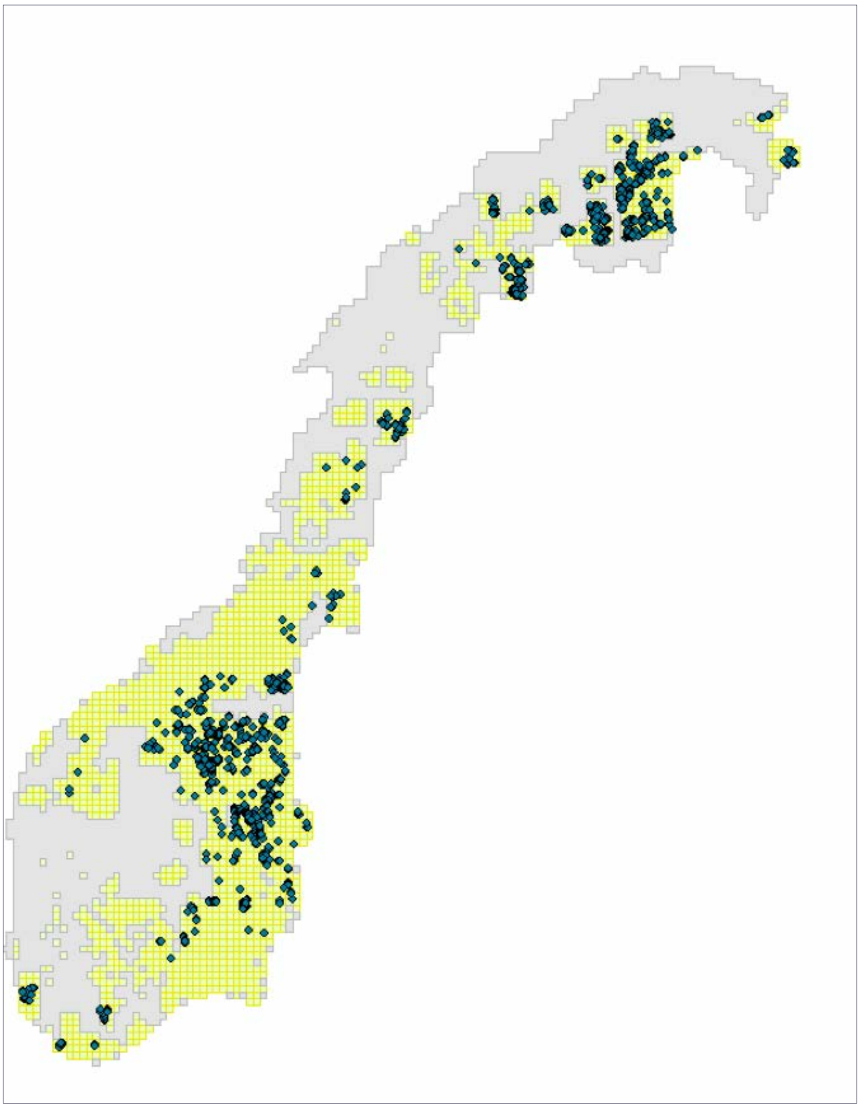

Figure 2 - A geographical representation of kettle holes in the NGU databases. Yellow areas show were detailed maps in the scale of 1:50 000 or better of surficial deposits with landforms exist. The amount and distribution of detailed mapping was used to determine a correction factor for an assessment that represent the total area. The kettle holes were overlayed by topographical maps to see if they had infrastructure or buildings in them or in their near vicinity to establish the amount of land use pressure on the landform.

The list of landforms that exist in the description system of NiN was established for a slightly different purpose back in 2009 is quite heterogenous and in need of revision. It contains large, common forms such as fjords and glaciers to depositional or erosional forms from glaciers and rivers, karst and down to rarities such as such as soil pyramids, and sinter terraces. It comprised 14 groups of landforms with 86 features altogether. All these landforms were assessed for the revised red list which was launched in 2018. Following the IUCN classification, 2 landform types were considered critical threatened (CR), 1 endangered (EN), 12 vulnerable (VU) and 12 near threatened (NT), whereas 1 had data deficiency (DD), see table 1. Important influential factors include land use, climate changes, tourism and river regulations. The list is followed up by the environmental authorities, with the development of new methods for mapping selected landforms on the red list and developing data to help municipalities and nature managers in their work. The revised Red List for Ecosystems and Habitat Types supports knowledge-based spatial planning and nature management.

This is, to our knowledge, the first time that geological landscape features have been quantified to establish rareness and resilience to this extent. It is also significant that geomorphological elements have been accepted in the red list system in their own right.

Table 1 - Red listed landforms in Norway
*Glaciers are divided in 6 different morphological forms in the list, all red listed as VU based on climatic scenarios.

Landform	Red list status
Earth pyramides	CR
Tufa/Serpentines	CR
Dripstone	EN
Glaciers*	VU
Delta	VU
Aeolian sand dunes	VU
Limestone caves	VU
Gullies in marine clays	VU
Meander	VU
Kettle holes	NT
Alluvial plains	NT
Aluvial fans	NT
Erosion brinks (rivers)	NT
Limestone ridge (folded)	NT
Ox bow lakes	NT
Coastal caves	NT
Quick clay slide pits	NT
Marine clay plains	NT
Levé	NT
Raised beach ridges	NT
Sub terrain rivers	NT
Black smokers	DD

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Abstract submitted to the X ProGEO Symposium

Spanish palaeontological geosite in danger? How mine restoration can contribute to science and education

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A series of open pits formerly used to supply limestone aggregates for road and railway construction is currently undergoing studies for full closure and environmental restoration of the production area. The large pits are located immediately to the southwest of the small town of Algora (Guadalajara, central Spain), and are the result of a protracted history of both open-air mining development and scientific discovery.

After starting production in 1965 amidst Franco's dictatorship, the ups and downs of the economy in subsequent decades forced several temporary abandonments with successive renewed exploitation. Now, in 2020, after almost a decade of inactivity resulting from the 2008 global financial crisis and its effects on the construction industry, the site is scheduled to undergo large-scale restoration as required by the Spanish environmental legislation affecting abandoned mine areas. The restoration plan was approved in 1989 and would include covering current outcrops to smooth out the relief, causing the loss of the scientific or educational potential of the site. But, why would we care about it? Does the geology of the site have any relevance?

Almost forty years ago, in 1981, Carlos Martín Escorza and Manuel Hoyos, two geologists from the Spanish National Museum of Natural Sciences (MNCN) were checking up karstic features in one of the quarries of Algora, when they stumbled upon several blocks of karstic breccia with small fossil bone fragments. The blocks had fallen from the walls of the quarry face, most probably from karstic cavities developed along fractures in the Upper Cretaceous limestone and dolostone (Morales et al., 2009, 2016). Lithostratigraphic correlation with karstic infillings of Neogene age in nearby areas of the Iberian Range suggested that these ones at Algora might also have a similar age. A later study of the microvertebrates in the breccia yielded a Ventian age (latest Miocene, MN13; Alberdi et al., 1984), thus confirming the presumed correlation. But what was most outstanding was the discovery, within one of the fallen breccia blocks, of a well-preserved palaeontological assemblage of ophidian fauna which yielded one new genus and three new species, apart from other more known snake fossil taxa (Szyndlar, 1985).

Figure 1 - General view of the quarry hosting the national palaeontological geosite with catalog code TM-049. The town of Algora (province of Guadalajara, Spain) is seen in the left background.

The microvertebrate palaeontological assemblage found at the Algora quarry identified and confirmed the site as a crucial reference for Europe: only one other site (Polgárdi, in Hungary) was known to have similar-dated snake fauna. The assemblage found at Algora was, and still is, the youngest West European fossil site containing scolecophidians (blind snakes).

But most interesting was the identification of abundant remains of elapids (poisonous snakes) with affinities to African cobras, thus confirming the faunal exchange across the land bridge between Iberia and Africa towards the end of the Miocene, as also evidenced for several groups of mammals. Interestingly enough, there is no fossil evidence that any snakes of African origin ever crossed the Pyrenees and dispersed in the remaining parts of the European continent (Szyndlar, 2012).

The Spanish national inventory of geological sites of interest, known as IELIG for its Spanish acronym and currently under way since 2009 (García Cortés et al., 2019), recently identified the quarry of Algora as a national palaeontological geosite with catalog code TM-049. The proposal of this new national geosite came from Jorge Morales, palaeontologist of the MNCN who compiled the information and submitted the proposal in February 2017. The work of Szyndlar (1985, 2012), with all the palaeontological details, more than justified the international relevance of the quarry, and was sufficient to identify it as a national geosite. The problem is that nowadays, 40 years after the breccia blocks with microvertebrate fauna were found, the quarry's active fronts have shifted and completely modified its original shape. The source cliff has disappeared, and it is now impossible to identify where exactly the fossil-rich breccia blocks fell from. Nevertheless, karstic cavities and fillings with potential for preservation are common in the quarry and prone for future studies. Furthermore, during quarry development in recent decades, new outcrops showed up in the Cretaceous host limestones and dolostones with good exposures of geological features such as faults, folds and sedimentary structures, as well as erosional and depositional karstic features (speleothems, breccias, etc.) in the Neogene cavities within the carbonates.

The plan of LafargeHolcim, the multinational company in charge of the environmental restoration of the quarry, is to formally proceed with the commitment imposed by Spanish legislation on mine restoration. However, the restoration plan was originally approved in 1989, a few years after the palaeontological discoveries were published, but the national geoheritage inventory had not yet been implemented, and so the scientific, educational and touristic value of the site had not yet been identified. Nevertheless, once aware of the scientific relevance of the site thanks to its recent cataloging, LafargeHolcim is currently reassessing the quarry's restoration plan in order to promote the educational and geotouristic potential of the site. In close cooperation with public administrations, the intention is to (1) fill in and smooth reliefs for security where necessary, maintaining areas with geological interest; (2) restrict uncontrolled access; and (3) facilitate public use through panels that explain the relevance of the site, publishing booklets for teachers, students and the general public. LafargeHolcim has already promoted and supported a similar project at the San Carlos Quarry of the Cerro Gordo Volcano, near Granátula de Calatrava (province of Ciudad Real, Spain). Here, and during the last decade, mining of the pyroclastic deposits has been simultaneous with the progressive development of scientific, educational and geotouristic activities, including a small museum and reception center, a large parking area, and a fully-interpreted itinerary with accessible facilities (https://volcancerrogordo.es/).

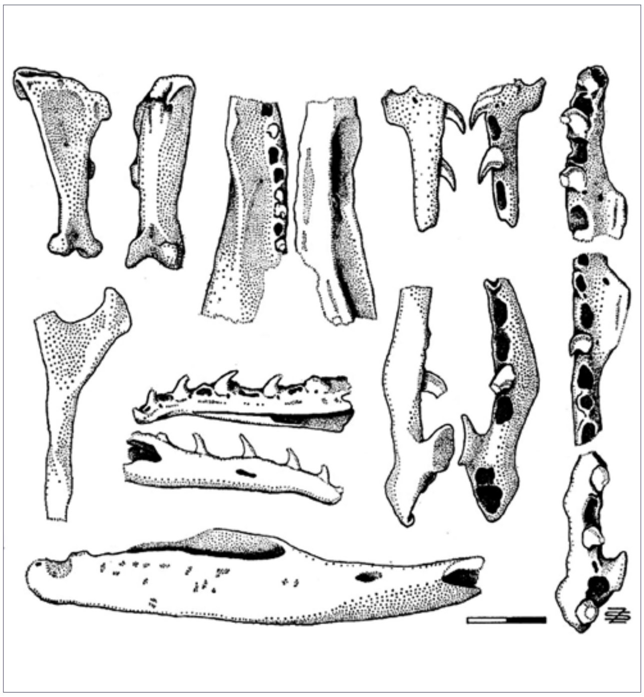

Figure 2 - Cranial bones of Elaphe algorensis, one of the three new species described from the ophidian fossil assemblage found at Algora quarry in 1981 (modified after Figure 3 of Szyndlar, 1985). The scale equals two millimeters.

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Assessing ecosystem services provided by geodiversity in the Sertão Central, Ceará, Brazilian Northeastern

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Introduction

Ecosystem Services (ES) are the goods and services provided by nature that benefit society and future generations (MEA 2005). As an essential element for human sustainability, geodiversity plays an important role in maintenance of ecosystems (Gray 2013, Brilha et al. 2018). In order to contribute to territorial planning and improvement of the sustainable use of geodiversity, the aim of this work is a preliminary qualitative assessment of the ecosystem services provided by geodiversity in the Sertão Central, hinterland of the state of Ceará, north-eastern Brazil, a semiarid region characterised by fragile socioeconomic and socioenvironmental conditions. The study area comprises about 9700 km^2 distributed in five municipalities. The geology consists of crystalline rock assemblages mostly affected by the West Gondwana amalgamation and collage during the Neoproterozoic, and by large peripheral depressions, residual massifs and inselbergs that are dominant in the landscape (Figure 1).

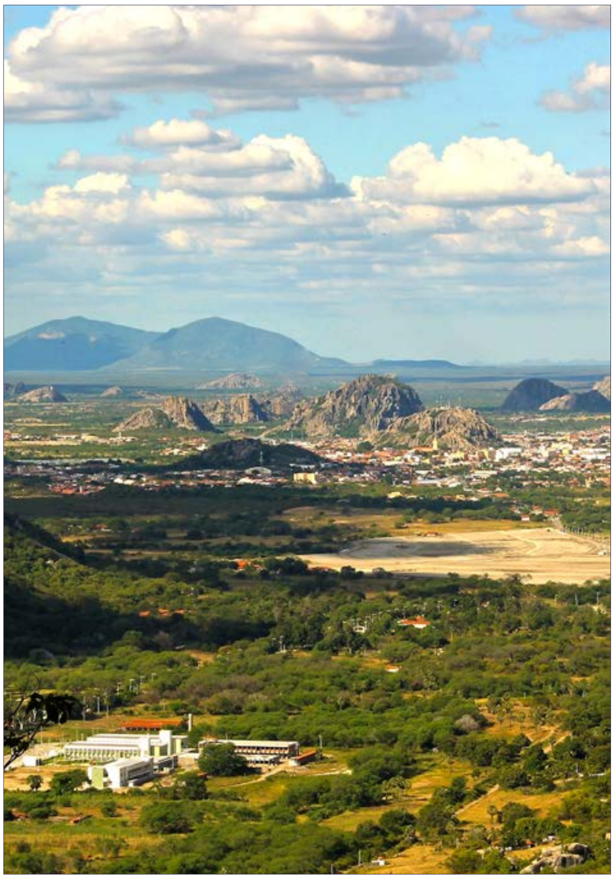

Figure 1 - Features of geodiversity in the study area: a large flat depression, inselbergs, and residual massifs composed by igneous and metamorphic rocks, and aligned following tectonic structures (photo taken during the rainy season).

Methods and results

The geological-environmental domains approach suggested by Brandão et al. (2013) was used to assess the ES. Following the Essential Geodiversity Variables (EGVs) described by Schrodt et al. (2019), detailed variables to guide the geodiversity analysis were proposed for the study area and, based on Brilha (2018), the main ecosystem services provided by geodiversity were identified.

Eight geological-environmental domains were defined: (i) Folded Proterozoic Sedimentary Sequences, (ii) Folded Proterozoic Volcano-Sedimentary Sequences, (iii) Gneiss-Migmatite and Granulite Complexes, (iv) Deformed Granitoid Complexes, (v) Strongly-Deformed Granitoid Complexes, (vi) Non-Deformed Granitoid Complexes, (vii) Mafic-Ultramafic Bodies, and (viii) Unconsolidated Cenozoic Sediments. Qualitative analysis allowed the definition of local EGVs (Table 1), and the identification of 27 goods and benefits provided by geodiversity in the study area (Table 2).

Table 1 - Examples of the EGVs in the working area (adapted from Schrodt et al., 2019).

EGV Class	General EGVs	EGVs in Sertão Central
Geology	Hardrock, fossil and mineral distribution	Stones, gemstones, and metallic minerals
	Unconsolidated deposits	Aggregates (sand and gravel)
	Geophysical processes	Mass movement and micro to minor earthquakes
Geomorphology	Landform distribution	Flat surfaces, mountains, and hills
Soil	Chemistry	Dominance of natural, low-to-moderate fertility soils
	Physical state	Dominance of poor-drained, shallow to moderate depth soils
Hydrology	Surface water	Intermittent rivers with dendritic patterns
	Groundwater	Fractured-rock and porous-rock aquifers, both with irregular hydrogeological potential

Discussion and conclusions

Our preliminary assessment elucidated the importance of geodiversity for the local economy, providing resources for industry, civil engineering, jewelry and tourism. The results also demonstrate the role of geodiversity in the mitigation of the effects of the local semiarid climate, like softening temperatures close to the mountains and regulating the groundwater reservoirs during dry seasons, for instance. On the other hand, the fragile soils and hydrological features highlight the vulnerability of the region, considering land and occupation misuses and climate changes. Additionally, it is also clear the influence and benefits of geodiversity in the local culture, such as in science, education, and cultural production (Figure 2).

Figure 2 - The most representative example for cultural services provided by geodiversity in the study area: the Pedra da Galinha Choca (Broody Hen Stone) represents a sense of place and a symbol to the local community, encompassing scientific values, and goods and benefits for recreation and tourism. The same place is also an example for supporting services, i.e., as a water reservoir for domestic and agriculture supply, habitat for both plant and animal species, and supporting for fish-farming.

Table 2 - Main goods and benefits provided by the geodiversity identified in the working area.

Regulation	Supporting	Provisioning	Cultural
Regulation of the water quality due to the circulation through rocks and sediments	Habitat for both vegetal and animal species	Building and ornamental stones (granites, gneiss, quartzites, marbles and conglomerates)	Scientific research into several branches of geosciences
Local climate regulation by ranges and hills	Platform for infrastructure and urban development, highlighting water reservoirs	Gemstones for jewellery and handcrafts (pegmatite minerals)	Sites of geoheritage and historical evolution of the Earth
Participation on water cycling (evapotranspiration)	Platform for agriculture development (subsistence and small farms)	Aggregates to construction industry (bricks, clay, sand, and gravel)	Educational value as field resources for geoscience students
Regulation of soil erosion and desertification processes	Platform for waste storage and cemeteries	Metallic minerals for industry (manganese, chromite, and EPG)	Sense of place, symbols, toponymies and spiritual values, mainly religious meanings
-	Life supporting for fish-farming	Inorganic nutrients essential to live and agriculture production	Physical and mental health promoted by contact with nature landscapes
-	-	Surface freshwater for domestic supply	Tourist attractions (water reservoirs, viewpoints, mountains)
-	-	Surface water for agriculture and industrial use	Inspiration for cultural production (books, paintings, movies, legends etc.)
-	-	Groundwater for domestic use	Recreation and sport activities (hiking, trails, cycling, rock climbing, air sports)
-	-	Groundwater for agriculture use	Use of local stones in historical monuments

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