GEOPARK COMPARISONS AND FUNCTIONAL MODELING

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ABSTRACT

UNESCO's Global Geopark Network reflects the importance of geo-heritage for society. The wide range of characteristics and the varied connections to the local ecology and culture are significant for their individual management. The aim of this article is to use comparisons between Geoparks as a step toward a generic, conceptual model that can be adapted and used to understand the crucial, functional relationships between system variables and how these variables can be optimized for stainable management. A general comparison of European Geoparks is combined with specific examples from England, Russia and Sweden. Geoparks combine geological, cultural and ecological heritage goals in varying degrees, but usually most balanced in the larger Geoparks with a pronounced landscape perspective, where the physical and biological resources have impacted cultural and ecological developments most clearly. "Functional Facies" are defined here by the functional associations between system components in the landscape. Modeling with different levels of detail can help deal with the relationship complexities, both for understanding the system and for predictive modeling for management decision support. System modeling of "Landscape Geoparks" can offer management support beyond preservation and educational measures that are most commonly in focus. Regional and global issues also need the holistic approach based on the physical and biological resources in the landscape that Geoparks can help provide.

Keywords: Geopark, sustainable development, geo-heritage, cultural heritage, ecology

INTRODUCTION

Currently, the UNESCO Global Geoparks Network has 169 Geopark sites in 44 countries. The Geopark concept is based on the importance of science, specifically Earth science, for the holistic understanding of the development of an area and our planet. A high level of education regarding geo-heritage leads to related insights concerning the physical landscape development and its close connection to ecology and cultural developments, both of which are dependent on resources in the landscape. Most importantly, the landscape conditions are decisive in terms of resource sustainability locally, such as fishing and farming practices, and globally, as part of a low carbon economy. The initiative and methodology for creating Geoparks comes from UNESCO [1]. In addition to the conservation of natural and cultural heritage sites, the creation of Geoparks helps develops new fields of research, education and related new branches in the economy. The economy, on the one hand, relies on the existing culture, folk crafts, traditional types of environmental management, and on the other hand, it benefits from the responsible use of regional resources.

The first step towards joining the Global Geoparks network is to create a national Geopark. At this stage, it would be prudent to evaluate the motivation and function of the proposed Geopark, especially if the goals are to include all three components of geo-heritage, cultural heritage and ecological resilience that are background motivations for most Geoparks. For this purpose, suitable steps in modelling the Geopark as a system were suggested and illustrated in [2], including: 1) system characterization, 2) system structural analysis, and 3) multi-criteria analysis of future scenarios [3] [4]. This model will allow, at the next stage, a more detailed study of the system functions of various components within the Geopark. A classification of "Functional Facies" in the landscape is an additional, logical step. The interrelated conditions and processes of these units will facilitate more specific evaluations, such as environmental risk assessments or carbon budgets. The scope of this article is more limited, and we aim to compare existing and a few prospective Geoparks in order to identify variations in their objectives and the basis for achieving their goals. Functional Facies and functional modelling will be shortly considered so that documentation and evaluation tools can be developed for this purpose.

METHODS

Information regarding existing Geoparks was taken from the UNESCO Global Geoparks website (https://en.unesco.org/global-geoparks) and the homepages for individual Geoparks linked from the UNESCO site. The comparisons were made on the relative importance (1-10 scale) of the three heritage goals: geological, cultural and ecological. Differences in the relative economic importance of tourism, geologic-resource exports (e.g. mining and energy extraction) and resource utilization (e.g. fishing and farming) were also estimated. The subjectivity involved is initially unavoidable, and needs to limited if other than very generalized conclusions are to be made in future studies. For our purposes, the consistent approach to ranking is sufficient for first-stage, conceptual modelling. Iterative modelling is one way to reduce subjectivity by introducing new data and constrains as the system becomes better defined. Our understanding of the variations between Geoparks are, then, an important step in Geopark model improvement. To make more specific comparisons, we have selected 3 Geoparks areas (existing or prospective), which we shortly present: "English Riviera", Devon, UK; YanganTau, Russia; Oka-Volga River Confluence, Russia, and Bohus Archipelago, Sweden.

RESULTS AND INTERPETATIONS

The plot of 26 European Geoparks suggest that most are largely focused on the Geologic heritage (Fig. 1), but with varying emphasis on the cultural heritage and ecological resilience. We have used the term "resilience" to imply that the natural landscapes often have an inherited, ecological sustainability that needs to be respected, but we realize that this is not always sufficient with rapid environmental changes with either natural or anthropogenic causes. Geopark diversity is expected, considering UNESCO's goals for the Geopark Global Network. Geoparks with very important and specific geologic outcrops are often focused on site-specific features, and found at the top of the ternary plots. Where the geologic history and geomorphologic developments have with created important landscapes, the Geoparks have stressed the close ties to

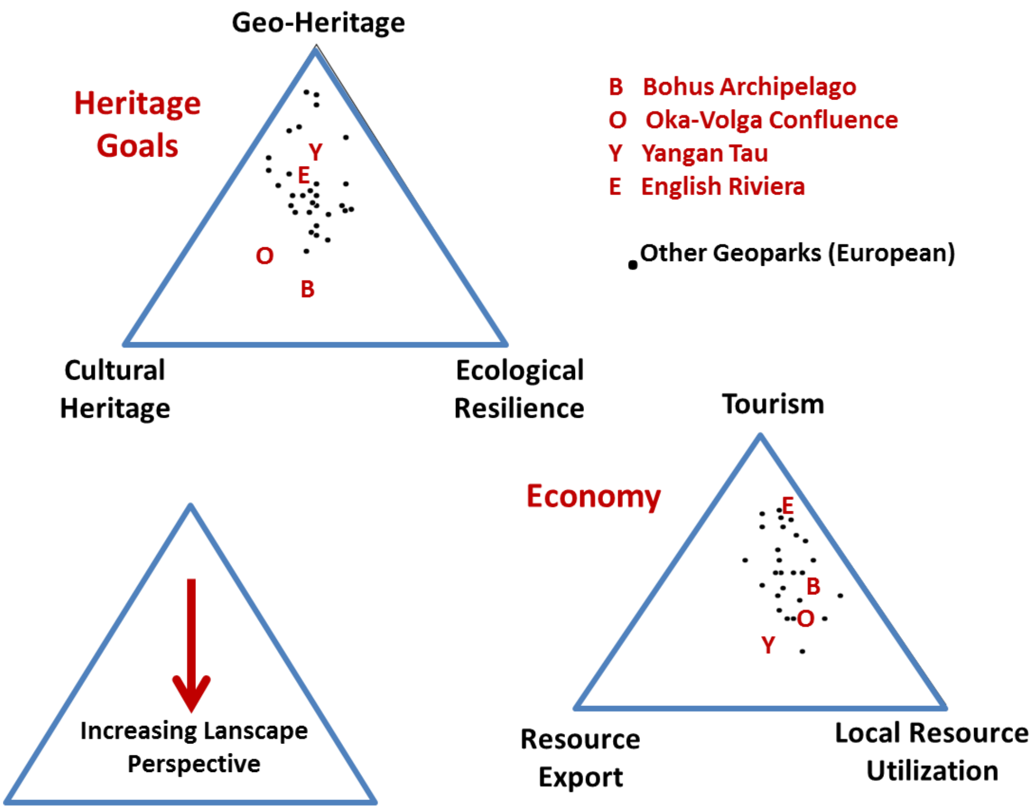

Fig. 1. Ternary plots of heritage goals and economic components of importance. The plots of some of the European Geoparks (black dots) all use relative values based on their descriptions on the UNESCO and the individual Geopark websites. Selected Geoparks examples (red) are discussed further in the text.

cultural development and ecology, both of which have dependent interrelationships with the landscape.

The balanced focus between the Geopark goals is, therefore, largely a result of the landscape perspective. These Geoparks that have a more focus on the three Geopark goals are also are balanced in the importance of the selected economic components: tourism, resource export and resource utilization (Fig. 1). These natural differences in Geopark character were previously suggested to motivate the term “Landscape Geopark” [2], which we will use here. Regarding regional sustainability goals, the Landscape Geoparks can have an integrated role for almost all management decisions. This does not imply that the site-oriented Geoparks are not important, but their role is not the same. Furthermore, environmental awareness and, especially, climate change has made the connection between local, regional and global process more evident. This increases the need for understanding landscape systems as important parts of the global whole. "Landscape Geoparks" should be given a special status and their ties to SDGs should be emphasized even more.

Fig.2. *Typical scenery in the English Riviera (left, with Permian Red Beds) and Yangan-Tau Geoparks (right, with limestone cliffs).*

One example of a successful Geopark is the "English Riviera" Geopark on the southern coast of Devon, UK (Fig. 2, Table 1) [5]. The site provides one of the longest records of Pleistocene in Western Europe, unaffected by glaciation events. This includes the 350-400 million yr. old Devonian limestones with rich marine faunas, which also were crucial for establishing the early geochronological divisions (e.g. Devonian System). The Geopark area includes three cities: Torquay, Paynton and Brixham and had intensive tourism. Apart from the striking coastal appearance of the rugged, Devonian limestone and Permian "Red Beds" (Fig. 2), a landscape perspective is not stressed in connection with either cultural or natural heritage. Rather, the Geopark is highly involved in educational services and events for tourist and schools, in addition to the importance for the scientific community. Tourism is also the main economic incentive. The English Riviera Geopark plots near the apex in both ternary diagrams in Fig. 1, and is not considered here to be a Landscape Geopark.

Geological features of the first UNESCO Geopark in Russia, Yangan Tau (Table 1, Fig. 2), include the Mechetlino and Bolshaya Luka deposits, as well as the fire-breathing mountain itself [6]. There are also natural heritage sites of the Republic of Bashkortostan, including sulfur springs - an underground source with mineral water, Kurgazak, Arkaulovskoye swamp - a carbonate low-lying swamp feeding on highly mineralized groundwater and atmospheric precipitation; unique geological sections; caves in which archaeologists were household items of ancient people were found, as well as mountains and rocks, which are striking in their beauty. In contrast to the highly populated English Riviera Geopark, Yangan-Tau is rural and has a greater connection to

Table 1. *General characteristics of selected Geoparks.*

Geoparks	Size km^2	Population, 1000	Geo-Heritage sites	Natural Heritage sites	Tourists 1000/yr
English Riviera	62	145.6	12	10	80
Yangan Tau	1774	24.2	34	40	5
Oka &Volga Confluence	9732	1692.9	3	20	580
Bohus Archipelago	4683	50	12	10	15

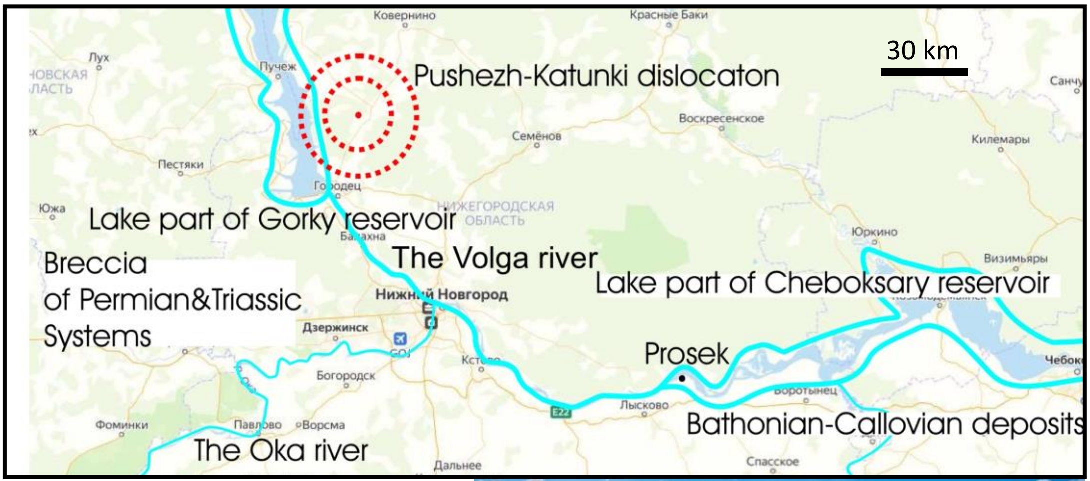

Fig. 3. *Confluence of the Oka and Volga Rivers, a prospective Geopark near Nizhny Novgorod, Russia. Geological heritage sites are indicated. Islands along the Volga River are seen in the photograph.*

the resource export and utilization components within the regional economy. Partly in response to this, the landscape-related cultural heritage and ecology are well reflected in the Geopark descriptions. Yangan-Tau is what we would characterize as a Landscape Geopark.

A unique landscape of stunning beauty and important geological features is the motivation for a possible Landscape Geopark at the confluence of the Oka and Volga Rivers in Russia (Fig. 3) [7]. Geotourism objects in the confluence of the Oka and Volga are outcroppings of Jurassic stratigraphic layers on the right bank of the Volga River, including breccias of the Puchezh-Katunki impact crater, the associated dislocation, and the Bathonian-Callovian deposits near the village Prosek. Both the geologic development and the modern fluvial geomorphologic environments are closely related to the landscape perspective would help connect the geo-heritage sites with the valuable cultural and ecological settings. The Geopark's ecological functions are largely due to the river confluence and resulting geomorphology, together with the background geological conditions. Nizhny Novgorod is one of the oldest Russian cities and continues to be an expanding, urban center, making the preservation of all three Geopark heritage goals critically important but also challenging. Oka-Volga would clearly represent a Landscape Geopark.

The Bohus archipelago coastal zone (see Fig.3) has geological, cultural heritage and ecological heritage are very consistent with the overall purpose of a Geopark, especially if distinguished as a Landscape Geopark. Rather than very specific sites or features, it is the landscape that has developed since the crystalline bedrock was first formed deep in the Earth's crust, nearly 1-2 billion years ago as part of the Baltic Shield [8]. Uplift and erosion produced a sub-Cambrian peneplain, but this became itself eroded along the tectonic fracture zones, resulting in the characteristic pattern of hills and valleys that we see today. The variation between hills with exposed bedrock or thin glacial deposits with relatively small valleys with marine muddy sediments on land is mirrored by a similar variety of deposits and habitats in the archipelago. Farming and fishing were adapted to these conditions, although today's economy is not supporting this cultural

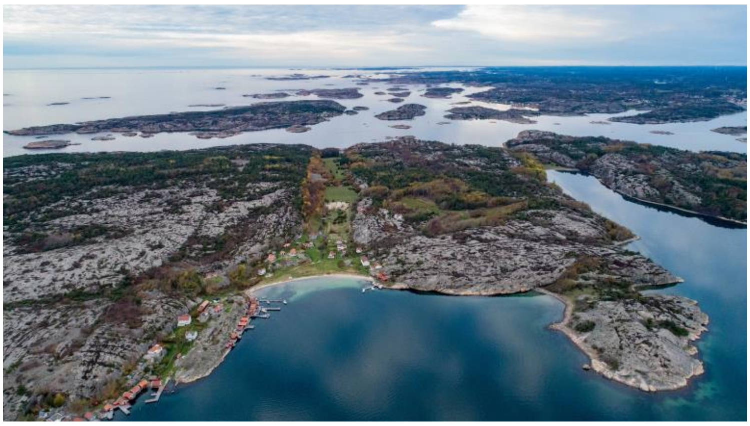

Fig. 4. *Typical landscape view in the prospective Bohus Archipelago Landscape Geopark (Sweden). Precambrian bedrock hills separate fracture-zone valleys with small-scale farms and highly varied, coastal habitats.*

heritage. Tourism is an increasingly dominant factor, as is ecological stress across the landscape. The landscape needs management that includes the attributes of both marine and terrestrial environments so that the resources can sustainably benefit the local permanent communities and the seasonal guests attracted to the same area.

DISCUSSION: FUNCTIONAL MODELING

The territorial area of Geoparks can vary significantly in order to include not only objects of geological heritage, but also settlements, objects of natural and cultural heritage (Table 1). The underlying geo-heritage differences that Geoparks are based can also largely explain the variability regarding the goals of each Geopark for the cultural and ecological goals. Although always included to some extent, the interconnections between these goals are often more obvious in larger Geoparks. This is evident in general distribution of heritage goals for European Geoparks and in the selected examples (Fig. 1). The English Riviera Geopark is much smaller and has its focus on geo-heritage, whereas the other three Geoparks described have a stronger landscape perspective.

A system model can help evaluate the physical, biological and cultural heritage, understand processes, and sustainably manage these resources. Initial conceptual modeling of the Bohus Archipelago Landscape Geopark [2] suggested that the general system variables were strongly interacting and complex. One way to deal with this complexity is to consider the system components at different scales of detail (Table 2). We use the term "Functional Facies" (FF) for classification units that are defined by the interrelated components within the system and that influence each other and important system processes. FF can vary in size and detail, depending on the available observations and interpretation objectives. Since most spatial modeling is done in a GIS, the scale could be expressed in pixel size, for instance, 10, 100 and 100 m.

The most detailed FF are necessary for careful evaluation since specific processes can often best be observed and dealt with on a site-specific scale. For instance, these FF components are likely related to land-use and can have close relationships to separate habitats, stressors and the connecting interfaces. Implemented management measures also need to be suitable for these site-specific characteristics. The medium-scale, regional FF identify associations between components that are relevant for interpreting process dynamics within specific environmental settings. The large-scale FF link the environments within the Geopark system to the even larger, regional environmental, providing a landscape perspective for management issues.

Table 2. *Functional Facies characterized at different scales and the relevance for Geopark system modeling and management.*

	Geo-REGIONAL Functional Facies	Geo-COMMUNITY Functional Facies	Geo-LANDUSE Functional Facies
Scale of detail e.g. pixel size in GIS	1000 m	100 m	10 m
Focus of characterization	Complex environment associations within the system	Local component associations	Site-specific components, relationships & processes
Typical interpretations	Total resource capacity and tipping-point criteria	Process dynamics coupled to resources	Habitats, stressors, & functional interfaces
Main objectives	System-based sustainable resource management	Proactive and nature-based, best practices	Practical, site-specific protection or remediation

Ideally, the functional modeling of Geopark systems can also be done at successive levels of detail, building upon the observations and understanding developed from the bottom up. For this purpose GIS data of different spatial resolution can be used, including satellite imagery for coarse scale evaluation, LiDAR for finer scale assessments and drone photography for obtaining highest level of detail. The transparent and open structure is favorable for iterative improvements as new data or theory are established. During each modeling exercise, the initial analytical phase identifies system components and then, during the synthesis phase, these are combined using their relative importance for specific management issues. One tool for this last, decision-support step is multi-criteria evaluation [2] [4], which may be performed using relevant GIS software.

CONCLUSIONS

A central and important strength of the UNESCO Global Geopark Network is the wide character diversity of the numerous Geoparks. The objectives and activities of the individual Geoparks can also be focused on different mixtures of local, regional or global connections to the geo-heritage, cultural heritage and ecological resilience goals that all Geoparks combine to some extent, especially in their educational activities. Larger Geoparks (“Landscape Geoparks”), tend a more balanced combination on all heritage goals, logically connected to the landscape influence on culture and ecology.

Therefore, we suggest that in addition to heritage preservation, system modeling of the Landscape Geoparks can, and should, offer valuable management support for reginal and global issues. For instance, if biodiversity and carbon-budgeting research is based on the Landscape Geopark modeling, it would be framed by the total capacity of physical and biological resources and it would utilize the endemic knowledge of historical developments related to these resources in the specific landscape. Many of the other Sustainable Development Goals are also suitably dealt with and implemented on the landscape level.

This does not imply that the site-oriented Geoparks are not important, and they should continue to stress the role that is most suited to each setting. Nevertheless, many of these can further develop the landscape connections in the Geopark vicinity for a more holistic motivation of all three heritage goals. It may also be prudent for many Geoparks to critically consider the impact of increased tourism, which is the most direct way that Geoparks usually say that they are sustaining local communities. Although not further consider here, the sustainability of tourism and the combined negative and positive impacts on our local and global environments are very relevant for Geoparks management, especially the Landscape Geoparks.

ACKNOWLEDGEMENTS

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