Geodiversity. The concept and scope of geodiversity

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Abstract. A definition of geodiversity is presented, analogous to that of biodiversity. An outline of existing Polish geodiversity studies is given, with emphasis on geoenvironmental cartography and regional monographs. The ideas of a European geodiversity atlas and geosphere monitoring program are put forward. The author postulates also to proclaim an international convention on geodiversity protection.

Key words: *geosphere, lithosphere protection, geosites, geoparks*

The principle of a sustainable development, declared during the conference *Environment and Development* (Rio de Janeiro, 1992), opened a new epoch in our approach to the management of natural resources. New ideas and new principles aiming at preventing further environmental degradation of the Earth have been formulated. It is necessary to maintain balance between individual elements of the natural environment, which has significant importance in supporting life on Earth. Maintaining proper environmental conditions to support life is the fundamental goal of humanity. In order to meet this challenge, the Convention on Biological Diversity was signed in Rio de Janeiro (Convention…, 1993). This convention assumes that the diversity is the major factor helping to maintain life on Earth. The principles of biological diversity emphasize "the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

The convention also defines the rules of environmental management and criteria of distribution of the achieved benefits.

The theory of biological diversity refers to all the biosphere levels: genetic, species and ecosystem diversity (for ecological systems, abiotic background — on which life develops — is taken into account). The issue of ecosystem diversity of phytocenoses (floral communities and landscapes) is a key problem today (Andrzejewski, 1996). The main fields of the protective activity are: counteraction, prevention, and suppression of the causes which reduce or destruct biodiversity. Over the last 12 years after the Rio de Janeiro conference, much work has been done in the field of biological diversity conservation. It has been a very quickly developing discipline amongst environmental sciences.

Rapid loss of biological diversity in the recent years is called the Sixth Extinction (Leakey & Lewin, 1995), alluding to the "Big Five" of mass extinctions in the Phanerozoic. Inhibition of this process is considered the major task facing our civilization.

In 2001, in Göteborg, the European Union strategy for sustainable development was accepted. The goal of that strategy is, among others, to reduce the rate of biological diversity loss in Europe by 2010. This is a very difficult job that requires multidirectional actions.

Development of life is strongly related to abiotic conditions. Geodiversity has been the basis for the increasing biological diversity during geological history. The environmental conditions within the lithosphere and on the Earth's surface have significant importance for the creation and development of life. We gradually begin to appreciate the significance of the geosystem in maintaining life. Research of the Solar System, conducted over the last years, distinctly shows that the terrestrial system plays a unique part in the process of the origin and evolution of life (Sagan, 1996). Therefore, it is necessary to pay more attention to the role and significance of the terrestrial system (geosystem). Particularly important is to determine the rules by which the Earth's geosystem operates. It refers to both recognition and determination of qualitative and quantitative relationships and interactions between these elements, phenomena and objects, as well as between neighbouring subsystems and systems. The changes occurring in the geosphere can be categorized into 4 groups: planetary, endogenic, exogenic and anthropogenic (Table 1).

Of special significance are those anthropogenic changes which increasingly disturb the natural balance in the lithosphere that has evolved for at least a few billion years. Human-generated changes intensified beginning in the 19th century and now they become faster and more widespread. Human activity has triggered the process of contamination and destruction of the natural environment throughout the globe.

The process of circulation of chemical elements, previously immobilised in the lithosphere, continuously increases. Their excessive concentrations result in increasing contamination by toxic compounds, spreading to other areas of the Earth and causing destruction and mutations in the living world. The magnitude of these alterations is so great by now that the mankind together with a major part of the biosphere could already be destroyed at any moment, e.g., as a result of a nuclear war. It is then necessary to develop a strategy for geosphere protection. The strategy should primarily concern operations which support maintaining geosystem efficiency in conformity with geodiversity created by natural processes.

Table 1. Changes in the geosphere

Planetary	Solar and supernovae radiation changes; interplanetary dust and meteorite falls; planetary collisions
Endogenic	Earth core convection; plate tectonic processes; volcanic processes; Earth's magnetism
Exogenic	Vertical Earth's crust movements — denudation and sedimentation; weathering; orogenic processes
Anthropogenic	Triggering circulation of chemical elements and compounds, including toxsic; radioactivity concentration; creating new chemical elements and compounds

source: Kozłowski, 2001

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Therefore, there is a need to protect geodiversity, as a human friendly quality and a feature indispensable for development of life, in particular of human life.

So it is necessary to define geodiversity: "geodiversity is the natural variety of the Earth's surface, referring to geological and geomorphological aspects, soils and surface waters, as well as to other systems created as a result of both natural (endogenic and exogenic) processes and human activity" (Kozłowski et al., 2004a). Geodiversity and biodiversity are the two elements determining the possibility of supporting a sustainable development. Such a development is "in accordance with the environmental conditions, optimizes the use of natural resources and environmental virtues, not destroys the natural environment, and reconciles the nature's laws and economic laws in harmony with the nature".

And so it can be said that the future of our planet depends on our ability to use natural resources and environmental values. The natural environment includes both world living and non-living. Close and direct relations between them force us to consider geodiversity and biodiversity inseparably. Previous studies have paid considerably more attention to the biosphere. Now it is the time to develop the issue of geospheres (=lithosphere + hydrosphere + atmosphere) protection. If we want to maintain the balance indispensable for further development of life, in particular of human life, there is a need to implement the two major global programmes:

- ❏ conservation of biological diversity,
- ❏ conservation of geodiversity.

Geodiversity refers to the epigeosphere (the outer sphere of Earth) which, together with the lower part of atmosphere — the troposphere, forms a spatially complex set. Thus, we deal with a problem of the use of abiotic resources, referred to as geoecology. In such terms, geoecology is complementary to the concept of bioecology. Geoecology cannot be, however, identified with landscape ecology encompassing a much broader area (geosphere, biosphere and noosphere) (Richling & Solon, 1996).

Geodiversity conservation is sometimes identified with the concept of geosozology. Geosozology is a science concerning how to protect and save the Earth. It focuses on protection of the upper part of lithosphere.

Geosozology is aimed at maintaining abiotic conditions in the biosphere, necessary for possibilities of further development of organic life on Earth. The concept of geosozology was developed during the studies on "Protection of the lithosphere", a scientific project conducted at the Polish Geological Institute in the period of 1990–1994 (Kozłowski & Wyrwicka, 1994). The term geosozology originates from the term sozology. The concept of sozology was developed in the 1960s by Walery Goetel (1966, 1971). Sozology is a science concerning how to protect and save. This term is derived from a Greek word "sodzo" or "sozo" that means: "I protect" in ancient Greek language, and "I save" in modern Greek.

Geodiversity refers to a set of interfingering spheres: the atmosphere, lithosphere, morphosphere, pedosphere, hydrosphere and biosphere. These spheres represent autonomous subsystems closely connected with one another, which can be determined through quantitative and qualitative studies of the energy and matter circulation in various temporal and spatial scales. Due to permanent relations and connections between these spheres, definite systems (system aggregations) of different spatial extents are created. They determine the temporal diversification of the landscape structure of the Earth's surface. Landscape protection becomes an increasingly urgent problem (Kozłowski, 1980).

Geodiversity should be dealt with as a determinant of life which can evolve on planets with an appropriate humidity and temperature, and when metastability is present (Postgage, 1997). The central problem with regard to the Earth is to maintain metastability with reference to the geological structure, topography, soils, surface waters and climate. These elements of the Earth's geosystem constitute geodiversity. The above-presented systems and connections are characterized by variable relationships. Their temporal activity pattern and spatial extent are varied, determining the nature of the moderate climate zone. The systems (types of connections) finally create the landscape structure of the region and entire country. It should also be emphasized that the systems, determined by landscape types, create the Earth surface system. Complexity and occurrence frequency of these systems are produced by both zonal and azonal factors. Geodiversity conservation means elimination of concentrations of unfavourable processes induced primarily by human activity. Unfavourable processes are those which pose a threat to life, in particular to human life.

Human activity has resulted in a widespread migration of chemical elements. Concentrations of chemical elements, exceeding limits tolerated by organisms, have lately appeared in many areas. The terms "toxic area", "danger zones" and "environmental risk areas" have therefore been introduced. In the 1980s, 10% of the total area of Poland was qualified as environmental risk areas. Today the risk is many times smaller.

Geodiversity studies in Poland

Geodiversity studies are conducted by the Polish Geological Institute and the Institute of Nature Conservation of the Polish Academy of Sciences. In the last years conservation of geological heritage has been increasingly discussed. In Poland, this issue is one of the major goals of the Environmental Protection Act (1991, with later amendments). The Polish Geological Institute runs succeeding studies on geological heritage conservation: "The programme of lithosphere protection" finished in 1997 (Kozłowski, 1998) and "Geodiversity protection" (Kozłowski, 2001). Inanimate nature protection has long been an issue of concern for the Institute of Nature Conservation in Kraków (Alexandrowicz, 1994, 1997, 2003).

In 1991, the International Declaration of the Rights of the Memory of the Earth was accepted during the first symposium devoted to geodiversity, held in France under the auspices of UNESCO. The next conference in Malvern (UK), 1993, resulted in a preparation of the postulate that there is a need to develop a world convention on the geological heritage protection. This issue is now under consideration by the European Association for the Conservation of the Geological Heritage (PRO-GEO) which operates within the framework of the International Union of Geological Sciences (IUGS) (Alexandrowicz, 1994). Prof. Zofia Alexandrowicz from Kraków, representing Poland, is the Chairperson of Working Group 2 including East European countries. From 14th to 17th October, 1997, the Working Group 2 meeting was held during the conference organized in Kraków by the Institute of Nature Conservation and the

Carpathian Branch of the Polish Geological Institute. That conference was devoted to establishing a list of geosites to the European list of Geological Heritage (Draft candidate list of geosites representative of Central Europe). Lithuania, Belarus, Ukraine, Slovakia, Czech Republic, Austria and Poland gave a number of geosite proposals. A total number of 131candidate geosites were presented, including 84 from Poland. The issues were later discussed on the ProGeo conference in Madrid, 1999 (Alexandrowicz & Kozłowski, 1999).

The second international conference *The European Association for Conservation of the Geological Heritage*, organized by the Polish Geological Institute and the Institute of Nature Conservation, was held in Kraków from 3rd to 4th October, 2003. In that conference the problem of "Geodiversity conservation — conserving our geologic heritage" was presented (Kozłowski et al., 2004a, b). Other problems such as geoindicators, geotypes and geoparks were also discussed. The conference materials will be published by the Polish Geological Institute as a *Special Paper* issue.

Geoenvironmental cartography

In Poland, detailed geoenvironmental mapping at scale 1 : 50,000 is widely developed. Three map series with an explanatory text are in preparation:

- ❏ geological-economic map,
- ❏ hydrogeological map,
- ❏ sozological map.

These maps are compiled in both analogue and digital versions, and play an important part in site planning and social education.

Geodiversity Atlas of Poland

Work has begun on the Geodiversity Atlas of Poland (Kozłowski, 2001). This atlas will include a number of maps, scale 1: 750,000, grouped into 8 categories:

- ❏ geodiversity of geological structure of Poland,
- ❏ geodiversity of the Earth's surface relief,
- ❏ geodiversity of soils,
- ❏ geodiversity of surface waters,
- ❏ geodiversity of groundwaters,
- ❏ geodiversity of mineral and therapeutic waters,
- ❏ geodiversity of thermal waters,
- ❏ landscape structure in terms of geodiversity conservation.

A five-step scale was used for geodiversity assessment to distinguish the following geodiversity classes: very high, high, moderate, low and very low (Table 2).

It would be useful if similar geodiversity atlases could be constructed for the other EU countries. It would permit to create a geodiversity atlas of Europe.

Table 2. Geodiversity assessment in Poland

Elements		Classes				
		A very high	B high	C moderate	D low	E very low
Geology — geodiversity		very high	high	moderate	low	very low
Relief	relief energy	areas >500 m a.s.l.	areas 200–520 m a.s.l.	areas 100–200 m a.s.l.	areas 40–100 m a.s.l.	areas >40 m a.s.l.
	relief diversity	high mountains	moderately high mountains	high uplands	intramontane valleys	lowland valley bottoms, coastal lowlands
	relief preservation	forestes, swamps, lakes	meadows, pastureland	arable land	urban areas	industrial, mining, and infrastructure areas
	total assessment	very high	high	moderate	low	—
Soils	agriculture production space, after JUNG	>90 pts	90–70 pts	70–50 pts	50–30 pts	<30 pts
	surface water erosion	very strong	strong	moderate	small	minimal
Surface water	water springs (discharge in 1/s)	>100	50–100	20–50	5–20	
	wetland	in national parks and reserves	undeveloped areas		developed areas	drained degraded and contaminated areas
	lakes (water quality)	class I	class II	class III	substandard waters, river waters	substandard waters (stagnant)
	rivers (wilderness)	natural channels in law-protected areas	natural channels in agricultural areas	stabilizes river banks	regulated river channels	channelized rivers
	rivers (water quality)	class I	class II	class III	contaminated by municipal sewage	contaminated by industrial and municipal sewage
Landscape structure	landscape (geodiversity)	very high	high	moderate	low	very low
	human impact on natural environment (anthropopressure)	environmental reinforcement	marshy meadow vegetation succession	small changes in land use	strong changes in land use	impact of urban areas and motorways

source: Kozłowski, 2001

Regional monographies on geodiversity

The Polish Geological Institute prepares a new publishing series entitled *Geodiversity conservation*. Three monographies on the Carpathians (Alexandrowicz & Poprawa, 2000), Holy Cross Mts. (Wróblewski, 2000) and Lower Silesia (Gawlikowska, 2000) have been produced so far. All of them include a text part and colourful maps at scales 1 : 200,000 to 1 : 400,000. The following problems are discussed:

- ❏ assumption data for geoprotection,
- ❏ geological structure outline,
- ❏ areas and objects protected, and selected for protection.

This series is addressed to the government and local administration authorities, as well as to all those interested in the country's nature. It is planned to continue the series, e. g., for the coastal area and Upper Silesia.

Geosites protection

It refers to individual sites of inanimate nature and areas of concentrated geological, geomorphological or landscape values (Wimbledon, 1999). In Poland, such objects are protected by the law as geological sites of international, stratigraphical and regional significance. 194 locations have been preselected for internationally significant geosites in Poland (Alexandrowicz, 2003). Stratigraphically important geosites are represented by 290 candidates preselected at the Polish Geological Institute. Regionally significant geosites are being selected during ongoing geoenvironmental mapping works. A total number of about 400 geosites is estimated to be preselected from the entire area of Poland.

Geological survey officers are obliged to make a short documentation and official legal application for each geosite. In Poland, the procedure of establishing geosites protection is fixed at the local community level.

Geoparks

Geodiversity protection programmes in larger areas can be accomplished by establishing geoparks. The first project of a transboundary area for geodiversity conservation was prepared for the borderland of Poland, Germany and Czech Republic (Badura et al., 2003). The establishing procedure for the creation of this geopark is now far advanced in Poland and Germany. There are also other geoparks proposed to be created:

- ❏ Polish Jura Geopark (near Kraków),
- ❏ Chęciny Geopark (Holy Cross Mts.),
- ❏ Pieniny Geopark (near Krościenko).

Polish legislation does not include the definition of "geopark" yet. It is necessary to redefine the term "geosphere", too. There is also an imprecise term in use: "protection of the Earth's surface".

Geochemical investigations

Substantial development of research on geochemical issues took place in Poland in the 1990s. A project of detailed geochemical maps in 1 : 25,000 scale, started at those times. *Geochemical Atlas of Poland* (Lis & Pasieczna, 1995; Pasieczna, 2003) was also published. A modern and comprehensive environmental geochemistry textbook *Zarys geochemii środowisk*a (Migaszewski & Gałuszka, 2003), covering the topics of circulation of chemical elements, the role of geotoxic substances and organic compounds, and geomedicine problems, has lately been published.

Monitoring of the geosphere

There is no separate item concerning monitoring of the geosphere in the Polish Nature Monitoring System. Meanwhile, the ongoing endo- and exogenic, and also anthropogenic changes require a continuous monitoring treatment.

The ongoing changes refer to the following:

A. Sector monitoring
1. Monitoring of changes in the lithosphere
— vertical movement,
— changes in magnetism,
— temperature changes,
— geochemical changes.
2. Monitoring of mining areas
— surface topography,
— hydrogeology,
— waste.
3. Monitoring of ground waters
4. Monitoring of surface erosion
— water erosion,
— wind erosion,
— landslides.
5. Monitoring of soils
— chemical composition,
— moisture,
— structure.
6. Monitoring of wetland environments
7. Monitoring of surface waters
— flowing and stagnant waters.
B. Spatial monitoring
8. Monitoring of land use
9. Urban monitoring
— waste

On a larger scale, only monitoring 3, 5 and 7 is currently performed.

Site planning

Geodiversity protection can be most effectively accomplished by a proper site planning based on the assumption of sustainable development. The European Regionalized Development Strategy (ERDS) is heading in this direction. The European Landscape Convention of 2000 also keeps up with the same trends.

From 1991 to 2003, already three versions of *The Ecological Policy of Poland* were proposed. There is still the crucial problem with devolving these directional assumptions to be carried out at the local (community) level.

Conclusions

Studies on geodiversity are a relatively young scientific field. There is a great disproportion between studies on biological diversity and on geodiversity. The former already has an international convention and many outstanding projects such as the European Ecological Network NATURA 2000. Currently there is a need to intensify works on geodiversity, in particular with reference to the following issues:

- ❏ establishing legal basis for geodiversity protection, e.g., geoparks,
- ❏ standardizing concepts and terminology,
- ❏ developing mapping of geodiversity, and preparing a regional and European atlas of geodiversity,
- ❏ preparing a draft of an international convention on geodiversity protection.

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In the foreground Lake Inulec, in the distance lakes Tałty and Mikołajskie, as well as lake Łuknajno — a World Biosphere Preserve. On the right the vast surface of Lake Śniardwy — the Poland's largest lake; photo M. Ostrowski