Geologia dell'Ambiente

Periodico trimestrale della SIGEA
Società Italiana di Geologia Ambientale

Supplemento al n. 3/2012
ISSN 1591-5352

Bari - Italy, 24-28 September 2012

Geoheritage: Protecting and Sharing

7th International Symposium ProGEO on the Conservation of the Geological Heritage
3rd Regional Meeting of the ProGEO SW Europe Working Group

www.geoheritagesymposium-bari2012.org

ProGEO
The European Association for the Conservation of the Geological Heritage

pianetaterra
Le Scienze della Terra per la Società
Commissione Italiana

preprint

Poste Italiane S.p.a. - Spedizione in Abbonamento Postale - D.L. 353/2003 (conv. in L. 27/02/2004 n° 46) art. 1 comma 1 - DCB Roma

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Supplemento al n. 3/2012
Anno XX - luglio-settembre 2012

a cura di VILLAGGIO Globale editore

Iscritto al Registro Nazionale della Stampa n. 06352
Autorizzazione del Tribunale di Roma n. 229
del 31 maggio 1994

Procedura per l'accettazione degli articoli
I lavori sottomessi alla rivista dell'Associazione, dopo che sia stata verificata la loro pertinenza con i temi di interesse della Rivista, saranno sottoposti ad un giudizio di uno o più Referees.

Redazione
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Pubblicità
SIGEA

Stampa
Tipolitografia Acropoli, Alatri - FR

Abbonamento annuale: Euro 30,00

Sommario

In copertina: Il promontorio di Capo Colonna Area calanchiva di Aliano

Mapping regional geodiversity in Brazil and Portugal

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KEYWORDS: GEODIVERSITY, ASSESSMENT, MAP, PARANÁ, XINGU, BRAZIL, PORTUGAL.

ABSTRACT

A methodology meant to be used in the quantitative assessment and mapping of geodiversity was defined for regional scale, following the initial proposal of Pereira et al. (2012). The method was tested in the Xingu Basin, Amazon, Brazil (about 510,000 km2), Paraná State, Brazil (about 200,000 km2), and Portugal mainland (about 89,000 km2). It is a GIS method intended to assess all features of geodiversity and to avoid overrating any particular one, such as lithology or relief, which is a common weakness in other methods. The procedure consists on the overlay of a grid over different types of maps at scales between 1:250 000 and 1:1 000 000. The number of geological units (stratigraphical and lithological) that occurs in each grid cell of the geological map is counted, producing a map of geological indexes. The geomorphological index map results from the sum of the relief and hydrographical indexes obtained from the geomorphological units map. Palaeontological and pedological index maps are obtained from counting palaeontological units and soil units, respectively. The singular occurrences index map is based on the number of occurrences such as precious stones and metals, energy and industrial minerals, mineral waters and springs. The final Geodiversity Map results from the combination of those five partial indexes. The Geodiversity Map is a GIS automatically generated map, which allows an easy interpretation by non specialists. The map can be used as a tool in land-use planning, particularly for the identification of priority areas for conservation, and for the use and management of natural resources.

INTRODUCTION

The concept of geodiversity is quite recent and considered by most experts as "the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, processes) and soil features. It includes their assemblages, relationships, properties, interpretations and systems" (Gray 2004). Usually, geodiversity is considered only as a theoretical approach with no particular use or application and is frequently associated with geological heritage and geoconservation issues (e.g. Alexandrowicz & Kozlowski 1999; Carcavilla et al. 2008; Gray 2004, 2008a, 2008b). Nevertheless, these concepts should not be misinterpreted as being one and the same. Whereas geodiversity refers to all abiotic variety of nature, geological heritage is the set of the most relevant geodiversity elements with particular importance for science, education or tourism (Pereira et al., 2012). During recent years, some attempts were made in order to give geodiversity a more practical approach. For instance, the Brazilian Geological Survey (CPRM) published the Geodiversity Map of Brazil (at 1:2,500,000 scale; CPRM, 2006), which is a synthesis of the major geosystems that constitute the national territory, as well as their limitations and potential uses (Silva, 2008). However, the CPRM geodiversity map is based only on lithostratigraphical and mineral resources databases and does not take into account other geodiversity elements such as landforms, soils, and hydrography, which are also important to support decision-making and land-use management (Pereira et al., 2012). In what concerns geodiversity assessment, the most promising methods are based on the definition and calculation of geodiversity indexes. However, most of them (e.g. Serrano and Ruiz-Flaño 2007; Jackova and Romportl 2008; Benito-Calvo et al. 2009; Zwolinski 2009; Hjort and Luoto 2010) do not consider the whole range of geodiversity elements. Pereira et al. (2012) developed a first approach for the calculation of geodiversity indexes by assessing all geodiversity components and to avoid overrating any particular component, such as lithology or relief. A geodiversity map based on the calculation of a geodiversity index and the outline of isolines was also produced by the authors. This type of map is a good planning tool and allows an easy interpretation by those with little or even no geological background. The state of Paraná (Southern Brazil) with an area of about 200,000 km2 has a set of different cartographical data and for this reason was used in the work here presented as a first test for the methodology proposed. GIS software was used for counting the geodiversity occurrences and the indexes calculation on the Xingu River Basin, Amazon, Brazil, an area of about 510,000 km2. The Geodiversity Map of the Xingu Basin consists of a GIS automatically generated polygon map.

METHODOLOGY

The above proposed method is based on the overlay of a grid over different types of maps, such as geological, geomorphological, and soil maps. The Geodiversity Map is an isolines map obtained from the calculation of a Geodiversity Index for each cell of the grid. Isolines join the central points of cells sharing the same geodiversity index (Pereira et al., 2012). Other thematic maps, such as the geological diversity map or the geomorphological diversity map can also be produced in a similar way. Maps at scales ranging from 1/1,000,000 to 1/250,000 were used. The grid gives raise to cells where units and occurrences can be counted and which allow the discrimination of results. Various grid sizes were tested in order to obtain the best balance between results discrimination and the number of cells. The best results were obtained with a grid-size of 25x25 km resulting in 371 cells for the Paraná State map. For the Xingu Basin, the GIS procedure has generated 2462 cells on a 13.8 x 13.8 km grid. For the Geodiversity Map of Portugal the grid size is still being tested. For each grid cell, the Geodiversity Index score is the sum of the following five partial indexes: i) The Geological Index is calculated by counting the number of geological units occurring in each cell of the grid, which is overlaid on the geological map. ii) The Geomorphological Index is the sum of two sub-indexes: Relief and Hydrography. The Relief Sub-index is calculated by counting units and contacts occurring in each cell of the grid overlaid on the Geomorphological Units Map, a three level classification of morphostructural units, morphosculptural units and morphosculptural sub-units (Santos et al., 2009; Pereira et al., 2012). For this purpose, a brand new map of geomorphogical units was produced for Portugal providing three 1st level units, nine 2nd level units, and 56 3rd level units. The Hydrography Sub-index is based on the assessment of stream categorisation using Strahler's method (Strahler, 1957). iii) The calculation of the Palaeontological Index follows a similar procedure to the one described for the assessment of the Geological Index: the number of different fossiliferous formations is counted in each grid cell overlaid on a geological map (Pereira et al., 2012). iv) The Pedological Index is obtained for each grid cell by counting the soil orders represented in the Map of Soils (Pereira et al., 2012). v) The Singular Occurrences Index is related with geodiversity features not covered in the previous indexes. It was considered: minerals such as precious stones, precious metals, metallic minerals, and industrial minerals; geological energy sources such as coal, oil shale, natural gas, and uranium; mineral waters and springs. Each map occurrence of any of the above items scores one point for the corresponding grid cell. Repeated occurrences of the same element in the same cell are not considered (Pereira et al., 2012).

RESULTS

Taking into account the minimum and maximum values obtained for the Geodiversity Index, five Geodiversity Index classes were considered: very low (<11), low (11-15), medium (16-20), high (21-25), and very high (>25). The Geodiversity Map of Paraná State shows some hot spots of very high geodiversity (> 25) in the east, a region with strong geomorphological contrasts and a large variety of geomorphological and stratigraphical units (Pereira et al., 2012). The Geodiversity Map of Xingu Basin also highlights a hot spot of geodiversity in a region with a larger diversity of rocks, soils and relief, as well as the presence of several mineral occurrences. The preliminary results for the Geodiversity Map of Portugal highlights the western region, which has a large diversity of stratigraphical and palaeontological Mesozoic and Cenozoic units. However, the rich geological diversity of Portugal also originates high values of the Geodiversity Index in other areas of the country. The three given examples show that areas where the occurrence of igneous plutonic rocks is higher have the lower Geodiversity Index.

CONCLUSION

Geodiversity Index maps can be produced for large territories if solid geological, geomorphological and soil units mapping is available. GIS procedures can be used to speed-up the calculation of the geodiversity index and its cartographic representation. Geodiversity can be represented as isolines or polygon maps allowing an easy interpretation by those with no or little geological background. Geodiversity maps can be used as a tool in land-use planning, particularly in identifying priority areas for conservation and the use and management of natural resources.

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