A NEW CLASSIFICATION OF GEOLOGICAL RESOURCES

UNA NUEVA CLASIFICACION DE LOS RECURSOS GEOLÓGICOS

JOSEP M. MATA-PERELLÓ
Ph.D. Dep. of Mining and Natural Resources, Polytechnic University of Catalonia, mata@emrn.upc.edu

ROGER MATA-LLEONART
Msc. Axial Geology and Environment, rmata@colgeocat.org

CARLA VINTRÓ-SÁNCHEZ
Ph.D. Dept. of Business Management, Polytechnic University of Catalonia, carla.vintro@upc.edu

Received for review June 5 th, 2010, accepted March 14th, 2011, final version April, 11 th, 2011

ABSTRACT: The traditional definition of the geological resource term excludes all those elements or processes of the physical environment that show a scientific, didactic, or cultural interest, but do not offer, in principle, an economic potential. The so called *cultural geo-resources* have traditionally not been included within a classification that puts them in the same hierarchical and semantic ranking than the rest of the resources, and there has been no attempt to define a classification of these resources under a more didactic and modern perspective. Hence, in order to catalogue all those geological elements that show a cultural, patrimonial, scientific, or didactic interest as a resource, this paper proposes a new classification in which geo-resources stand in the same hierarchical and semantic ranking than the rest of the resources traditionally catalogued as such.

KEYWORDS: geological resource, classification

RESUMEN: La definición clásica del término recurso excluye a todos aquellos elementos o procesos del medio físico que presentan un interés científico, didáctico o cultural y que como contrapartida no ofrecen en principio un potencial económico. Los llamados *geo-recursos culturales* no se han incluido hasta la fecha en una clasificación que los situé en el mismo rango jerárquico y semántico que el resto de los recursos, ni se ha intentado realizar una clasificación de los recursos bajo una perspectiva más didáctica y acorde con nuestros días. A partir de la idea de dar un reconocimiento de recurso a todos aquellos elementos geológicos que presentan un interés cultural, patrimonial, científico o didáctico se propone una nueva clasificación, en la que los llamados geo-recursos se sitúen en el mismo rango jerárquico y semántico que el resto de los recursos clásicamente definidos.

PALABRAS CLAVE: Recurso geológico, Clasificación

1. INTRODUCTION

Since the remotest of times, the resources that the lithosphere offers have played an essential role in the economic and social development of humanity. Any element present in the environment has its origins in a geological resource, and as a matter of fact, the current exploitation of geological resources is vital for human beings. This leads us to an unavoidable need for an exhaustive knowledge and for a characterization and classification of these resources.

Different proposals of resource classification can be found in the literature. These classifications have been periodically updated by several authors, and the most general ones are universally accepted. Nevertheless, they are all quite far from the current conception of the term *resource*.

We assume that a geological resource is any solid, gas, or liquid element that is in or on the earth's crust and in optimum concentration for its exploitation. However, in our opinion this definition still remains incomplete and we consider as resources all those geological elements that have a scientific, landscaping, or patrimonial value, and especially those with a didactic value. For example, Riba [1] gives an extensive definition and describes natural resources as goods obtained from nature, along the ground, subsoil, water, etc. that are necessary to satisfy human needs. A similar conception of natural resources is found in the definition of Foley, McKenzie, and Utgard [2] in which knowledge plays a central role in the accomplishment of human needs. Both definitions stress the importance of the didactic value.

This article presents a new classification of geological resources that puts both the typical resources and the didactic-type resources in the same hierarchical ranking.

2. ANALYSIS OF THE GEOLOGICAL RESOURCES CLASSIFICATION

Not too long ago, the knowledge of geology was mainly based on the geological history of Earth and its natural resources, which are essential components of our daily lives. It is important to notice that any element present in the environment has its origins in a geological material (for example the fuel for vehicles and means of transport, the chairs we sit on, the frames of our glasses, etc.). Thus, our society depends on geological resources to such an extent that these resources have conditioned the subsistence of the human being and the evolution of the planet itself.

This reality has led to a traditional characterization and classification of resources based on purely economic criteria, which is not an inheritance of the US Geological Survey classifications. For example, the Dictionary of Geology [1] defines the term *geological resource* as any solid, gas or liquid element that is in or on the earth's crust and that is presented in optimum concentrations for its exploitation.

In accordance with this definition, Brobst and Pratt [3] have classified natural resources into reserves and resources, among which they distinguish between renewable and non-renewable.

On the other hand, geological resources have been divided into different types according to their characteristics, properties, and origins, but without regard for their possible multiple uses or profitability.

Several classifications have been suggested by different authors. In accordance with these classifications, it can be determined that mineral resources have traditionally been classified as: industrial or non-metallic, metallic, mineral, energetic materials, rocks and gems. This classification has been in force during the 70s, 80s, and 90s, and it has been updated with modifications introduced by governments or by the technical and scientific entities of each country.

Some national governments hold specific classifications, for example the Spanish Government establishes the same groups as the ones depicted in the nation's Law of Mines [4] which include: resources of section A: stone; resources of section B: ground water, mining-medicinal water, thermal water; resources of section C: minerals; and resources of section D: energetic materials.

Precisely, the individual classifications adopted by each national government show the low level of practical utility that traditional classifications have. This fact points to the need for us to regulate geological resources considering the particular socioeconomic situation of a given region, even though the individual classifications are seemingly biased by the traditional classifications and therefore follow the same pattern as the traditional classifications.

A breakthrough classification is the proposal of Ordóñez et al. [5] that divides the resources into: energetic, raw materials for industry, hydraulic, edaphic, and cultural-landscaping. The approach held by the authors tries to extend the term *geological resource.*

Currently, different authors have adopted the term *cultural geo-resources* when referring to geological elements that have contributed to a high scientific and didactic value [5].

3. THE DRAWBACKS OF THE TRADITIONAL CLASSIFICATION

The traditional classification of resources (Table 1) holds some practical drawbacks if we analyze its application within social and economic activity. Specifically, three inherent problems can be highlighted:

The first problem is that the classification referred to does not contemplate the possibility of a resource being included simultaneously in two different groups. For example, is it not possible that an energetic material may also be an industrial mineral? Cannot a metallic mineral be an industrial mineral too? Do rocks not have an industrial use?

In fact, many metallic minerals are industrial minerals too, so there is an overlap among the different groups (Fig. 1).

Table 1. Traditional classification of geo-resources

RENEWABLE	NON RENEWABLE
Water	Rocks
	Non metallic minerals
	Metallic minerals
	Gems
	Industrial rocks or minerals
	Energetic materials

The second problem is that there is only a hierarchical and semantic order: renewable and non-renewable. But when we consider the subgroups renewable and non-renewable, we observe that there is no hierarchical level and that the substantives assigned to describe the subgroups do not share the same root words, and therefore the semantic criteria is not sustained. Consequently, we are not able to know which group is more important and it is difficult to enlarge the classification in an orderly way.

The third problem is that the traditional classification is not adapted to the current trends of sustainable development, as is described in the 1992 Rio Conference. Only the elements that have some economic value are considered to be being resources in the traditional classification, and the other elements that present social or educational profits are discarded. In this regard, it is fundamental to have the resources that will be used in education included therein.

Some authors have gauged this last problem, and have introduced some definitions of the geological resource terms that take human and not just economic needs into consideration. For example, the Dictionary of Geology [1] offers the following definition of natural resource: "any natural asset obtained from nature, along the ground, subsoil, water, etc. to satisfy human needs." Similarly, Foley et al. [2], UNESCO and PROGEO [6] have introduced these considerations in their programs to catalogue the geological patrimony.

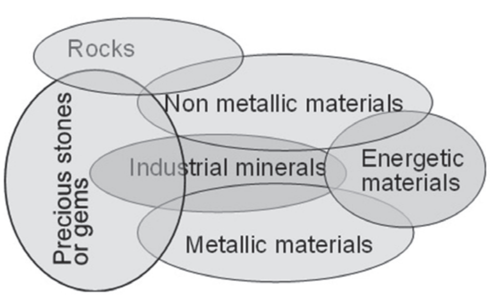

Figure 1. Graphic outline of the overlap among different groups of geological resources [7]

4. A NEW CLASSIFICATION FOR GEOLOGICAL RESOURCES

As stated above, the traditional classification does not entirely fit in with the current trends in geology which are aimed at protecting, preserving, and spreading the knowledge of geological elements of scientific and didactic interest. Such a classification does not consider those outcrops, materials, structures or geological processes that present a didactic value (and do not have an economic interest) to be resources; and neither does it contemplate the guidelines stated in the 1992 Rio Conference. Thus, all those geological elements that have value should be catalogued as an economic, social, scientific, landscaping, patrimonial, or didactic resource.

The drawback that impedes progress is that although the patrimony or the geological resources of cultural, scientific, and didactic types have been included within the classifications of geological resources, how to fit these resources correctly into the subgroups or categories defined by the classifications has not been dealt with, since they have not been placed on a hierarchical and semantic scale. Thus, these resources have only been referred to as *cultural resources*, *cultural geo-resources*, or *patrimonial resources*.

One of the first approaches to the inclusion of the geological resources of a cultural type into the same level than the rest of the resources is that of Elizaga [8] in which the so-called *cultural geo-resources* are introduced. This approach has been widely accepted up to the present time and it constitutes an important milestone. Nevertheless, it does not achieve placing patrimonial type resources at the same level than the rest of the resources, but rather, establishes them as a mere addition.

On the other hand, the so-called *cultural* or *patrimonial geo-resources* have been mainly classified according to their physical or genetic characteristics into different groups: tectonic, volcanic, stratigraphical, geomorphological, and mineralogical [9]. This classification is very suitable for cataloguing patrimony, and it has been employed in the majority of inventories and catalogues carried out. But, as it focuses on purely geological aspects, it is not quite effective for use in entities not devoted to geology.

The classification suggested in this paper attempts to classify the geological resources, including the so-called *cultural geo-resources*, considering their potential and usage. It is structured into two main groups: extractable and non-extractable geological resources.

The non-extractable group includes those outcrops, elements, or geological processes that present a cultural, scientific, didactic, patrimonial, or recreational value. According to this order of ideas, the so-called *geo-resources* are integrated into the same level as the rest of the economic resources.

The extractable resources group includes any solid, gas, or liquid element that is in or on the earth's crust in optimum concentration for its exploitation. Also, the extraction of these resources must be a basic element for the subsistence of society and therefore does not generate irreversible natural, social, or educational impacts.

The proposed classification considers non-extractable resources to be any solid, gas, or liquid element, or any geological process that is found in or on the earth's crust and that has some optimum characteristics that make it suitable to be used in educational and/or cultural activities, or that favors the sustainable development of society and therefore increases human quality of life. This is why conservation and advising protection are needed to assure sustainable extraction. In accordance with this new classification, it is also necessary to redefine the concept of *reserve*.

All known and identified resources that can be exploited with an economic, social, cultural, touristic, scientific, and/or educational profit, and that benefit social needs, will be considered as reserves. The classification proposed for the first group includes different subgroups, each of which sustains the hierarchical level with respect to the other ones and the semantic level, since it is recommended to denominate each subgroup with the beginning words "destined for..." or "used as...".

The classification introduced in this paper achieves the three main goals of any systematic classification:

1. Resources that have a non-limited scientific, cultural, patrimonial, or didactic value are included within the classification of resources of economic value.

2. The new types of resources, which are in the same hierarchical and semantic rank sustaining the levels of classification together with the typical resources, are integrated in the classification and therefore they are not included as an addition or appendix.

3. The resources are classified according to their characteristics, properties, and utilities, and not only considering the characteristics themselves as it was done up to a few years ago.

4. A single resource is not limited to one field alone, since that resource can present multiple benefits.

The proposed classification is detailed on Table 2, and it should be complemented with the classification of Mata-Perelló [10] for the group of extractable resources.

Table 2. Reclassification of geological resources

EXTRACTABLE	NON-EXTRACTABLE	
E1. Destined for metallurgy and extractive chemistry	NE1. Scientific	
E2. Destined for energetic activities	NE2. Cultural	
E3. Destined for transformation or manufacture industries	NE3. Heritage	
E4. Destined for public construction works and complementary industries	NE4. Didactic	N
E5.Destined for farm activities and soil usages	NE5. Recreational	
E6.Used as gems or decorative elements		
RENEWABLE		

In view of the simplicity of this new classification and of its ease of use, we consider it to be unnecessary to make an explanatory description beyond what is seen on the table.

A second level of division for each group of extractable resource is detailed below:

E1. GEOLOGICAL MATERIALS DESTINED FOR METALLURGY AND CHEMISTRY

1.1 Minerals and applications of metallic chemical elements

1.2 Sources of non-metallic chemical elements

1.3 Melt materials and refractory materials [11]

E2. GEOLOGICAL MATERIALS DESTINED FOR ENERGETIC ACTIVITIES

2.1 Minerals of radioactive elements used in nuclear fission

2.2 Geological materials used in nuclear fusion

2.3 Geological materials used in thermoelectric plants

2.4 Geological materials used in hydroelectric energy

2.5 Geological materials used for tidal energy

2.6 Geological materials used for geothermal energy

2.7 Materials used in obtaining solar energy

2.8 Materials used in obtaining wind power

E3. GEOLOGICAL MATERIALS DESTINED FOR HEAVY TRANSFORMATION OR MANUFACTURE INDUSTRIES

3.1 Materials destined for heavy industry and agronomic activities (fertilizers, pesticides, and micronutrients are also included)

3.2 Materials destined for the asphalt industry

3.3 Materials destined for the rubber industry

3.4 Materials destined for the pottery industry

3.5 Materials destined for the cosmetic and perfume industry

3.6 Materials destined for the detergent and soap industry

3.7 Materials destined for the electrical power industry

3.8 Materials destined for the electronic industry (including laser)

3.9 Materials destined for the explosives and fuel industries

3.10 Materials destined for the medical industry (including antiseptic materials and purifiers of waters)

3.11 Materials destined for the cold and heat industry (including preservatives)

3.12 Materials destined for the mechanical industry (including abrasive materials)

3.13 Materials destined for the mining and geological industries (the ones related with the surveys are included, too)

3.14 Materials destined for the optic industries

3.15 Materials destined for the wastepaper basket industry

3.16 Materials destined for the adhesives industry

3.17 Materials destined for the pyrotechnic industry

3.18 Materials destined for the plastic industry

3.19 Materials destined for the chemical industry

3.20 Materials destined for the watch industry

3.21 Materials destined for the coir industry

3.22 Materials destined for the textile industry

3.23 Materials destined for the transport industry

3.24 Materials destined for the glass industry

3.25 Materials used as absorbents in different industries

3.26 Materials used as binders in different industries

3.27 Materials used as insulators in different industries

3.28 Materials used as antifreeze

3.29 Materials used as industrial materials in different activities

3.30 Materials used as lubricants in different industrial activities

3.31 Materials used as industrial pigments, dyes, tinges and colors (leads -of pencil- are also included)

E4. DESTINED FOR THE CONSTRUCTION, IN PUBLIC WORKS AND IN RELATED INDUSTRIES OF COMPLEMENTS.

4.1 Geological materials used in the construction of walls, coatings and roofs

4.2 Metallic materials used in the manufacture of structures in construction and in public works

4.3 Geological materials used in binders

4.4 Geological materials used in the manufacture of ceramic materials [12]

4.5 Geological materials used in the manufacture of glasses
4.6 Geological materials used in obtaining pigments and mineral colors
4.7 Geological materials used as insulators

E5. DESTINED FOR FARM ACTIVITIES AND SOIL USAGES.

5.1 Geological materials or processes to help in developing agronomic zones
5.2 Geological materials used to improve farm or agronomic activities
5.3 Geological materials, outcrops o reprocesses to maintain the adequate soil conditions or to reduce its vulnerability

E6. GEOLOGICAL MATERIALS (OR WORKED) USED AS GEMS, OR ORNAMENTAL MATERIALS.

A subdivision for non-extractable is not included, as it depends on the specific needs and characteristics of every zone.

5. CONCLUSIONS

The classification presented in this paper holds important advantages, especially in the field of education and more specifically in the first levels of education to help students understand that one resource belongs to one group or another depending on its use, the type of resource an outcrop is, or that a bed of chalks has portrayed a formation to itself (as for example a bed of iron). This would enhance a global perception of the environment.

On the other hand, the application of this classification simplifies the development of studies like evaluations of environmental impacts or the development of special plans for natural spaces management, and it also facilitates the management of protected zones.

Mackeley [13] evaluates the importance of geological resources in society considering the level or quality of life. He formulates (1) that the standard of living (L) depends on natural resources (R), energy (E), capacity of inventiveness (I) and population (P).

$$L = (R \cdot E \cdot I) / P \qquad (1)$$

Until not too long ago, the USGS only considered and introduced in the calculation the resources of an economic type, in part due to the difficulty of including geo-cultural resources at the same level.

The new classification proposed in this paper, enables us to perform the evaluation considering both the extractable and the non-extractable resources at the same rank. Thus, now the quality of life also depends on geological resources that do not offer a direct economic benefit but offer a patrimonial interest.

REFERENCES

[1] Riba, O., ET AL., Diccionari de Geologia. Pub. Institut d´Estudis Catalans. Enciclopèdia de Catalunya, Barcelona, 1407 P. 1998.

[2] Foley, D., Mckenzie, G., and Utgard, R., Investigations in Environmental Geology, Prentice-Hall, New Jersey, 1999.

[3] Brobst, D. and Pratt, W., United States Mineral Resources, U.S. Geological Survey Professional Paper 820 P., 1973.

[4] LEY DE MINAS, Ley 22/1973 de 21 de julio de Minas. España, 1973.

[5] Ordóñez, S., Calvo, J.P., Lunar, R. and Lopez Vera, F., Concepto y tipos de recursos naturales, Geología y Medio Ambiente. CEOTMA, Madrid, 1981.

[6] Parkes M. (ED.), Natural and Cultural Landscapes, The Geological Foundation. Proceedings of a conference and the ProGEO Third General Assembly. Dublin Castle, Ireland. Royal Irish Academy, 9–11 September 2002.

[7] Bennet, M and Doyle, P., Environmental Geology, John Wiley & sons Ltd. Chichester, England, 1997.

[8] Elizaga, E., Georrecursos culturales, In: Geología Ambiental (Eds. Ayala-Carcedo and Jordá Pardo), IGME, pp. 85-100, 1988.

[9] Ayala-Carcedo, F.J., et al., Geología y Medio Ambiente. Guía didáctica y colección de diapositivas, Instituto Geológico y Minero de España (IGME), Madrid, 1998.

[10] Mata-Perelló, J.M., Unpublished: Los materiales geológicos y su aprovechamiento por la sociedad, UPC, 1996.

[11] Pérez, G.Z; Vargas, Y.C. y Córdoba, E.M., Beneficio

de arcilla caolinítica de la región de Barichara (Santander) para la fabricación de refractarios. *Revista Dyna*, Nº 164 (diciembre de 2010), vol 77, Revista Dyna, pp.28-38. 2010

[12] Santos, J.D; Malagón, P.Y. y Córdoba, E.M., Caracterización de arcillas y preparación de pastas cerámicas para la fabricación de tejas y ladrillos en la región de Barichara, Santander. Nº 167 (junio de 2011), vol 78, Revista Dyna, pp.49-58. 2011

[13] Mckelvey, V., Mineral resource estimates and public policy, In: Mineral Resources (Eds. Brobst and Pratt), U.S. Geological Survey Professional Paper 820, pp. 9-19, 1973.