

THE GEOLOGICAL CHART OF THE VOLCANIC ZONE OF LA GARROTXA NATURAL PARK

M. Losantos ⁽¹⁾; L. Planagumà ⁽²⁾; J. Pijuan ⁽²⁾; A. de Paz ⁽¹⁾; C. Puig ⁽¹⁾ and E. Bassols ⁽²⁾

(1) *Unitat de Geologia. Institut Cartogràfic de Catalunya (SGC-ICC). Dpt. de Política Territorial i Obres Públiques. mlosantos@icc.es, apaz@icc.es, cpuig@icc.es.*

(2) *Parc Natural de la Zona Volcànica de la Garrotxa (PNZVG). Dpt. de Medi Ambient i Habitatge. lloren@toscaea.org, jpijuan@gencat.net, webassol@gencat.net.*

KEY WORDS: *Geological map, Popularization, Quaternary Volcanism, Active Tourism, Catalonia.*

The aim of this work is to present the first geological map to cover in its entirety one of Catalonia's Natural Parks: the Geological Chart of the Volcanic Zone of la Garrotxa Natural Park (PNZVG in its Catalan abbreviation). This is one of the most singular protected areas in Catalonia, because it is the most well preserved volcanic area in the whole Iberian Peninsula, and so it is of a great geological interest.

PROJECT FRAMEWORK

The first detailed geological map of the Volcanic Zone of la Garrotxa was made by Mallarach in 1982, a nice piece of work which is currently out of print. Further enlargements of the protected area and new advances on its geological knowledge, lead the Park's staff to consider the compilation of a new, specific map in collaboration with the Geological Survey of Catalonia (SGC), thus updating the first one and covering the entire, expanded new area.

Within the framework of competences of the Servei de Parcs Naturals del Departament de Medi Ambient i Habitatge de la Generalitat de Catalunya (DMAH) there are some precedents of this kind of documents, as is the case of the Pedraforca Massif, inside the Natural Park of the Cadí - Moixeró, from which a conventional geological map of this emblematic area was published.

From the part of the former Servei Geològic de Catalunya (SGC) and the Unitat de Geologia de l'Institut Cartogràfic de Catalunya (UG-ICC), the orders for detailed geological mapping of a certain part of the quaternary volcanoes started in 1984 (Mallarach 1984, 1987 and 1989, Martí, 1987, Gimeno, 2000) and they were reviewed as they were being incorporated to the sheets of the Mapa Geològic de Catalunya 1:25.000 series (MGC25M) which cover the areas with quaternary volcanic outcrops.

The collaboration established during the last years between the PNZVG and the UG-ICC

allowed the definition of the cartographic units of volcanic rocks (Losantos and Puig, 1997) which have been used for the geological mapping works of the Zona Volcànica de la Garrotxa. Later on, the contents and the characteristics of a map on the volcanism of the PNZVG were jointly established.

The publication of this Geologic Chart is thus the result of an order of the Dept. de Medi Ambient i Habitatge (DMAH) to the Institut Cartogràfic de Catalunya (ICC). At the same time the geological cartography of the GIS of the PNZVG (Vulcà project) will be updated and completed with the geological data obtained by the Unitat de Geologia of the ICC during the compilation of the sheets of the MGC25M corresponding to the Zona Volcànica de la Garrotxa.

BACKGROUND

It's a well-known fact that volcanism is one of the most popular geological phenomena since it is one of the few processes that can be witnessed. Eruptions can last for weeks, months or even years. In addition to that, volcanism is a phenomenon that creates new landscapes. A volcanic eruption anywhere in the world is major news.

For some time now, the visitors to the Information Centres of this Natural Park confirmed a clear request for informative geological guides and maps. This request can be explained if we take into account that most of the visitors to the Park can be classified as what is called "active tourism", that is, those who show interest in acquiring knowledge in an easy way during their visit to these areas.

The published information available to the visitors to the PNZVG can be summarized as follows:

- *El Parc Natural de la Zona Volcànica de la Garrotxa.* "The volcanic zone of la Garrotxa Natural Parc". Booklet and topographic map which includes the services provided by the Park and details of Nature Trails.
- *El Vulcanisme. Guia de Camp de la Zona Volcànica de la Garrotxa* (Martí et al. 2000) "Vulcanism. Field guide of la Garrotxa volcanic zone". Divulging book on

general vulcanology, including the most interesting outcrops in the park. Edited by PNZVG. 3000 copies have been published with sales of 400 units per year.

- Explanatory panels on the subject of interesting outcrops, not necessarily related to the nature trails, are spread all along the park.
- *Mapa Geològic de Catalunya 1:25.000*, sheets Olot, Santa Pau, Banyoles, Amer and Canet d'Adri (1997-2003). This is a general geological map, so its aim is not divulgative. The whole area of the park is covered by 9 sheets, three of which are yet to be published.

The geological maps *El vulcanisme de les comarques Gironines* (Pallí, 1981) and *Carta Geològica de la Regió Volcànica d'Olot* (Mallarach, 1982) have been out of print for a long time.

All the cartographic documents quoted here, including the out of print geological maps, are available to the interested persons in the PNZVG library, together with other information on vulcanology.

One of the visitor's suggestions collected in the Information Centres of the Park is the re-edition of the *Carta Geològica de la Regió Volcànica d'Olot* (Mallarach, 1982). On the other hand, a study on the contents in the subject of environmental education, concludes that most of people are unable to read and interpret a topographic map (Fanlo, 1995). The ability to interpret a geological map has not been asked about, but naturally it should be much less.

It was then necessary to make available to the visitors to the PNZVG a cartographic document with geologic content, which is plain and understandable, focussed on volcanism and related processes.

Taking advantage of the UG-ICC's knowledge on the subject of geological cartography and the PNZVG's experience in publishing divulging literature, it was possible to define more clearly the aim of the printed Chart: to improve the Visitors' perception of the whole Park by relating geologic and geomorphologic features of volcanic origin. The nature trails, the outcrops with information panels and sites of geological interest described in the Field Guide of la Garrotxa Volcanic Zone will also be noted.

THE QUATERNARY VOLCANISM IN LA GARROTXA VOLCANIC ZONE

The Volcanic Zone of la Garrotxa is located in the North-East of Catalonia. It is one of the best preserved volcanic quaternary areas in the Iberian Peninsula and is therefore of great geologic and touristic interest. From the history of the Geology point of view, this area already aroused the interest of Charles Lyell, who visited it in 1830.

Volcanism in this area is related to the extensional context which affected the Western Mediterranean during Neogene and Quaternary. In

the Volcanic Zone of la Garrotxa only poorly differentiated alkaline basalts are represented.

Each volcano in the Volcanic Zone of la Garrotxa was the result of a single short-lived eruption but combining different processes of expulsion of the molten lava in many volcanic vents. Two main kinds of volcanic activity can be recognized: effusive and explosive.

During effusive phases, basaltic lava flowed away from the volcanic vents. Lava flows show currently a massive aspect, with columnar and slabby jointing. Except for the most recent ones, the surfaces of the lava flows are strongly weathered, including the development of andosols on their tops which allow for fertile cultivated lowlands. These basalts are only well exposed in scattered outcrops located in erosive scarps of the drainage network.

The explosive activity produced strombolian and hydromagmatic deposits and morphologies. Cinder cones are the result of explosive strombolian volcanic activity, which piled up pyroclasts. The small sizes of the more of forty cinder cones in the park make them very attractive for the public. Hydromagmatic explosive activity produced pyroclastic flows and pyroclastic surge deposits. Explosive hydromagmatic crater exhibit an evident round depressed shape in the bedrock.

Concerning the age of the volcanic activity in the area, the oldest dated lava flow is $590,000 \pm 200,000$ YBP and the most recent is $11,500 \pm 1,100$ YBP (Puiguriquer, 2005).

MAIN FEATURES OF THE "GEOLOGICAL CHART OF THE VOLCANIC ZONE OF LA GARROTXA"

The GIS tools have been used to prepare and homogenize the two geological databases available in the UG-ICC, each one covering a part of the future Geological Chart. The first one is coming from the MGC25M and cover 2/3 of the whole chart; the second comes from BGC50M (Geological data base of Catalonia scale 1:50.000, Puig et al, 2000). The first works consist in establish equivalences between cartographic units in both databases and the aggregation of some of them to simplify the Pre-quaternary bedrock geology.

In order to improve the area covered by the BGD50M some data on volcanic rocks has been taken out from the PNZVG GIS ('Vulca' project). The photogeological analysis of the quaternary sedimentary deposits has also been added. In some areas it has been necessary to revise specific outcrops to establish more carefully the boundaries between cartographic units, especially those of volcanic flows.

AREA

The area shown in the Geological Chart is larger than the PNZVG surface because the lava flows coming from volcanic vents included in the Natural Park extend beyond the Park's boundaries in the Llèmana, Brugent, Fluvià and Ser rivers. We considered that this extended area provides a high degree of completeness.

SUPPORT

Publishing a conventional geological map has been disregarded, as it would only be readable by geologists. The Geological Chart is printed on a hill-shade from the DEM (Fig. 1). This support makes the reading of the geological information easier, especially in those areas where the geological elements have a strong morphological expression, as is the case of recent volcanoes.

VOLCANIC ROCKS

In the Geological Chart lava and pyroclastic flows have been related to their volcanic vent or, when that is not possible, to the zone of exposure. Each lava flow is represented in the Geological Chart by means of a different colour and an indicative acronym. Lava flow directions are also shown, and in the most recent ones tumulus have been represented.

In some volcanoes spatter are also recognized. Basalts in vents or necks and ring-dykes have been considered as a whole.

Pyroclastic cones are shown with their geomorphological features, that is slope and crater rims symbolized. In the hydromagmatic explosive craters their rims are also represented. Pyroclastic mantle bedding have been considered as undifferentiated in relation to their magmatic or hydromagmatic origin and to the volcanic vent they come from. These are usually built up by

pyroclastic flow deposits associated with strombolian air-fall deposits.

QUATERNARY SEDIMENTARY DEPOSITS

The quaternary sediments are closely related to the volcanic activity and the morphological changes involved, especially those favoured by river valley volcanic damming. In the Volcanic Zone of la Garrotxa alluvial and lacustrine deposits are widely represented. All these units have been substantially simplified and their relative chronology has also been removed to simplify the reading of the chart, for there are quaternary deposits related with several volcanoes.

GEOLOGY OF PRE-QUATERNARY BEDROCK

Pre-quaternary bedrock has been simplified in the Chart in comparison with a conventional geological map; several Palaeogene sedimentary units have been grouped according to their lithology and origin, forgetting about geochronological criteria. Palaeozoic rocks have also been simplified.

GEOLOGICAL STRUCTURE

In the whole Geological Chart the contacts between cartographic units have not been printed and the minor faults and folds affecting Palaeogene bedrock have also been omitted. Only the major faults have been represented but without any indication about their displacements.

MAP KEY

Just as for the criteria of cartographic units' definition, the map key is essentially descriptive (Thorpe and Brown, 1985) although a short explanation about the origin of each geological unit has been included.

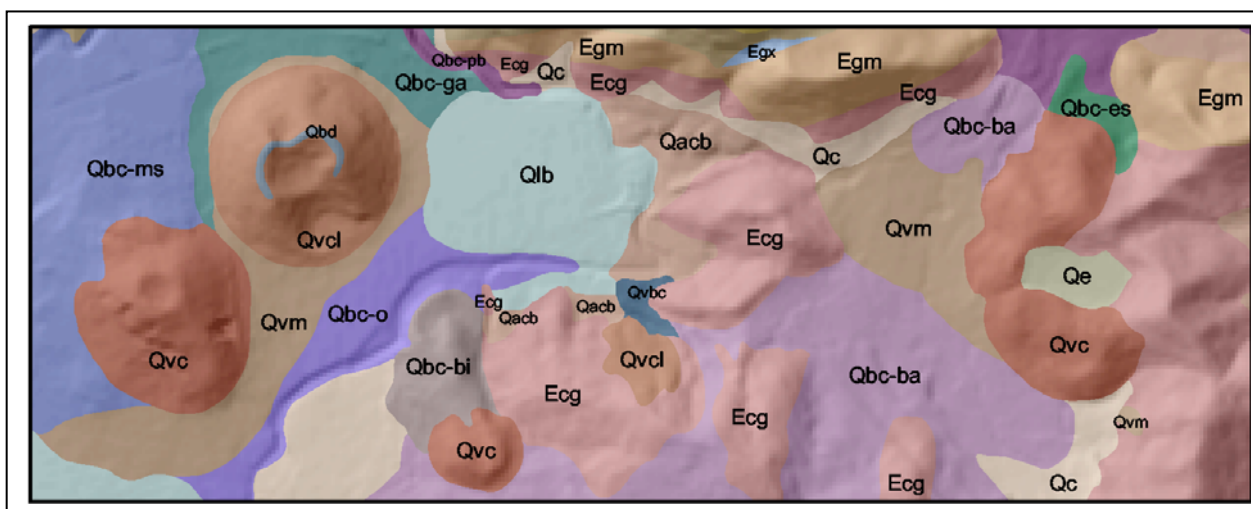


Figure 1 - Image of a sector from the "Carta Geològica del Parc Natural de la Zona Volcànica de la Garrotxa".

DATA BASE OF THE NATURAL PARK OF LA GARROTXA VOLCANIC ZONE “VULCÀ”

Although the Geological Chart expresses the geological information in a relatively simplified way, all the geological data referring to the relationships between volcanoes and lava flows used for its compilation will be added to the geological database of PNZVG “Vulcà”.

The “Vulcà” project was developed jointly between the Centre de Recerca Ecològica i Aplicacions Forestals (CREAF), ICC and DMAH. In 1995 “Vulcà” was implemented as a tool for the Park Natural management.

In the Geothematic Module lithologic and geomorphologic maps are available (Mallarach, 1998) as well as geological sites of special interest (Planaguma, 2001). Borehole position and absolute dating are also provided.

Obviously the main contribution to “Vulcà” is the mapping of the different lava flows and the features of their contacts. That is a great improvement especially where there is an overlay of two or more lava flows.

Subsurface extension of lava flows overlapped (or covered) by quaternary sedimentary deposits was previously included in “Vulcà” but is not printed in the Geological Chart. Now, the correlation between outcropping lava flows and buried ones may be possible.

The knowledge of bedrock features and an approach to their hidrogeological behaviour will be a good tool for the interpretation of hydromagmatic phenomena.

CONCLUSIONS

Compilation of the “Geological Chart of the volcanic zone of la Garrotxa” allows us to establish the appropriate methodology which is useful to generate divulging geological maps.

As a result, a simplified geological map will be published, for wandering around the Park, without pretending to be an in-depth interpretation. This map intends to ease the interpretation of the landscape and to focus on the volcanoes, lava flows and other products of the eruptive activity.

All that remains now is to wait for the response of the Park’s visitors to that new “*Carta Geològica del Parc Natural de la Zona Volcànica de la Garrotxa*”. We hope that the visitors will welcome the new chart and will provide positive feedback on its usefulness.

In any case, we would like that this document will become the first of a special “Geological Charts” series aimed at the most interested visitors of all the Natural Parks in Catalonia.

ACKNOWLEDGEMENTS

We would like to thank X. Berástegui, M. Vilà and E. Pi for their helpful comments.

REFERENCES

- FANLO, E., 1995. Recerca sobre els continguts en matèria d’educació ambiental a la població local de la Zona Volcànica de la Garrotxa. Inèdit.
- GIMENO, D. (RSE), 2000. Cartografia geològica dels materials volcànics dels voltants de Santa Pau (Garrotxa). SGC. Inèdit.
- LOSANTOS, M. and PUIG, C., 1997. Estructura de la llegenda general per als materials volcànics quaternaris del Mapa geològic de Catalunya 1:25.000. 2 Jornades de Recerca al PNZVG.
- MALLARACH, J.M., 1982. Carta Geològica de la regió volcànica d’Olot. Litologia i Geomorfologia. Ed Maber. Ajuntament d’Olot.
- MALLARACH, J.M., 1984. Revisió del vulcanisme Quaternari de Catalunya, Primera part. Mapa dels dipòsits volcànics quaternaris, 1ª part. SGC. Inèdit.
- MALLARACH, J.M., 1987. El vulcanisme quaternari de la conca mitjana del riu Ter. Mapa dels dipòsits volcànics del Gironès (4 mapes), 2ª part. SGC. Inèdit.
- MALLARACH, J.M., 1989. Monografia sobre el vulcanisme quaternari a Catalunya. SGC. Inèdit.
- MALLARACH, J.M., 1998. El vulcanisme prehistòric de Catalunya. Diputació de Girona.
- MARTÍ, J., 1987. Memòria sobre l’estudi del vulcanisme explosiu Gironí i ordenació del risc volcànic. SGC. Inèdit.
- MARTÍ, J., PUJADAS, A., FERRÉS, D., PLANAGUMÀ, L. and MALLARACH, J.M., 2000. El Vulcanisme. Guia de Camp de la Zona Volcànica de la Garrotxa. Ed. PNZVG.
- PALLÍ, L., 1981. El vulcanisme de les comarques Gironines. Diputació de Girona i Col. Universitari de Girona.
- PLANAGUMA, L., 2001. Cartografies d’afloraments i dipòsits d’interès del Parc Natural de la Zona Volcànica de la Garrotxa. Inèdit.
- PUIG, C., BERÁSTEGUI, X. and BARNOLAS, A., 2000. The new 1:50,000 geologic map of Catalonia and related databases. An ITGE-ICC corporate experience. Proceedings of the Third Congress on Regional Geological Cartography and Information Systems. Munich.
- PUIGURIGUER, M., 2005. Cerca, compilació i anàlisi de la bibliografia existent entorn a la cronologia de la zona volcànica de la Garrotxa. PNZVG. Inèdit.
- THORPE, R. and BROWN, G., 1985. The field description of Igneous Rocks. GSL Handbook. Open University Press.
- VAQUER, R. and MARTÍ, J., 1983. Informe sobre la denominació dels materials volcànics (gredes) objecte d’explotació a la zona Olot-Santa Pau, Garrotxa. SGC. Inèdit.

GEOSCIENCE TEACHING FOR ENVIRONMENTAL EDUCATION: THE CASE OF SAO JOSE DO RIO PRETO, SAO PAULO STATE, BRAZIL

Celso Dal Ré Carneiro ⁽¹⁾ and Joseli Maria Piranha ⁽²⁾

(1) Department of Geosciences Applied to Teaching, Institute of Geosciences – The State University of Campinas, Unicamp. P.O. Box 6152, 13083-970, Campinas, Sao Paulo, Brazil; cedrec@ige.unicamp.br.

(2) Department of Chemistry and Environmental Sciences, Unesp – São Paulo State University, Institute of Biosciences, Letters and Exact Sciences; Cristovao Colombo Street, 2265, Sao Jose do Rio Preto, Sao Paulo, Brazil; joseli@ibilce.unesp.br.

KEY WORDS: *Geologic information; geosciences education; information technologies, water.*

INTRODUCTION

Sao Jose do Rio Preto (SJRP) is a municipality situated 450 km far from the Sao Paulo city, the capital of the Sao Paulo State. Since the end of the 1970's, a fast and uncontrolled phenomena of urban growth turned critical the situation of freshwater public supply in SJRP. At the same time the population growth has intensified pressures on the use and protection of water reserves. Under crescent restrictions to the use of available surface reserves, a higher demand for water has elevated the demand for underground water, due to the good quality of the collected resource and also for the low costs of production, as long as treatment facilities are not necessary.

By the other hand there was no criteria for the exploitation control and preservation of the quality of the reserves. This is an optimal example of the more general situation of exploitation of water resources in the São Paulo State. It stresses out the need of urgent management measures to turn the development into conditions of sustainability.

Identifying the effects of urban population growth as a cause of overpressure on underground water resources the city uses is one thing; protecting them is another.

The present communication aims at to synthesize the main features and some results of an experience of education and learning that has been conducted there since 2004 to address the challenge of sustainability.

A STEP FOR DIFFUSION OF KNOWLEDGE IN THE SOCIETY

Two specific inter-related factors have expanded the city's demand for knowledge on water issues:

- the local population has presented special concern with the precarious and problematic situation of water public supply;
- increasing public claims exerted a strong influence on governmental agencies in setting measures towards

improving the conditions for sustainable development of the city.

People's concern with water issues has stimulated children to look for information from their teachers. A corollary of this scenary was a strong increase on the request of courses and other education alternatives offered by educators in the city.

The experience here described puts into evidence that an organized participation of the people can be able to promote and to support management initiatives. The engagement of the society may represent a valuable partnership for a government.

THE CASE STUDY

Situated in a recharge area of the water-bearing Bauru system, a hydrogeologic unit responsible for the supplying of about 70% of the cities of Sao Paulo State, and presenting such characteristics of intensive urban development, the city motivated some research to evaluate the situation of use of the water reserves from the point of view of land occupation and associated environmental issues.

The bedrock is mainly composed by impure sandstones of the Bauru Group, which composes the Parana sedimentary basin. From the decade of 1990 on a series of surveys for characterization of potential sources of pollution of hydric resources in the city have been developed along with studies on the local public supply and characteristics of exploitation of the main surface and underground water reserves that constitute sources of water in the city. The results were synthesized by Piranha *et al.* (2004).

The studies have allowed production of land occupation thematic maps, which relate water demand and the environmental situation. They make it possible to construct databases that may help planning of urban and agricultural development, with special attention to the use of water reserves, exploitation, pollution risks, control, mitigation of impacts and recovery. They constitute, thus, an environmental diagnosis of the