

Geological Heritage of the International Douro Natural Park (NE Portugal): geoconservation strategies

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1. The International Douro Natural Park (PNDI): rich geodiversity and relevant geological heritage

The portuguese national park system covers about 7% of the portuguese territory and includes one national park, twelve natural parks, nine natural reserves and three protected landscapes, among other local areas.

In 1998, Portugal assigned the status of Natural Park to the deep valleys of the international Douro and Águeda Rivers – the International Douro Natural Park (*Parque Natural do Douro Internacional*, PNDI) – in the Portuguese-Spanish border, northeastern Portugal. The 851 km² of the park include 130 km of these international rivers and a narrow contiguous area of the old peneplain landscape known as Iberian Meseta. The establishment of this park was due to the high relevance of the geomorphology, wildlife, natural flora and cultural heritage.

The PNDI is located in one of the most complex geological areas of the Variscan Central Iberian Zone (CIZ), having a diversified geology dominated by a sequence of autochthonous units largely covering the geological scale, from the Neoproterozoic to the Cenozoic, and a sequence of allochthonous units that belong to the nappes front of the Morais Massif (Fig. 1, Plate D; see Ribeiro, 1974, Ribeiro *et al.*, 1990, Pereira *et al.*, 2000 and 2004 for a synthesis of the geology of NE Trás-os-

Montes). These successions include the Precambrian Massif of Miranda do Douro (Ribeiro, 1974; Castro *et al.*, 1998; Ferreira *et al.*, 2000), one of the rare evidences of the pre-Variscan basement in CIZ, as well as a great diversity of Variscan granitic rocks (Ferreira *et al.*, 2000; Miranda, 2003; Dias *et al.*, 2003; Gomes, 2005).

The PNDI is an example of a national protected area with a notable geodiversity and peculiar landscapes associated with the fluvial canyons of the international Douro and Águeda Rivers (NE Portugal-Spain border; Fig. 2, Plate D). The spectacular steep cliffs, regionally named *Arribas do Douro*, are the major landscape feature of the region and the 'ex-libris' of the PNDI (Fig. 3, Plate D). They were developed during the incision of the Douro River and its tributaries on the Iberian Meseta, crosscutting granitic and metasedimentary terranes, under the control of the fracture network. This geological setting provides one of the most important nesting habitat in Europe for vultures, eagles and black storks. The floristic heritage found on the rock slopes and ancient floodplains is also relevant. Evidence of the close relationship with the geological characteristics is also given by the millenary human occupation of the abrupt slopes, profiting from the microclimatic conditions for the production of wine, olive and almond, as well as by the traditional uses of geological materials by man.

In conclusion, the PNDI has a relevant geological heritage (Ferreira *et al.*, 2003), which provides the support for its biodiversity. Therefore, the nature conservation policies must take this strong linkage into account.

2. The PNAT project: geoconservation strategies and initiatives in the PNDI

Protected areas constitute key zones to implement geoconservation strategies but, as in many other countries, geology is absent from the majority of the portuguese protected areas statutes (Brilha, 2002). Efforts are being developed by portuguese geologists in order to change this situation. On the other hand, the integration of relevant geological information in the park management plans is nowadays being requested by park managers.

Since 2000 Portuguese geologists from the University of Minho and from the Geological Survey are working together in protected areas from Northern Portugal, namely in the PNDI in the scope of a multidisciplinary research project (PNAT project), sponsored by FCT (Portuguese Science and Technology Foundation) and ICN (Portuguese Nature Conservation Institute). This project aims to: (i) improve the geological knowledge in the PNDI; (ii) proceed with the inventory and characterisation of geosites; (iii) create scientific instruments to support a sustainable management of resources and territory; (iv) contribute to the increase of public awareness of Natural Heritage.

In order to achieve the above objectives, the following activities were developed: (i) improvement of the geological mapping; (ii) characterisation of geomorphological features and processes and development of the geomorphological mapping; (iii) inventory of geological resources; (iv) systematic inventory and characterisation of geosites, with reference to its content, value, utility and relevance, and their integration in a database; (v) characterisation of geological materials through specific studies, as a support for mapping and geosites characterisation.

As results of the project, deliverables are being made available to the PNDI managers as scientific support for management plans in this area, namely: geological and geomorphological maps at 1:100 000 scale (Figs. 1 and 2, Plate D); geological resources map; geosite map with a synthesis of the characterisation parameters. Furthermore, this project is providing several products with the purpose of increasing public awareness of geodiversity and geoconservation (Dias & Brilha, 2004). Among these outputs we emphasise interpretative panels, geological guides and booklets for either specific geosites or trails, and web pages. Two additional initiatives are being developed in the scope of this project: the training of staff from this Natural Park who, in the future, will be guiding field trips; and the organisation of guided field trips (summer field trips addressed to the general public, as well as guided field trips specifically addressed to the school population).

The experience obtained with this project shows that comprehensive projects like this one should be applied to other Portuguese protected areas where the knowledge and management of geological heritage is still far from adequate.

Stop description and topics for discussion

The Theme 3 of Field Trip *Geology as background for a top-class geological and cultural heritage in the Douro region (Northern Portugal)* intends to give a large overview of the geological heritage of the PNDI and propose some topics for discussion about geoconservation and adopted strategies. Two stops are previewed (see Fig. 4, Plate D for their geological setting).

Stop 3.1 – The international Douro river: landscapes and biodiversity

Location

Carrascalinho viewpoint (Fornos, Freixo de Espada à Cinta, PNDI).

Points of interest

- The Iberian Meseta and the incision of the Douro River on the high plateau;
- Geomorphology of the international Douro River valley;
- Tectonic control of the channel;
- Granites and granitic morphology.

Topics for discussion

- Geodiversity – biodiversity linkage;
- Geoconservation policies: experiences and challenges;
- Geological heritage and sustainable development;
- Increase park managers awareness of geological heritage.

Description

The Iberian Meseta is a large geomorphological unity, developed in granitic and metasedimentary rocks of the Hesperian Massif. The Meseta is an old and

extensive plain, one of the largest in Europe, located about 700 m above sea level.

The Douro River, in the PNDI area, carved an entrenched valley cutting the high plateau, as can be seen at the Carrascalinho viewpoint (Fig. 5, Plate D). Here the Douro River crosscuts Variscan granitoids, being exposed some typical granite landforms (tors and other castellated forms, blocks, wedges, *gnammas*). The Douro channel orientation is clearly controlled by the fracture network. The main orientation of the international Douro course is influenced by the NNE-SSW to NE-SW fractures. Locally, the valley is under the control of NW-SE, N-S, and E-W fractures, which promote the occurrence of incised meanders. The major fractures are late Variscan and some of them were reactivated during the Alpine orogeny.

The present day Douro River represents a snapshot of an ancient fluvial evolution. The former Douro basin has been considered an intracontinental basin of cratonic type. Its western boundary is a relatively flat Hercynian border that remained essentially passive during the Cenozoic (Santisban *et al.*, 1996; Alves *et al.*, 2004). Probably until Zanclean, fluvial drainage in NE Portugal was endorheic, towards the Douro basin. The major hydrographical reorganization in the area occurred during Miocene-Pliocene times. In the Late Pliocene, an important fluvial network was already captured by the fluvial pattern that drained towards the Atlantic. Therefore the endorheic Tertiary Douro Basin turned into a generally exorheic basin by the end of the Pliocene (Pereira *et al.*, 2000). The landscape reflects an active Quaternary downcutting of the basement, associated with the incision of the Douro River and its tributaries. This process is controlled by the Atlantic base level and by the fracture network (Alves *et al.*, 2004).

The geomorphological features induce different climatic characteristics between the high plain and the valley. Climate in the valley has Mediterranean characteristics, and is more humid and softer than at the plateau. The mean annual temperature in the valley is 15°C, with few days below 0°C in the winter. These particular climate conditions allowed the establishment of fauna and flora typical of southern latitudes along the Douro River and its tributary, the Águeda River. Another evidence of the close relationship between geological, geomorphological, and climatic characteristics is given by the millenary human occupation of the slopes taking advantage of a particular microclimate for the production of wine, olive, almond and orange.

As referred, two complementary geomorphological units characterize the PNDI: the high plateau and the canyons.

A large diversity of landforms occurs on the canyon sidewalls, such as vertical cliffs, steep dipping slopes, some with inverse dip, convex surfaces, domes, turrets, castellated blocks, angular blocks, split blocks, foliation slabs, wedges, rock caves, cliff-foot caves, clefts and rocky steps (Alves *et al.*, 2004). This diversity of morphological features, as well as the nearby high plain, offers a diverse flora and fauna habitat, which are important for the ecological balance of the park.

The plateau is an ecological mosaic of woods, groves, corn-lands, and other plantations. This diversity allows the existence of insect species and wild mammals, as the roe deer, the wild boar, the wolf, the otter (in the main rivers), bats, and also reptiles and amphibians. There are also autochthonous species of cattle and sheep, which contribute for the nourishment of the eagles and vultures communities. The plateau around the main valleys is dominated by pastureland, sclerophyllous scrub, *Quercus* sp. and *Juniperus oxicedrus* woodland.

Several species of animals and plants have their main habitat inside the canyon. The geological and ecological features are a benefit for cliff nesting species, in particular for the eighteen bird species that build their nests in colonies on rocky clefts, caves and steps (Monteiro, 1998). These bird species are the PNDI emblematic group, as for example: Griffon Vulture (*Gyps fulvus*); Egyptian Vulture (*Neophron percnopterus*), elected for the park symbol; Golden Eagle (*Aquila chrysaetus*); Bonelli's Eagle (*Hieraaetus fasciatus*); Peregrine Falcon (*Falco peregrinus*); Eagle Owl (*Bubo bubo*); Black Stork (*Ciconia nigra*); Chough (*Pyrrhocorax pyrrhocorax*). The PNDI is one of the most important areas in Europe for this group of species. The bare rocks are also inhabited by floristic species growing in fractures and clefts, some of them millenary. In the canyon several species are frequently found, such as the alder, the arbutus-berry, the ash-tree, the juniper, the lotus-tree, the oak, the oak evergreen and also plantations of wine, olive, almond, chestnut and orange in the southern area of the park.

This rich biodiversity was responsible for the classification of this region as Site of Community Importance (SCI) and Special Protection Area (SPA).

In conclusion, the PNDI presents a richness of natural features constituting a reference in the Portuguese natural park system. In this natural park the

most significant geomorphological feature is the fluvial canyon of the Douro River and its tributary, the Águeda river, dissecting the high plateau of the Iberian Meseta and crossing various geological terranes where a large diversity of landforms are exposed. This relevant geosite, locally known as *Arribas do Douro*, the PNDI *ex-libris*, conditioned the establishment of many ecosystems. This is an ecological region of great value, due to a large number of species, particularly rupicolous birds, sedentary and migratory, which search this area for nesting. The valley/plateau landscape features provide the support for the food chain equilibrium of the various ecosystems. Due to the strong links between PNDI geodiversity and biodiversity, conservation policies must be undertaken together. This holistic approach is very important for park management and, consequently, for environmental education.

Stop 3.2 – The Ribeira do Mosteiro geosite: adopted strategies to raise public awareness of geological heritage

Location

Ribeira do Mosteiro viewpoint (Poiares, Freixo de Espada à Cinta, PNDI)

Points of interest

- The Lower Ordovician Quartzite Formation: stratigraphy and tectonics
- Variscan tectonics at different scales
- Landscape controlled by lithology and tectonics
- A geosite with scientific and pedagogical values
- A geosite and an interpretative panel
- A geosite and a thematic trail

Topics for discussion

- Geosites inventory: methodology
- Raise public awareness of geodiversity and geoconservation: strategies and experiences

- Interpretative panels: how to make geological panels appropriate for users
- General trails vs. thematic trails

Description

The Ribeira do Mosteiro viewpoint is a geosite with relevant scientific, pedagogical and aesthetic values (Fig. 6, Plate D).

Here, the lower member of the so-called Armorican Quartzite Formation is well represented (Fig. 4, Plate D). The Lower Quartzites member (Ribeiro, 1974; Rebelo, 1983) is composed by cm- to dam-thickness beds of compact quartzite intercalated with mm- to m-thickness beds of darkish grey or pinkish phyllites and quartz-phyllites. Ferreira da Silva & Ribeiro (1994) estimated a maximum thickness of about 400 m for the Quartzite Formation in this area. Sedimentary structures are frequent in the quartzite layers, namely: cross- and graded-bedding, convolute lamination, load casts, pseudonodules and, in some places, ripple marks. The Lower Ordovician age for the Quartzite Formation is confirmed by several authors (e.g. Teixeira & Rebelo, 1976; Rebelo & Romano, 1986; Coke & Gutiérrez-Marco, 1995; Coke, 2000; Sá *et al.*, 2003).

The Ribeira do Mosteiro viewpoint is located in the Poiares synclinal, a Variscan megastructure with E-W major axis and sub-vertical axial plane. Spectacular disharmonic folds with large amplitude can be seen from this viewpoint. Observation of folded structures at different scales, from the outcrop to the landscape and even to the cartographic scale, can here be emphasised. Other geological and geomorphological features are remarkable: differential weathering and erosion controlled by lithological contrasts; the Ribeira do Mosteiro valley, an incised valley controlled by lithology and tectonics.

In conclusion, the Ribeira do Mosteiro geosite meet the following characteristics: relevant litho-stratigraphic, tectonic and geomorphological contents with scientific, pedagogical and aesthetic values; good accessibility and low vulnerability. Therefore, some initiatives were developed in order to make public this natural heritage and having also in view to contribute to the increase of public awareness of Geology and Earth

Heritage. These initiatives are being carried out in a joint effort with the PNDI managers and technical staff. We emphasize the following initiatives that are being carried out in a joint effort with the PNDI managers and technical staff:

- Interpretative panel

A thematic panel was set up at the Ribeira do Mosteiro viewpoint. Contents, design and presentation of the panel follow a set of guidelines. Contents are interpretative rather than informative and based on features that can be observed (lithology, folding and land-shaping processes), with a clear distinction between observation and interpretation. A lectern-type (130x100 cm) presentation and a graphics-rich/text poor layout are used. Basic contents are displayed at the centre of the panel, occupying the majority of the surface. Additional information and/or interpretation are given in a left-side coloured strip. At the bottom schematic cross-sections present the geological evolution of the region.

- Trails

This viewpoint integrates a pedestrian trail of about 8 km, as well as a more extensive car circuit linking the two main villages in the region (Poiães and Barca d'Alva). The trails have geological, geomorphological, cultural and archaeological interest. The Ribeira do Mosteiro viewpoint is the last stop of the pedestrian trail, being the on-site interpretative panel a support for a synthesis of the observed geological and geomorphological features.

- Guided field trips

Summer field trips addressed to the general public are being organised, as well as guided field trips specifically addressed to the school population.

The Portuguese government (the former Ministry of Science and Technology) promotes, since 1998, a very successful programme called "Geology in the Summer" with the aim of raising public awareness of Geology. During the summer season geologists organize field trips and other activities all over the country, which

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constitute a good opportunity to talk about geodiversity, geological heritage and geoconservation, and the importance of geology in our society. Several "Geology in the Summer" activities inside the PNDI were organised, in particular at the Ribeira do Mosteiro area. This experience, as well as other experiences in the Montesinho Natural Park (NE Portugal) and in the Peneda-Gerês National Park (NW Portugal), shows that the public is very interested in learning about geological features, probably due to a general insufficiency of available geological information and to the fact that guided walks and personal interaction with geologists is greatly appreciated.

Organisation in the scope of the project POCTI/PNAT/CTE/15008/99 *Geology of the Montesinho and the International Douro Natural Parks (NE Portugal): Characterization of the Geological Heritage* (Earth Sciences Centre, University of Minho and Geology Department, National Institute of Engineering, Technology and Innovation), sponsored by FCT (Portuguese Science and Technology Foundation) and ICN (Portuguese Nature Conservation Institute).

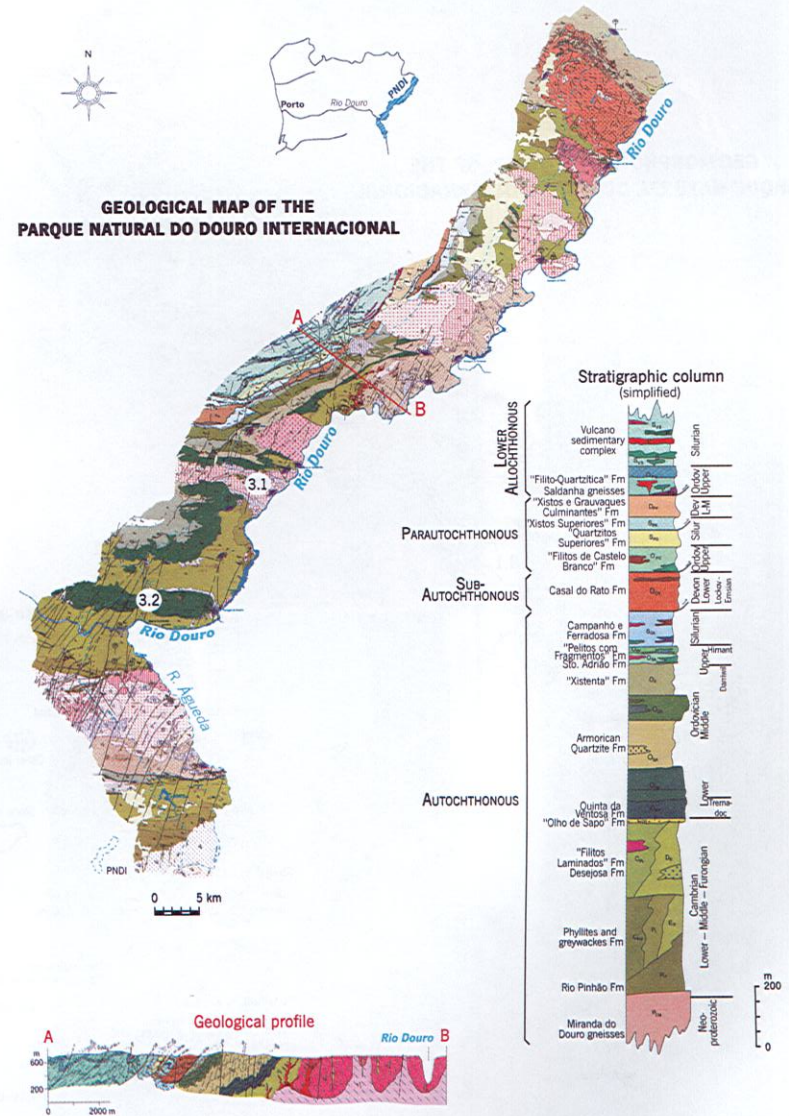
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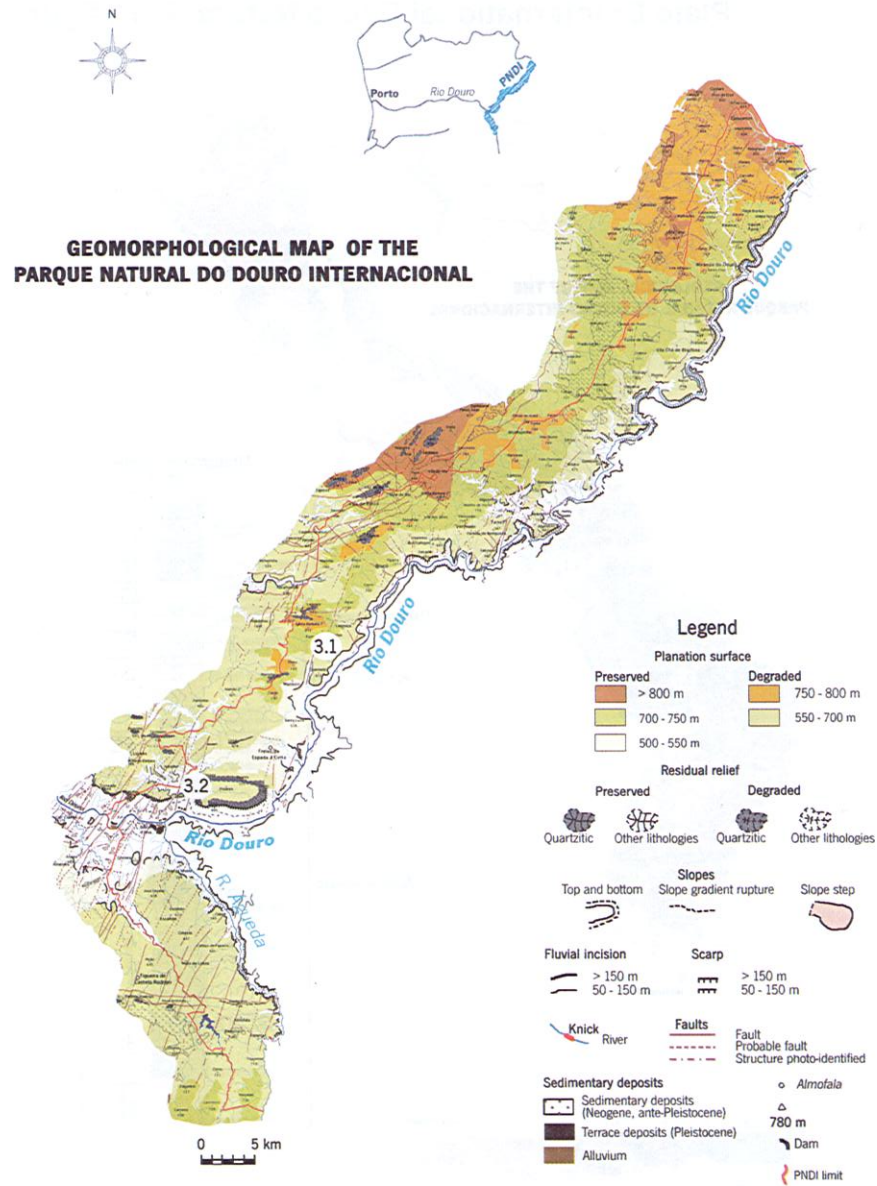
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Plate D: International Douro Natural Park figures



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Fig. 1: Geological sketch map of the PNDI, after Carta Geológica do Parque Natural do Douro Internacional, at 1:100 000 scale (N. Ferreira, Coord., in publication). Stops location: 3.1 and 3.2.



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Fig. 2: Geomorphological sketch map of the PNDI (after Carta Geomorfológica do Parque Natural do Douro Internacional, at 1:100 000 scale (M.I.C. Alves & D.I. Pereira, in publication). Stops location: 3.1 and 3.2.

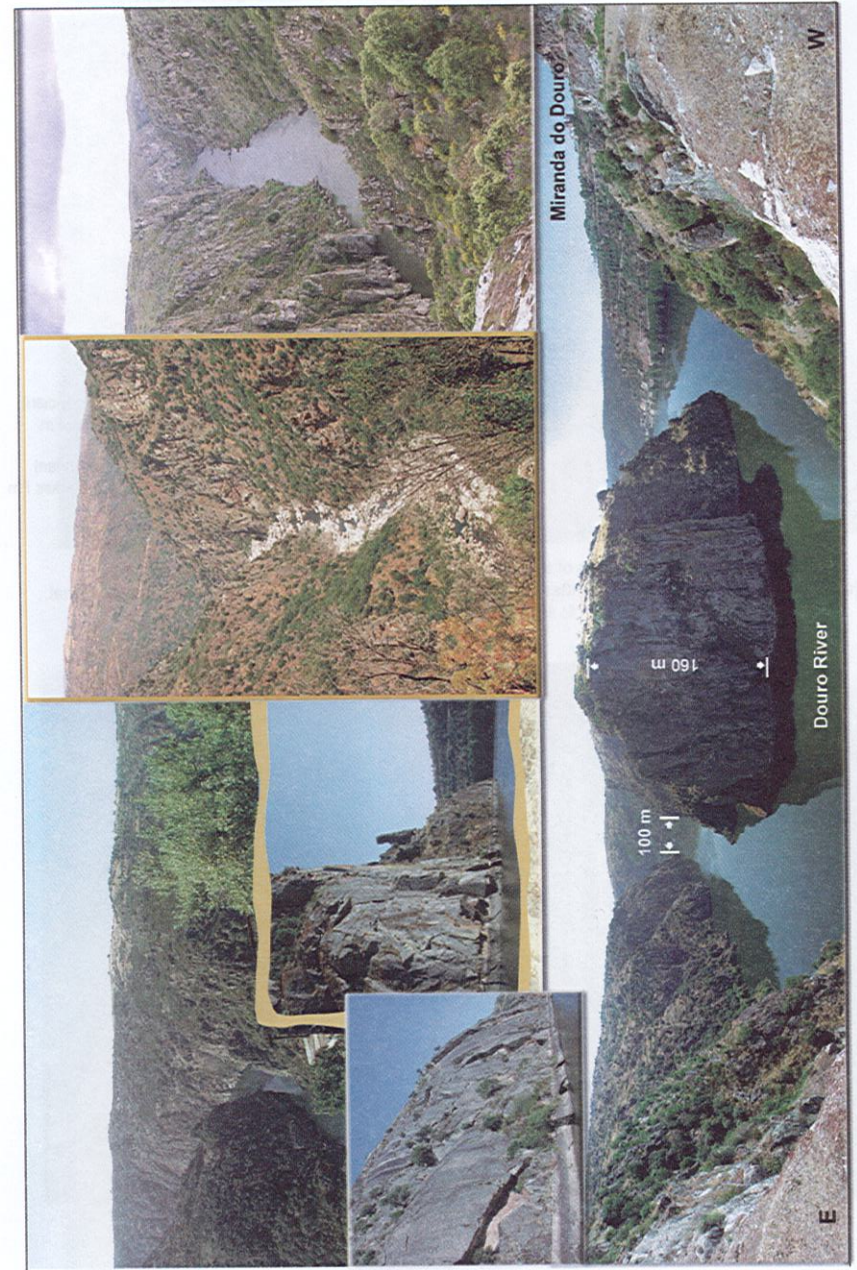
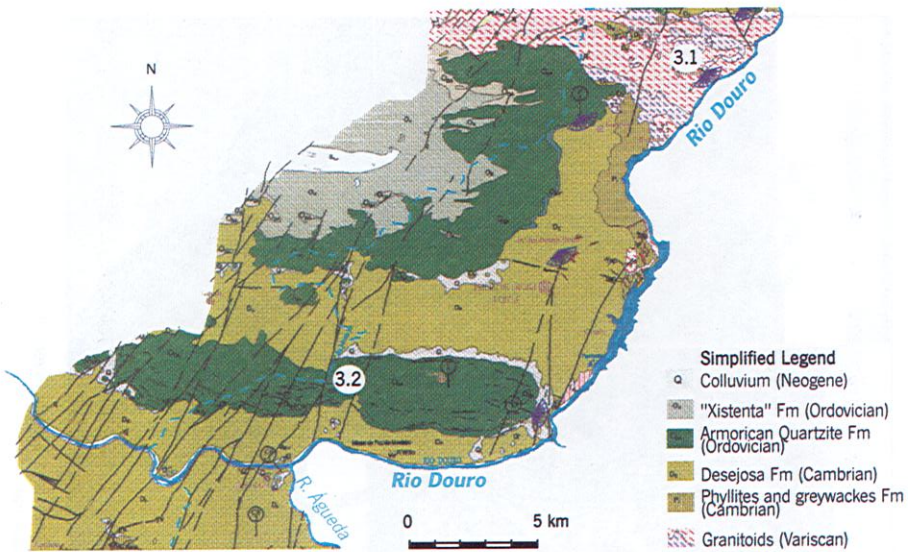


Fig. 3 – Views of the fluvial canyons of the international Douro and Águeda Rivers at the Parque Natural do Douro Internacional



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Fig. 4: Geological setting of the Carrascalinho and Ribeira do Mosteiro viewpoints (stops 3.1 and 3.2, respectively). After Carta Geológica do Parque Natural do Douro Internacional, at 1: 100 000 scale (N. Ferreira, Coord., in publication).



Fig. 5 – The Iberian Meseta and the incision of the Douro River from the Carrascalinho viewpoint (PNDI).

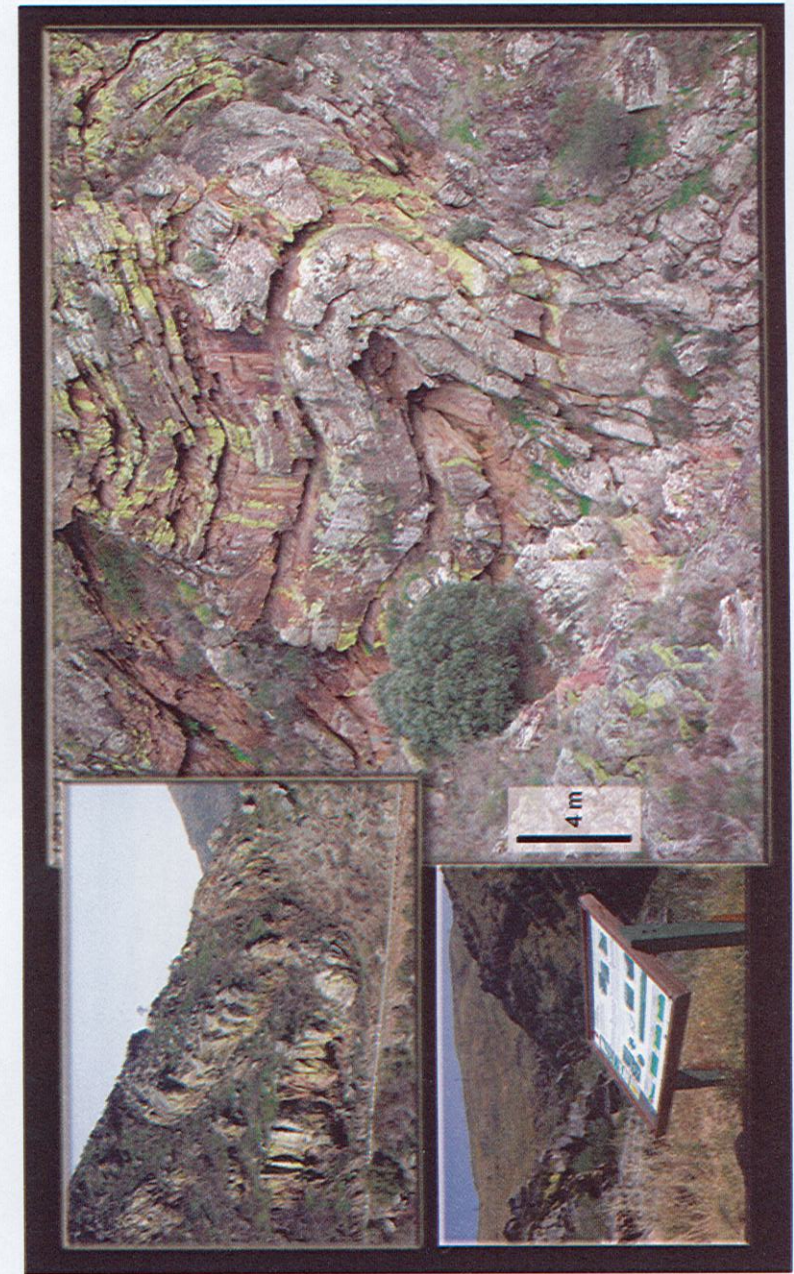
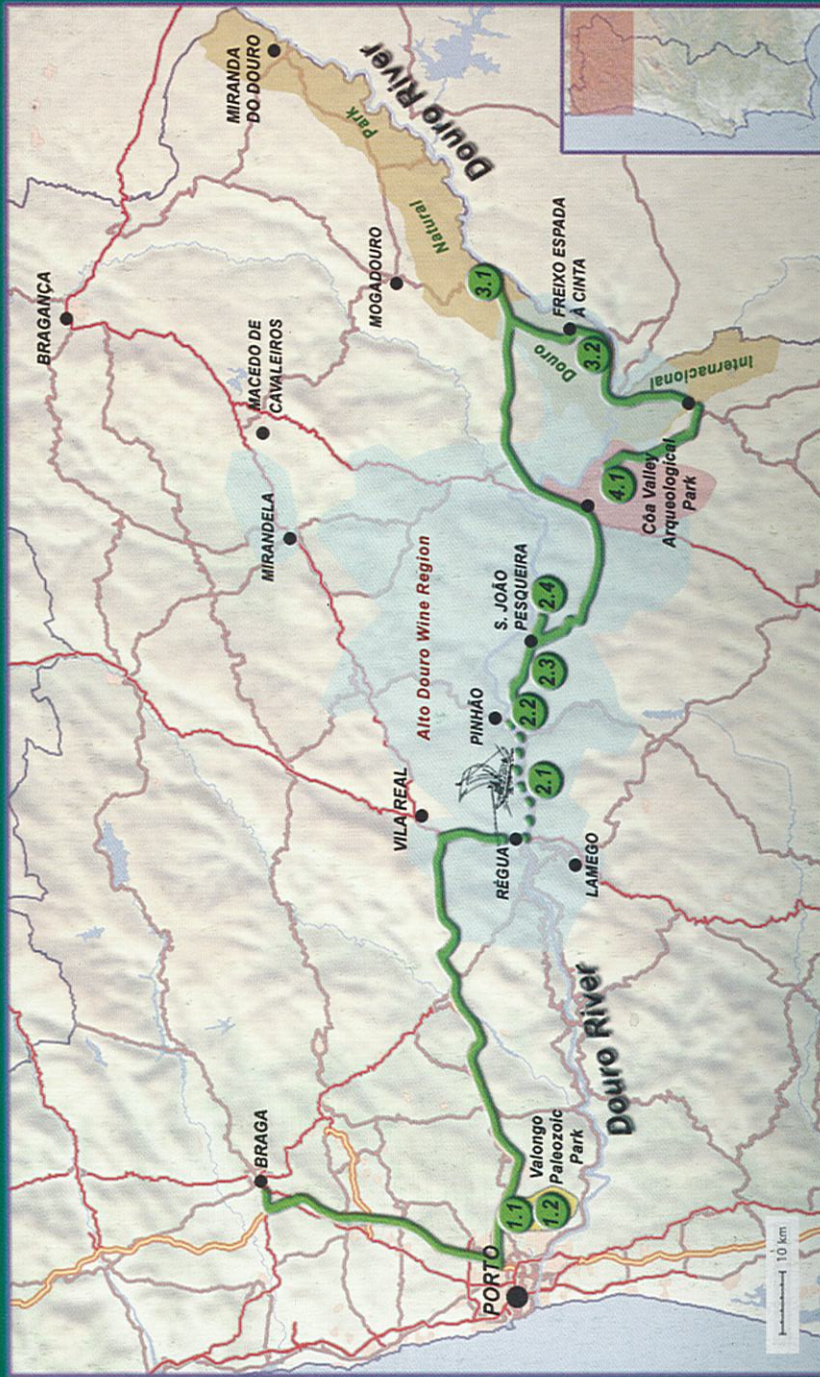


Fig. 6 – General landscape and Variscan folding affecting the Lower Ordovician Formation (Ribeira do Mosteiro viewpoint, PNDI).



Geology as background for a top-class geological and cultural heritage in the Douro region (Northern Portugal)

Geology as background for a top-class geological and cultural heritage in the Douro region (Northern Portugal)

Field Trip Guide Book



Edited by:

Diamantino Pereira and Paulo Pereira