Clay mineralogy and geochemistry of soils from Serra da Estrela Natural Park (Central Portugal): preliminary results

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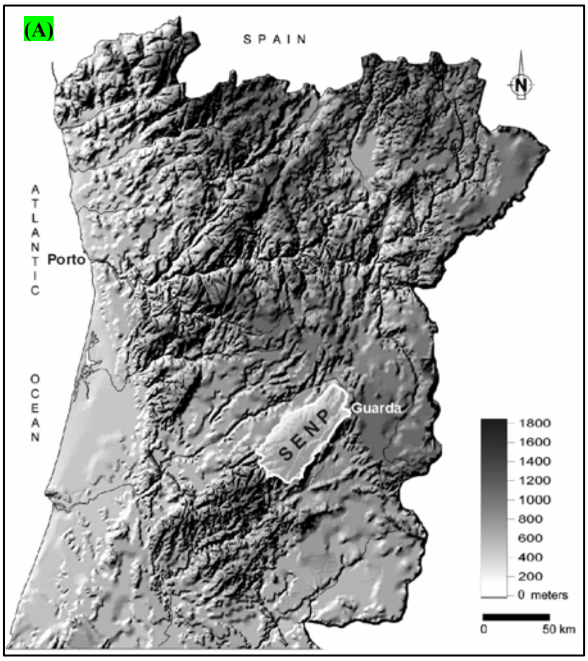
Resumo
Neste trabalho apresentam-se resultados preliminares de estudos mineralógicos e geoquímicos de solos de um sector do Parque Natural da Serra da Estrela (Maciço Ibérico, Centro de Portugal).. O estudo é parte de um projecto integrado que aborda de modo multidisciplinar a caracterização dos recursos hidrogeológicos da Serra da Estrela. O estudo do solo compreendeu diversas campanhas de amostragem, realizadas em 2004, entrosadas com estudos de cartografia geológica e hidrogeológica de pormenor. A mineralogia principal destas amostras é essencialmente detrítica, composta por filossilicatos (ilite, caulinite, vermiculite, interestratificados de ilite-esmectite e esmectite) acompanhados por quartzo, plagioclase e feldspato-K. De entre os elementos químicos maiores analisados, Al e Fe são os que apresentam os valores mais significativos, seguidos por K e, em algumas amostras, por Ca e Mg; o Na apresenta sempre valores muito baixos. Por fim, tecem-se algumas considerações sobre as condições geológicas relacionadas com a formação dos solos estudados.

Abstract
This paper presents preliminary results concerning soil mineralogy and geochemistry in a sector of Serra da Estrela Natural Park (Iberian Massif, Central Portugal). The study is a component of an integrated multidisciplinary approach planned to carry out a broad characterisation of groundwater in Serra da Estrela granitic massif. The soil study included several fieldwork campaigns carried out during 2004, along with geological and hydrogeological mapping studies. The mineralogy of these samples is basically detrital, consisting mainly of phyllosilicates (illite, kaolinite, vermiculite, illite-smectite mixed-layers and smectite), followed by quartz, plagioclase and K-feldspar. Al and Fe show the higher values for the analysed set of elements, followed by K and, in some samples, Ca and Mg; Na shows always very low values. Some considerations relating to the soil formation geologic conditions are also presented.

Introduction

This paper presents preliminary results concerning soil mineralogy and geochemistry in a sector of Serra da Estrela Natural Park (Fig. 1). The study is a component of an integrated multidisciplinary approach intended to carry out a broad characterisation of groundwater in Serra da Estrela (Iberian Massif, Central Portugal). The Serra da Estrela mountain region presents specific geologic, geomorphologic and climatic characteristics that play an important role on soil formation and, therefore, on infiltration and aquifer recharge. The study area consists of the river Zêzere basin upstream the village of Manteigas and its surroundings, corresponding to *ca.* 28 km^2. The altitude of the catchment ranges from 875m a.s.l. (at the streamflow measurement weir of Manteigas) to 1993m a.s.l. (at the Torre summit). The most important geologic units consist of Variscan granites; Precambrian-Cambrian metasedimentary rocks; alluvium and Quaternary glacial deposits. The main regional tectonic structure is the NNE-SSW Bragança-Vilariça-Manteigas-Unhais da Serra fault zone (Ribeiro 1988, Ribeiro *et al.* 1990). The most important landforms of this sector of Serra da Estrela are two plateaus, separated by the NNE-SSW valley of river Zêzere (Fig. 1): the Torre – Penhas Douradas plateau (1450-1993m a.s.l.), and the Alto da Pedrice – Curral do Vento plateau (1450-1760m a.s.l.). Another distinctive feature of the basin is the presence of Late Pleistocene glacial landforms and deposits (Daveau *et al.* 1997). According to Daveau *et al.* (1997) and Vieira & Mora (1998), the Serra da Estrela climate has a Mediterranean regime with a high mean annual precipitation reaching 2500mm in the upper areas. Mean annual air temperatures are below 7ºC in most of the plateau area and, in the Torre vicinity, they may be as low as 4ºC.



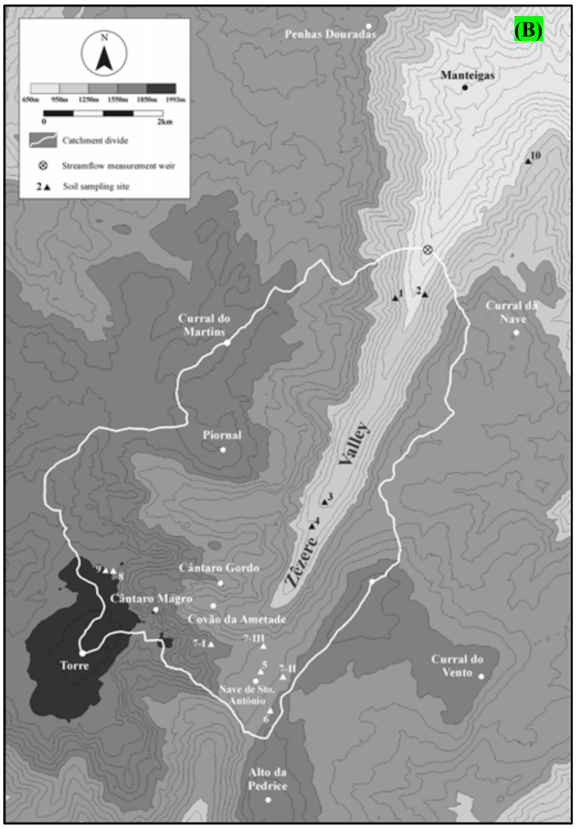


Figure 1 — **A)** Morphological features of Northern and Central Portugal and location of Serra da Estrela Natural Park (SENP); **B)** Hypsometric features of Serra da Estrela region and soil sampling sites (see table 1 for site identification).

Soil features

The main soil features in this sector of Serra da Estrela result from the way how the formation factors act. According to Jenny (1994), the soil system is described by the following factors: parent material, climate, topography, organisms and time. Human action is often referred as an additional item to be considered (*e.g.*, Botelho Costa 1995). The soil study included several fieldwork campaigns carried out throughout 2004. During these campaigns, soil samples were collected in order to obtain a geochemical and mineralogical characterisation.

Table 1 — Main soil system features.

Sampling site	Parent material	Topography	Land cover	Generic soil profile
1	Glacial deposit	Base of slope	Maritime pine woodland	A-C
2	Glacial deposit	Base of slope	*Genista florida* and *Cytisus* sp.pl. scrubland	A-C
3	Glacial deposit	Valley-bottom	Meso-hygrophilous grassland	A-C
4	Glacial deposit	Slope	Meso-xerophilous grassland	A-C or A-B-C
5	Glacial deposit	Valley-bottom	*Nardus stricta* grassland	A-C
6	Granite	Base of slope	Heathland	A-C or A-C-R
7 (I, II, III)	Glacial deposit	Base of slope and plateau	Heathland	A-C
8	Granite	Plateau	*Nardus stricta* grassland	A-R
9	Granite	Plateau	Common juniper shrubland	A-R
10	Granite	Slope	*Quercus pyrenaica* forest	A-B-C-R

Table 1 includes a preliminary description of the main soil system characteristics at each sampling site. Soil classification according to the FAO-UNESCO criteria is being produced but is not yet available.

Materials and methods

A total of 20 samples were collected at 10 sampling sites and prepared for mineralogical and chemical analysis. The samples were dried at 35-40ºC, sieved through a 80# (180 mm) plastic screen, homogeneized and quartered. The mineralogical analysis of samples was carried out, particular on their fine (80#) and clay (<2μm) fractions. Mineralogical studies were based on X-ray diffraction, using a Phillips PW 3040/60 diffractometer. All samples were analysed in the range from 2º to 40º 2θ, at 1° 2 θ/min, with Cu-Kα radiation. The XRD reflections were evaluated with the Phillips X'Pert 1.2 and Profit softwares. For the semi-quantitative mineralogical determination, the relative content of each identified mineral was estimated on the basis of its characteristic peak area corrected by the corresponding reflective power (Rocha 1993), as recommended by Schultz (1964) and Pevear & Mumpton (1989). The chemical analysis was performed in a certified commercial Canadian laboratory (ACME Analytical Laboratories, Ltd; ISO 2002 Accredited Lab. – Canada). Representative 0.500g subsamples were extracted for one hour with aqua regia (3-2-1 HCl-HNO3-H2O) at 95ºC and the extracts were analysed by ICP-MS for Fe, Ca, P, Mg, Ti, Al, Na, K, S, and some trace elements.

Results and discussion

The mineralogy of these samples is essentially detrital, consisting mainly of phyllosilicates (essentially mica/illite, kaolinite, vermiculite, illite-smectite mixed-layers and smectite), followed by quartz, plagioclase and K-feldspar. Other accessory minerals are also present in smaller proportions (commonly just vestigial): siderite, opal C/CT, anhydrite, hematite, ilmenite, anatase, zeolites and jarosites. Samples related to granites show higher amounts of phyllosilicates. In these samples, illite (the predominant clay mineral for almost all the samples) generally decreases whereas kaolinite (and, occasionally, vermiculite and/or smectite) increases.

Table 2 — Geochemical data from the studied samples.

	Fe %	Ca %	P %	Mg %	Ti %	Al %	Na %	K %	S %
P1A 80#	2.43	0.09	0.114	0.30	0.075	2.07	0.006	0.30	<0.05
P1C 80#	2.48	0.06	0.139	0.36	0.085	3.20	0.005	0.39	<0.05
P2A 80#	2.48	0.02	0.059	0.27	0.059	2.48	0.004	0.27	<0.05
P2C 80#	1.73	0.04	0.154	0.40	0.050	3.47	0.004	0.29	<0.05
P3A 80#	0.92	0.16	0.086	0.11	0.011	1.01	0.007	0.18	<0.05
P4A 80#	0.83	0.40	0.091	0.08	0.010	0.63	0.003	0.13	<0.05
P4C 80#	0.88	0.38	0.272	0.12	0.025	0.86	0.004	0.19	<0.05
P5A1 80#	0.86	0.01	0.062	0.04	0.006	1.25	0.003	0.13	<0.05
P5A2 80#	0.78	0.01	0.071	0.05	0.004	1.15	0.005	0.14	0.07
P6A 80#	1.06	0.02	0.068	0.06	0.010	1.62	0.003	0.12	<0.05
P6C 80#	0.25	0.01	0.094	0.02	0.006	2.31	0.002	0.09	<0.05
P7IA 80#	0.57	0.08	0.039	0.06	0.012	0.48	0.003	0.12	<0.05
P7IAC 80#	0.93	0.14	0.091	0.09	0.019	0.77	0.003	0.17	<0.05
P7IC 80#	0.52	0.36	0.201	0.07	0.025	0.51	0.003	0.17	<0.05
P7IIA 80#	0.59	0.03	0.078	0.06	0.004	1.02	0.008	0.16	<0.05
P7IIIA 80#	0.25	0.01	0.089	0.03	0.002	1.47	0.003	0.06	<0.05
P8A 80#	0.11	0.01	0.097	0.01	0.001	1.17	0.006	0.05	<0.05
P9A 80#	0.28	0.01	0.085	0.20	0.001	0.8	0.003	0.09	0.07
P10A 80#	2.47	0.12	0.062	0.88	0.137	3.71	0.006	0.3	<0.05
P10C 80#	3.24	0.08	0.037	1.13	0.097	4.58	0.006	0.46	<0.05

The chemical data (Table 2) is in accordance with the mineralogical composition, with Al and Fe presenting the higher values for the analysed set of elements, in relation to the predominant phyllosilicates (illites and kaolinites), followed by K and, in some samples, Ca and Mg. On the other hand, Na always shows very low values.

Samples showing relatively higher values of Al, Fe and K are those related to granites and to glacial deposits located on slope and/or base of slope. Ca shows its higher values in samples related only to glacial deposits located on slope, base of slope and plateau. Ti shows some interesting values in samples related to an increase in kaolinite and vermiculite.

Concluding remarks

The mineralogy and geochemistry of the studied samples is, as natural, closely related to a detrital origin (absolute predominance of quartz, mica/illite and feldspars; more significant values of Al, Fe and K) nevertheless putting in evidence some distinctive features such as: samples related to granites show higher amounts of phyllosilicates (but show a decrease in illite whereas kaolinite increases); samples showing more significant values of Al, Fe and K are those related to granites and to glacial deposits located on slope and/or base of slope whereas Ca shows its higher values in samples related only to glacial deposits located on slope, base of slope and plateau.

References

Botelho Costa, J. 1995. *Caracterização e constituição do solo*. Fundação Calouste Gulbenkian. Lisboa, 527pp..

Daveau, S., Ferreira, A.B., Ferreira, N. & Vieira, G. 1997. Novas observações acerca da glaciação da Serra da Estrela. *Estudos do Quaternário*, Lisboa, 1: 41-51.

Jenny, H. 1994. Factors of soil formation, a system of quantitative pedology. Dover Publications, Inc.. New York, 281pp..

Pevear, D.R. & Mumpton, F.A. 1989. *Quantitative mineral analysis of clays*. CMS Workshop Lectures, 1. The Clay minerals Society, Colorado (USA).

Ribeiro, A. 1988. A tectónica Alpina em Portugal. *Geonovas, Assoc. Portg. Geol.*, Lisboa, 10: 9-11.

Ribeiro, A., Kullberg, M.C., Kullberg, J.C., Manuppela, G. & Phipps, S., 1990. A review of Alpine tectonics in Portugal: foreland detachment in basement and cover rocks. *Tectonophysics*, 184: 357-366.

Rocha, F. 1993. *Argilas aplicadas a estudos litoestratigráficos e paleoambientais na Bacia Sedimentar de Aveiro*. Ph.D. thesis, Aveiro University, Aveiro, 399 pp.

Schultz L. G. 1964. Quantitative interpretation of mineralogical composition from X-ray and chemical data for Pierre shale. *U.S. Geol. Surv. Prof. Paper*, 391-C: 1-31.

Vieira, G.T. & Mora, C. 1998. General characteristics of the climate of the Serra da Estrela. In: Vieira, G.T. (ed.), *Glacial and Periglacial Geomorphology of the Serra da Estrela. Guidebook for the field-trip, IGU Commission on Climate Change and Periglacial Environments.* CEG and Department of Geography, University of Lisbon, Lisbon, pp. 26-36.