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(Meta)cherts, (meta)lydites, (meta)phthanites and quartzites of the série negra (Crato-S. Martinho), E. Portugal: towards a correct nomenclature based on mineralogy and cathodoluminescence studies

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ABSTRACT
Keywords: black quartzites; Série Negra; metasandstones; mineralogy; cathodoluminescence (CL).

The black quartzites of the Proterozoic Série Negra have been previously referred to as and interpreted to be cherts, metacherts, (meta)lydites, (meta)phthanites and quartzites by various researchers. However, the range of terms used implies a specific protolith and environment of deposition, i.e. a chemical vs. a clastic depositional environment. Mineralogically these units are composed of quartz, biotite ± chlorite, pyrite, chromite, ilmenite, chalcopyrite, pyrite with inclusions of magnetite, magnetite, rutile, Fe-oxides, marcasite and arsenopyrite. In addition, amorphous carbon is an important constituent of these rocks. The use of CL on quartz grains shows evidence of different generations of quartz, i.e. quartz cores surrounded by rims that could represent detrital sand grains with overgrowths.

There is clear indication that these rocks had a sandstone protolith and hence should be termed quartzites or metasandstones.

RESUMO
Palavras-chave: quartzitos negros; Série Negra; meta-arenitos; mineralogia; luminescência catódica.

Os quartzitos negros da Série Negra têm sido referidos como chertes, metachertes, (meta)liditos, ftanitos e quartzitos. Porém, os diferentes termos implicam distintos paleoambientes de deposição, ou seja um ambiente clástico ou um ambiente de deposição química. A mineralogia destas rochas é composta por quartzo, biotite ± clorite, pirite, cromite, ilmenite, calcopirite, pirite com inclusões de magnetite, magnetite, rútilo, óxidos de Fe, marcassite e arsenopirite. Estas rochas evidenciam quantidades importantes de carbono amorfo. Estudos de luminescência catódica nos grãos de quartzo indicam gerações distintas de quartzo; núcleos differentes de bordos, que podem indicar sedimentação de detritos arenosos.

Existe assim, indicação clara para a adopção dos termos quartzito or meta-arenito para descrição destas rochas.

Introduction

Within the Tomar Cordoba Shear Zone (TCSZ), NE Ossa Morena Zone crop out several typical, lens-shaped dark or black silicified units (Fig. 1) that form part of the Proterozoic Série Negra metasedimentary succession. These units have, over the last three decades, been referred to as cherts, metacherts, (meta)lydites, phthanites (siliceous shales) and quartzites in the literature (e.g. Gonçalves, 1971; Gonçalves and Fernandes, 1973; Gonçalves *et al.,* 1971, 1972a, 1972b, 1978; Abalos and Eguíluz, 1989; Gonçalves and Cavalhosa, 1994; Pereira, 1995, 1999; Pereira and Silva, 2000; de Oliveira, 2001; Bandres *et al.,* 2002, amongst others). This range of terminology and interpretation has been brought about by the appearance of these black silicified units in the field, which in some cases is very fine grained although in others is coarser grained. However, the chosen nomenclature implies the difference between chemical and clastic sedimentation processes and, ultimately, whether these have been correctly applied to the rocks in question.

Due to the persistence of the terms *chert, metachert, (meta)lydite,(meta)phthanite* and *quartzite* in the literature, the purpose of this paper is to provide a first approach to the correct lithological nomenclature of these units by collating several field (in the Crato-São Martinho area) and petrographic observations as well as mineralogical data and preliminary cathodoluminescence (CL) studies.

Black quartzites within the TCSZ
Stratigraphic setting

Within the TCSZ, the Série Negra rocks occur both north and south of the Blastomylonitic Belt. Stratigraphically the Série Negra is made up of the (lower) Morenos and (upper) Mosteiros Formations. The Morenos Formation is made up of micaceous schists that are locally garnet-bearing, metalimestones and calc-silicate assemblages, meta-arkoses, meta-arenites (quartzites) and micaceous and siliceous schists, amphibolites and metapyroclastic rocks. The Mosteiros Formation consists of black schists/slates, greywackes, black metacherts (quartzites?), limestones and amphibolites (Oliveira *et al.,* 1991).

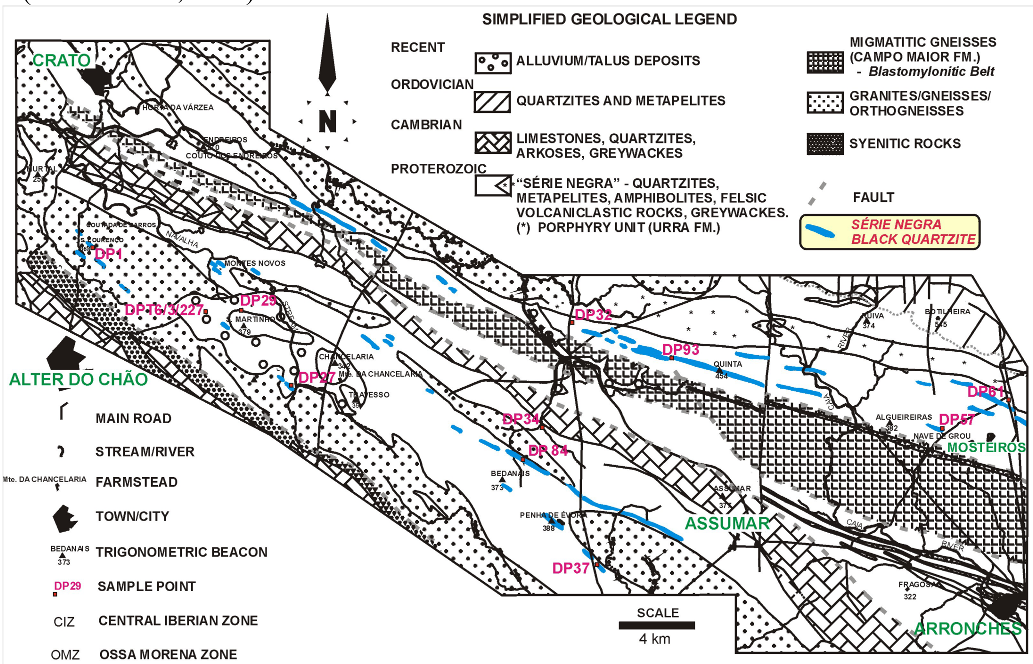

Figure 1 – Simplified geological map of the TCSZ with the location of the black quartzite outcrops and respective sample points used for this study. (Adapted after Gonçalves *et al.,* 1971; 1972a, 1972b).

Outcrop setting

In the Crato-S. Martinho area, the black quartzites crop out in relatively short ribbon-like or lens-shaped outcrops which trend NW-SE, parallel to the regional foliation, and are closely associated with prominent gold prospects (de Oliveira, 2001). Outcrops are generally narrow and short (2-3 m wide and 5-10 m long, respectively) but can be several hundreds of metres long and up to 60-80 high relative to the surrounding Alentejo Plain.

Grain size varies from outcrop to outcrop but invariably most are very fine grained, highly siliceous and resistant to weathering and breakage. These rocks appear homogeneous in some outcrops although in others there is a marked inhomogeneity that defines centimetre-scale layering that may represent bedding.

Petrography

Petrographically the black quartzite samples studied, whose locations are shown in Fig. 1, consist primarily of quartz (± biotite ± chlorite). In thin section, quartz grain sizes are shown to vary from 6 to 63 µm in a fine-grained sample and from 30 to 600 µm in a coarse-grained sample. In the coarser-grained samples accessory biotite (± chlorite) is found interstially to quartz and at times aligned parallel to regional foliation (NW-SE).

The most common opaque phase seen interstitially to quartz is amorphous carbon. Within the quartz there is a very fine mineral phase, present as inclusions in quartz, which creates, in plane polarised light, a blue-grey shadow at low magnification (5x/10x) and which disappears at higher magnifications. These are heavy mineral concentrations that are observed as dark streaks across the samples when viewed in very thin (up to 200 µm thick) wafers.

In addition, rare, discrete sub-rounded grains of magnetite (at times with nuclei of spinel), chromite and ilmenite have been observed. These are larger than the accompanying quartz grains and their roundness implies abrasion.

Other accessory opaque minerals include euhedral pyrite containing traces of chalcopyrite, euhedral pyrite containing magnetite inclusions (magmatic origin?), rutile, Fe-oxides, marcasite (after pyrrhotite) and euhedral arsenopyrite crystals.

Heavy mineral concentrates

Heavy mineral concentrates were obtained by crushing cleaned handspecimen samples. The heavy mineral concentrates yielded, through heavy mineral concentration, three separate fractions; non-magnetic (NM), magnetic (MG) and "super magnetic" (SMG). The Fe-oxides in the MG fraction are weakly magnetic to the extent that they will adhere to a magnet but if brought into direct contact with the magnet. The magnetite in the SMG fraction is strongly magnetic.

The results of the heavy mineral separation in samples DP27 (amphibolite facies metamorphic grade) and DP93 (greenschist facies metamorphic grade) are summarised in Table 1. A common heavy mineral mixture observed in both samples in the SMG fraction is quartz with black inclusions, creating the "shadows" mentioned above.

Table 1 - Results of the heavy mineral separation carried out on black quartzite samples DP27 and 93. NM- non-magnetic; SMG-super magnetic; MG- magnetic. (Note: relative % is per separated fraction).

Sample DP93			Sample DP27		
Minerals	Fraction	Relative % within fraction	Minerals	Fraction	Relative % within fraction
Euhedral pyrite	NM	75-100%	Euhedral pyrite	NM	75-100%
Anatase	NM	<1%	Andalusite	NM	<1%
Cinnabar	NM	<1%	Rutile	NM	<1%
Magnetite	SMG	5-25%	Zircon	NM	<1%
Fe-oxides	MG	50-75%	Magnetite	SMG	5-25%
			Fe-oxides	MG	50-75%
			Biotite	MG	5-25%
			Euhedral tourmaline (broken)	MG	<1%
			Ilmenite	MG	<1%
			Amphibole	MG	<1%
			Staurolite	MG	<1%

Preliminary CL studies

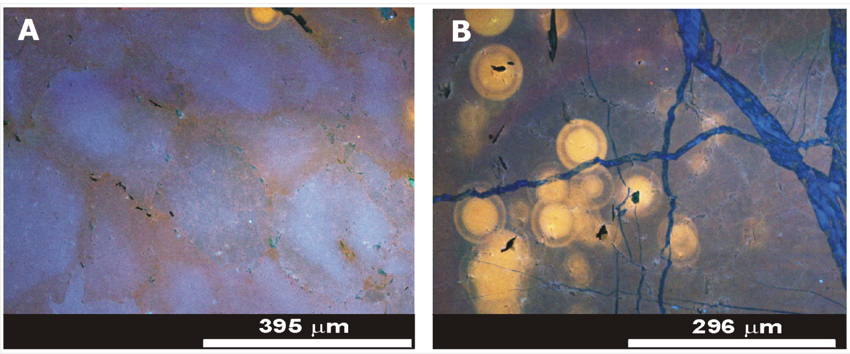

Figure 2 - ***A***- CL image of sample DP1 showing support for the existence of a quartz-cemented protolith. There are equant regions of light blue CL that are about the right size and shape to represent former sand grains. The 'fuzziness' of the CL at the boundaries of these different areas most likely represents the effects of the incipient homogenisation that would have gone to completion if the rocks were heated a little more. These grains are surrounded with cement marked by a pink-purple CL region. ***B***- Cathodoluminescence image of the bright luminescent halos around the inclusions of grothite in sample DP84.

CL imaging is a highly effective technique for discriminating detrital quartz from authigenic quartz in quartz-cemented sandstones (e.g. Ramseyer and Mullis, 2000) and can detect quartz of different origins or reveal processes of crystal growth, recrystallisation, alteration or diagenesis by variable CL colours (Götze *et al.,* 2001). Contrast in CL between bright detrital quartz and more weakly emitting quartz cement survives to at least 200 °C in deep sedimentary basins, although at some still-poorly defined level of heating, homogenisation of quartz CL occurs (e.g., Ramseyer *et al.,* 1988). However, preliminary work suggests that the differentiation between grain and cement survives longer (to higher temperatures) in the blue-wavelength CL.

Fig. 2A shows that a sandstone precursor to these quartzites is plausible given the CL image obtained. The quartzites contain equant regions of blue coloured CL that are the right size and shape to represent former detrital sand grains. The fuzziness of the CL at the boundaries of these different areas most likely represents the effects of incipient homogenisation that could have gone to completion had the rocks been heated further.

Many of the samples manifest relatively uniform CL except for bright luminescent halos around mineral inclusions (possibly V-bearing titanite, Figure 2B). Development of such cathodoluminescent halos in quartz by radiation damage is a well-known phenomenon (e.g. Owen, 1988; Rink and Odom, 1989; Meunier *et al.,* 1990). A few of the halos in sample DP84 were cut through the centres hence allowing the acquisition of EDS spectra of the mineral inclusions. The principal elements are Ti, Si and Ca, with additional amounts of Al, V, and Fe, which suggest the presence of various vanadium-bearing titanite and/or other radioactive minerals.

Conclusions

The characteristic dark colour of the black quartzites may be derived from the copious quantities of finely disseminated heavy mineral concentrations within the quartz grains.

Both sandstones and cherts could be possible protoliths for these rocks prior to metamorphic-induced recrystallisation. Field identification of these rocks can lead to error because these rocks are extremely hard and fine- to medium-grained. However, several lines of evidence point to their having a detrital rather than chemical origin. These are 1- the absence, in these rocks, of very thin layering or laminations as found in true cherts, 2- the presence of centimetre-scale layering that is often folded, 3- the presence of subrounded (detrital) opaque minerals, 4- the presence of abrasion resistant, heavy minerals such as zircon and tourmaline and 5- CL textures from at least two samples studied being consistent with relict quartz grain overgrowth patterns.

Based on the results obtained and given a probable sandstone or arenite protolith nature of these rocks, the terms *chert, metachert, (meta)lydite, (meta)phthanite* should be abandoned and the terms *quartzite* or *metasandstone* adopted to describe the Série Negra rocks in the Crato-S. Martinho area.

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