Key Engineering Materials Vol. 548 (2013) pp 212-219
© (2013) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/KEM.548.212

The Example of the Quartzite from the "Upper Quartzite Formation" from Trás-os-Montes and Alto Douro (Northern Portugal); its Characterization to Use as Natural Stone

Sílvia Aires[1,a], Fernando Noronha[1,b], Cristina Carvalho[2,c], António Casal Moura[2,d] and João Farinha Ramos[2,e]

[1]Centro de Geologia da Universidade do Porto – FCUP, DGAOT, Rua do Campo Alegre 687, 4169-007 Porto, Portugal

[2]LNEG – Rua da Amieira, Apartado 1089, 4466-901 S. Mamede de Infesta, Portugal

[a]silviayres@hotmail.com, [b]fmnoronh@fc.up.pt, [c]cristina.carvalho@lneg.pt, [d]casal.moura@lneg.pt, [e]farinha.ramos@lneg.pt

Keywords: Alto-Douro, Natural Stone, Portugal, Quartz Phyllite, Quartzite, Trás-Os-Montes.

Abstract. Metaquartzite from Serra da Garraia and Zebras were studied. These rocks belong to the "Upper Quartzite Formation" of the “Parautochthonous Complex”. They are light grey and present, sometimes, a brownish patina. The quarries range from 2 to 10m high and 25 to 40m long. This study consists on the petrographic, chemical and physical-mechanical characterization of these rocks, aiming the determination of their potential as natural stone. The petrographic studies revealed that the rocks are formed by quartz and white mica and accessory opaque minerals (titanomagnetite, magnetite, and hematite) and zircon. The petrographic studies and SiO_2 and Al_2O_3 values revealed a different evolution for Garraia and Zebras in terms of textural maturity and mineralogical differentiation. The studies allowed the distinction between quartzites and quartz phyllites. The physical-mechanical analyses attest that all the studied rocks can be used as natural stones.

Introduction

The purpose of this work was to characterize the quartzite rocks from Garraia Mountain and Zebras locality in terms of ornamental stones and to give a contribution for the increase of the population’s interest in the use of this geological resource.

Several methods were applied to study those rocks, such as geological survey, mineralogy and petrography (optical microscopy, scanning electron microscopy, X-ray diffraction, and separation of heavy minerals), geochemistry and physical and mechanical tests (determination of water absorption at atmospheric pressure, determination of apparent density and of open porosity, determination of compressive strength, determination of flexural strength under concentrated load, determination of the abrasion resistance by wide wheel abrasion test, and determination of resistance to ageing by thermal shock).

Geology

The studied outcrops are located in Trás-os-Montes and Alto Douro (TMAD), in NE of Portugal. The exploitations of Garraia (Ga1 and Ga2 samples) are located in Garraia Mountain, Palheiros parish, Murça municipality in Vila Real district. The exploitations of Zebras (Zb1 and Zb2 samples) also belong to the Vila Real district, and are located in Zebras area, Vales parish, near the Santa Comba and Garraia Mountains, in the Valpaços municipality.

Trás-os-Montes and Alto Douro (TMAD) is located in the NW sector of the Iberian Massif (IM). The studied sites are situated in the “Galiza Trás-os-Montes Zone” (GTMZ), in the “Parautochthonous Complex” (Fig. 1). They belong to the "Upper Quartzite Formation" (S_{PQ}) Upper Silurian in age [1, 2, 3].

All rights reserved. No part of contents of this paper may be reproduced or transmitted in any form or by any means without the written permission of TTP, www.ttp.net. (ID: 81.84.254.201-13/02/13,21:22:18)

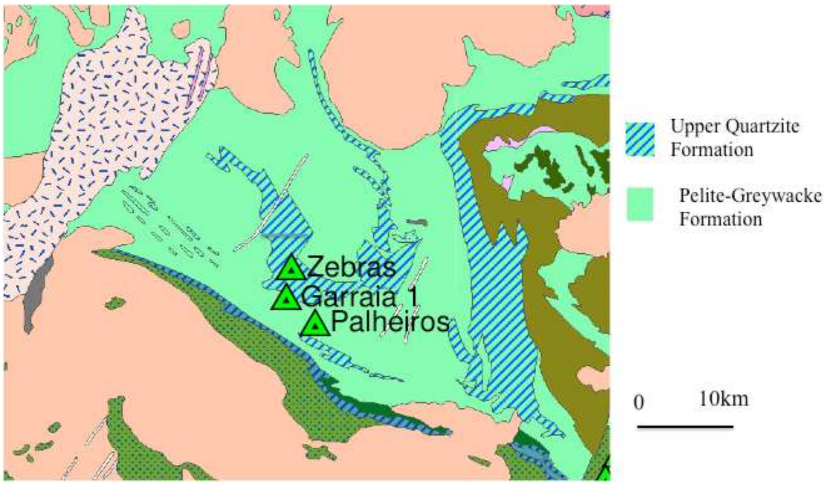


Fig. 1 - Localization of studied sites (From [2], adapted).

Quarries Characterization

Garraia 1 is a quarry 5m high and 40m long. The quartzite is laminated, exhibiting a greyish colour with a brownish patina. The rock exhibits a sub-horizontal slate cleavage N90ºE to N110°E (Fig. 2). There are several joint systems (Fig. 3).

Fig. 2 - Quartzite on Garraia 1 quarry.

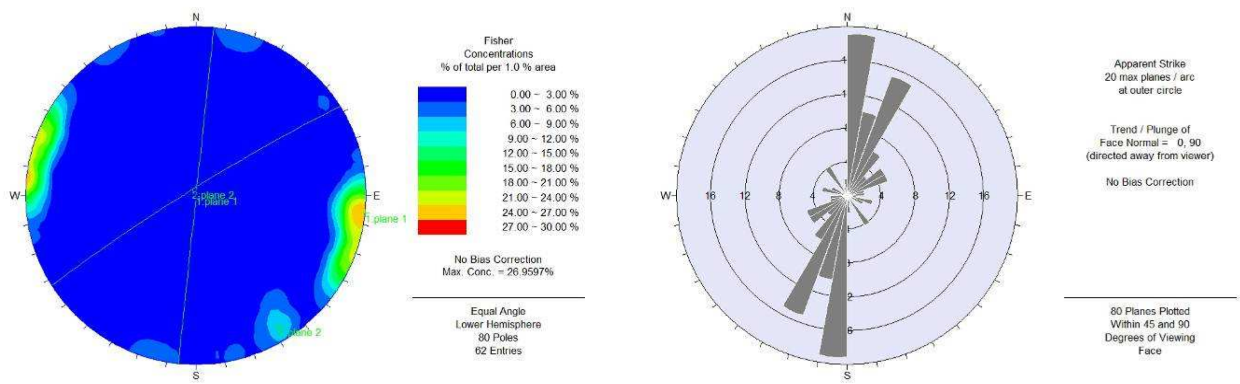


Fig. 3 - Joints diagram from Garraia 1.

Garraia 2 is a smaller exploitation than Garraia 1. This facies is a less laminated quartzite with whitish colour but exhibiting sometimes a brownish patina. The stratification is parallel to the slate cleavage (N75°E, 18°N e N55°E, 15°N). There are some quartz veinlets N120°E, 90° (Fig.4). The joint systems are represented in Fig. 5.

Fig. 4 - Aspect of quartzite with quartz veinlets from Garraia 2.

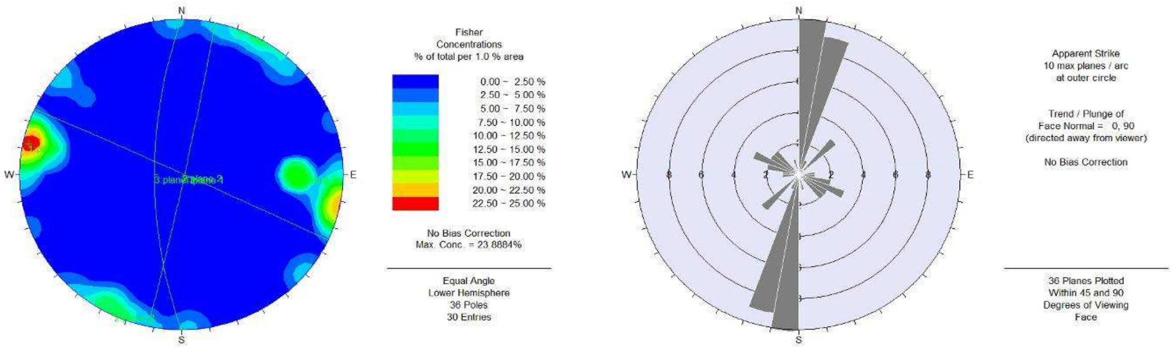


Fig. 5 - Joints diagram from Garraia 2.

Zebras 1 quarry is 25m long and 4m high on slate quartzite. The rock presents a brownish patina and is well laminated, sometimes exhibiting quartz nodules. The stratification is parallel to the slate cleavage (N60°E, 05°N). The different joint systems are represented in Fig. 6.

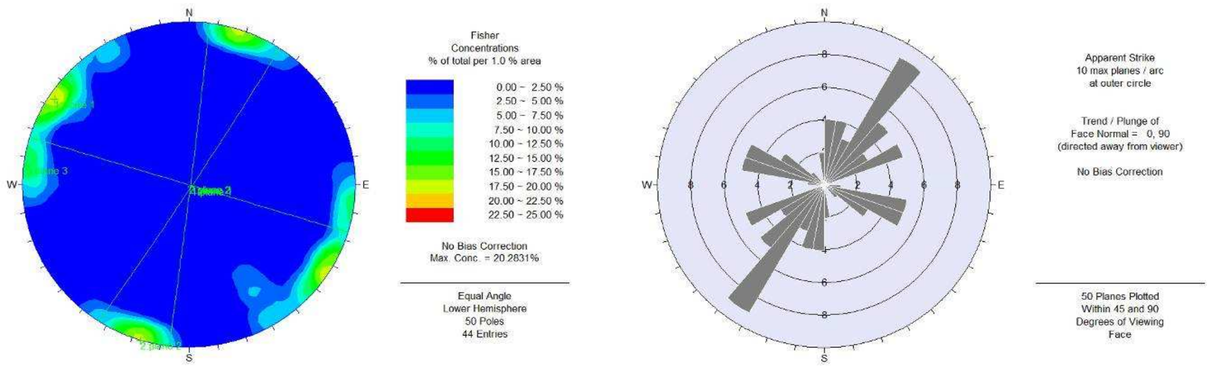
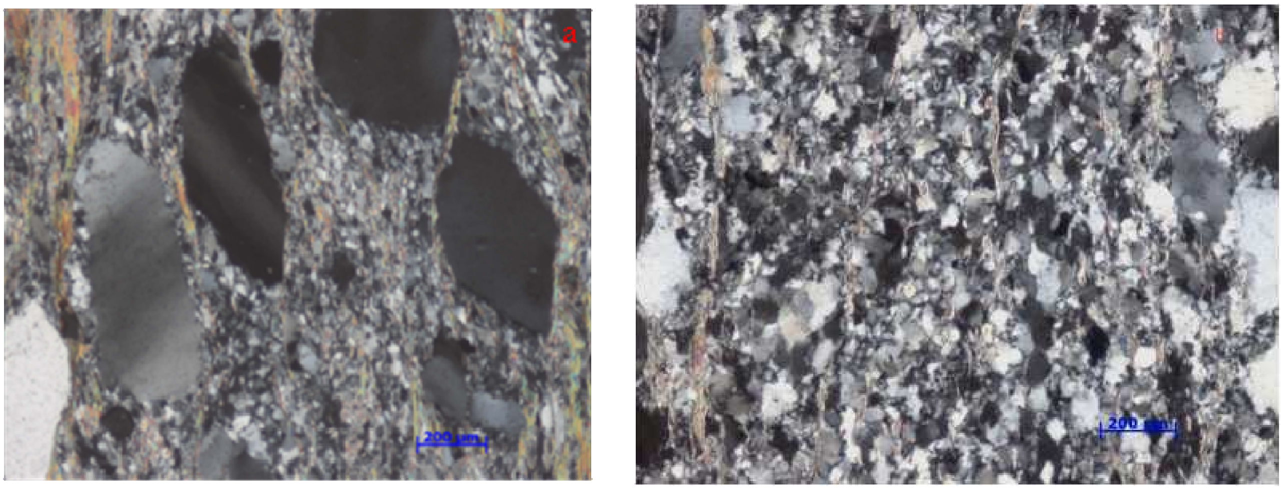


Fig. 6 - Joints diagram from Zebras 1.

Zebras 2 is a new exploitation, with 2m of height on slate quartzite. The slate cleavage N30°E, 12°E is parallel to the stratification. It is well visible a horizontal crenulation N100°E. There are spaced quartz veinlets N140°, 90°. The main joint systems are sub-vertical N10°E to N30ºE; N60°E and N100°E.

Petrography

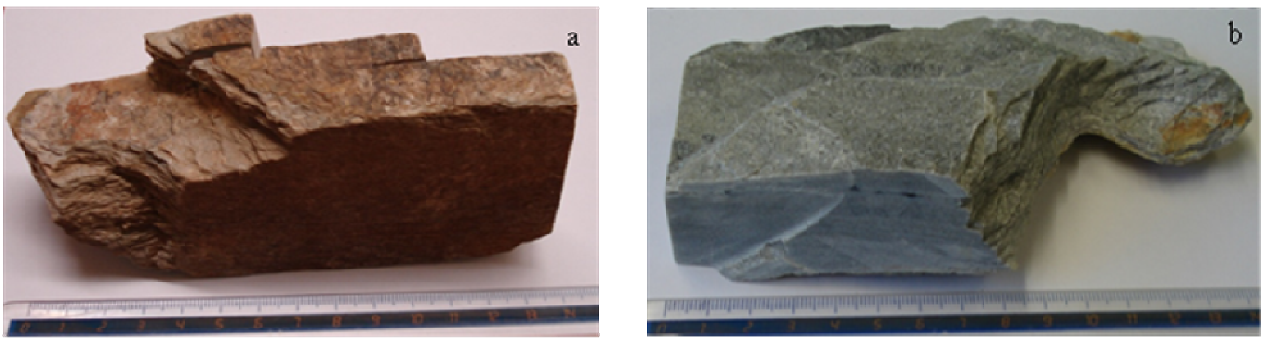
The samples referred as Ga1 and Ga2 are characterized by a light grey colour. They are finely laminated and have an evident slate cleavage. Although the grain size is very small, sometimes small quartz clasts (Ga1) and some oxides (Ga1) are visible. Quartz is the most abundant mineral in these rocks, also having in its composition fine white mica (less important in Ga2), corresponding to a matrix, opaque minerals, zircon and oxides. The texture is granoblastic to lepidoblastic (Fig. 7).



a) b)

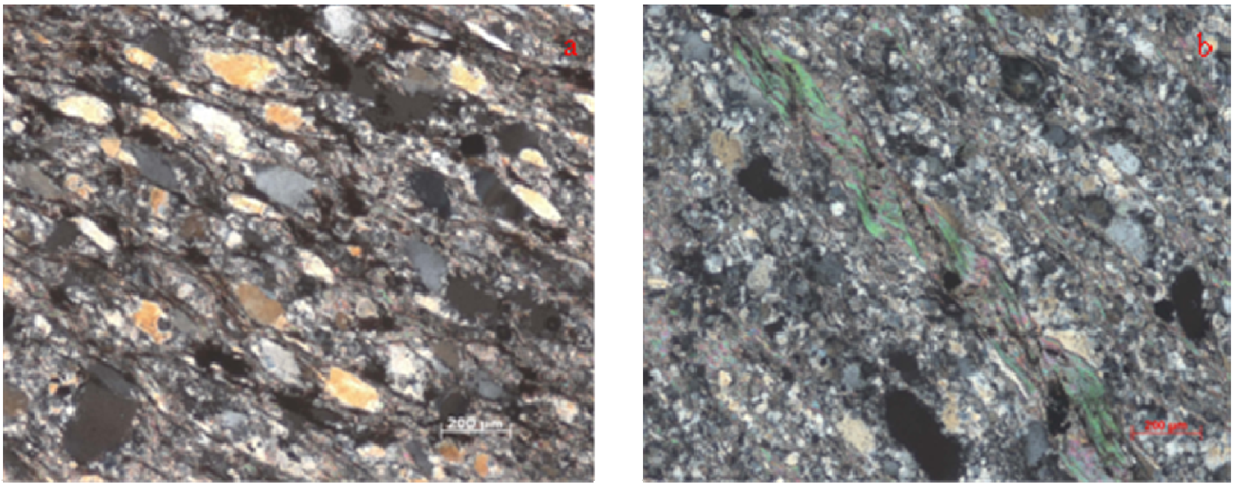
Fig. 7 - a) Lepidoblastic texture with quartz clasts and mica and recrystallized quartz in Ga1; b) lepidoblastic texture in Ga2.

Zb1 is grey colour rock but usually exhibiting a brownish colour (oxidation) (Fig. 8a). This rock has a lepidoblastic texture and foliation marked by alignment of white mica and stretched quartz crystals (Fig. 9a). On its composition, this rock also has opaque minerals, oxides and zircon. Zb2 is a light grey rock (Fig. 8b). In these samples the grain size is very small and the minerals can't be macroscopically identified with the exception of quartz. These rocks have a lepidoblastic texture marked by deformed quartz and white mica (Fig. 9b). Zircon is a usual accessory mineral presenting a round shape.



a) b)

Fig. 8 – a) Zb1 hand sample aspect with brownish colour; b) Zb2 hand sample aspect.



a) b)

Fig. 9 - a) Lepidoblastic texture, quartz stretched parallel to the foliation in Zb1; b) lepidoblastic texture with crenulation in Zb2.

The observation of heavy diamagnetic mineral concentrates reveals zircon mixed grains (quartz with opaque minerals). Zircon is present in all studied samples, however, in Ga1 has the peculiarity of being pink, while in the other samples is hyaline or translucent yellow. The paramagnetic fractions showed that the most abundant mineral is an opaque exibithing, in all samples, a rounded shape. The study of this mineral by SEM revealed that it was a titanomagnetite, sometimes with addition of Cr and Ni. Another paramagnetic mineral also present in all samples is hematite in the form of subhedral crystals. The magnetite is also present in all samples.

Geochemistry

Table 1 presents the results of chemical analyses for the determination of oxides (in weight percentage) in the rocks Garraia (Ga 1 and Ga2) and Zebras (Zb1 and Zb2) and, for comparative study, two samples from Cubo Unit (Cb) also described as quartzite (MA 132) and quartz phyllite (MA 133) belonging to “Upper Quartzite Formation” at NW of studied quarries at Vila Pouca de Aguiar area [4]. Comparatively, Ga1, Ga2 and Zb2 rocks are richer in SiO_2 with more than 90% (91.2%, 96.0%, and 90.3%, respectively) while Zb1 has 79.13%. Zb1 is the richer in Al_2O_3 (11.44%) and Ga2 the poorest (2.3%). For the remaining oxides, we must refer the low values of Na_2O, CaO, P_2O_5 and MnO (<0.1%). The values of K_2O range between 0.77 and 3.38%, the last one occurring at Zb1 which is also the richest in Al_2O_3. The comparison with results from “Cubo Unit” (Cb) suggests that Ga1, Ga2 and Zb2 corresponds to (meta) quartzites such as MA 132, and Zb1 corresponds to quartz phyllite as MA 133, with the corresponding greater abundance of white mica.

Fig. 10 presents the SiO_2 versus Al_2O_3 variation diagram. The analyses reveal that all samples are mineralogically mature (SiO_2 > 79 wt%). However, they also reveal a different evolution for Garraia and Zebras in terms of textural maturity and mineralogical differentiation. Ga2 sample is the most mature and the most evolved; and Zb1 sample is the less mature and the less evolved. Ga1 e Zb2 remain between Ga2 e Zb1, but closer on mineralogical differentiation and textural maturity from Ga2. Fig. 11 shows the enrichment in Al_2O_3 and TiO_2 from Ga2 to Zb1 related to the amount of matrix, which is poor in Ga2 and more abundant in Zb1; so it is probable that the ilmenite is associated with micaceous matrix.

Table 1. Results of chemical analyses for the determination of oxides in the rocks.

		Ga1 (1)	Ga2 (2)	Zb1 (3)	Zb2 (4)	MA 132 (5)	MA 133 (6)
SiO_2	[wt%]	91.2	96.02	79.13	90.3	92.50	78.99
Al_2O_3	[wt%]	4.62	2.3	11.44	4.86	4.69	10.48
Fe_2O_3*	[wt%]	1	0.63	2.82	0.96	0.32	3.08
MnO	[wt%]	0.002	0.002	0.007	0.003	0.00	0.03
MgO	[wt%]	0.14	0.07	0.36	0.13	0.00	0.65
CaO	[wt%]	0.03	0.01	0.02	0.01	0.00	0.08
Na_2O	[wt%]	0.03	0.02	0.09	0.04	0.02	0.85
K_2O	[wt%]	1.6	0.77	3.38	1.62	1.16	2.83
TiO_2	[wt%]	0.207	0.1	0.506	0.193	0.16	0.48
P_2O_5	[wt%]	<0.01	<0.01	0.05	0.02	0.00	0.11
L.O.I.**	[wt%]	0.81	0.34	2.26	0.92	1.02	2.17
Total	[wt%]	99.65	100.3	100.1	99.05	99.87	99.75

(1) Quartzite; (2) Quartzite; (3) Quartz phyllite; (4) Quartzite; (5) Quartzite [4]; (6) Quartz phyllite [4].
* total Fe as Fe_2O_3 ; ** Loss On Ignition.

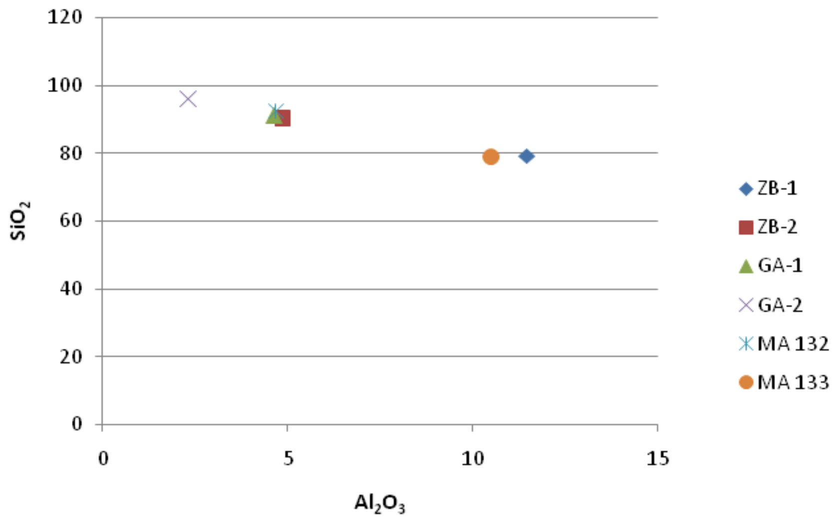


Fig. 10 - SiO_2-Al_2O_3 variation

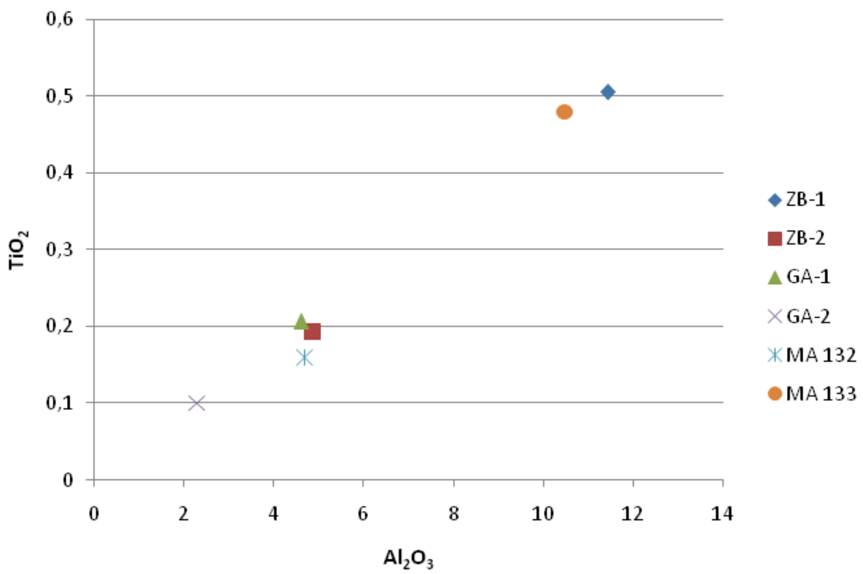


Fig. 11 - TiO_2-Al_2O_3 variation diagram.

Physical and Mechanical Characterization

The rocks under study were subjected to tests for determination of their physical and mechanical characteristics and definition of their use [5]. The results obtained for each rock are summarized in Table 2. Fig. 12 shows the aspect of Zebras' specimens after compressive strength test and the Zb1 and Zb2 specimens aspect after flexural strength under concentrated load test. At the end of the 20 cycles of thermal shock, the samples don't show substantial modifications on their aspect.

Table 2. Results of physical and mechanical tests.

	Ga1	Zb1	Zb2
Water absorption at atmospheric pressure, [%]	0.7	0.3	0.3
Apparent density, [kg/m^3]	2630	2630	2650
Open porosity, [%]	1.6	0.8	0.8
Compressive strength, [MPa]	150	89	87
Flexural strength under concentrated load, [MPa]	35.6	29.6	37.7
Abrasion resistance – Wide wheel abrasion test, [mm]	19	18.5	16.5
Resistance to ageing by thermal shock, [loss of mass %]	0.07	0.01	0.03

Fig. 12 - a) Zb1 specimens after compressive strength test; b) Zb1 (1) and Zb2 (2) specimens after flexural strength under concentrated load test.

Concluding Remarks

The analysed samples are laminated rocks, with fine granularity and different degrees of oxidation. In Ga2 and Zb2 samples the grain size is very small and the minerals cannot be macroscopically identified, but in Ga1 and Zb1 it is possible to identify small quartz clasts.

Using petrographic methods, it is possible to identify a specific orientation of the quartz and white micas, which confers to all the rocks a lepidoblastic texture. In their mineralogical composition, all the samples present opaque minerals, identified by SEM (being titanomagnetite more abundant, and hematite). Ga2 presents less mica and more quartz content, which indicates absence of matrix. Zb1 is the richest in mica. This fact confirms the results obtained from the chemical analysis; Ga2 is the sample with the highest content of SiO_2 (96.02%) and the lowest content of Al_2O_3 (2.3%). On the contrary, Zb1 presents the lowest content of SiO_2 (79.13%) and the highest content of Al_2O_3 (11.44%).

The SiO_2 and Al_2O_3 values and the petrographic studies revealed a different evolution for Garraia and Zebras in terms of textural maturity and mineralogical differentiation. Ga2 sample is the most mature and the most evolved and Zb1 sample is the less mature and the less evolved. The studies allowed the distinction between quartzites and quartz phyllites: Ga1, Ga2 and Zb2 are quartzites and Zb1 a quartz phyllite.

The results obtained from the physical and mechanical laboratorial tests indicate the applicability of the rock types (Table 3).

Table 3. Rocks applicability.

	Ga1	Zb1	Zb2
Rustic masonry	+	+	+
Resistant masonry / columns	+	+	+
Pavements of high traffic	conditioned use outdoors	+	
Pavements of very high traffic			+
Cladding	mainly indoors	+	+

Acknowledgements

This work was performed under the project PTDC/CTE-GIN/70704/2006, "SCHISTRESOURCE" funded by FCT - Portuguese Foundation for Science and Technology. Sílvia Aires benefit from a FCT grant.

References

[1] F. Noronha, C. Carvalho, S. Aires, A. Casal Moura, J. Farinha Ramos: Characterization of "Xisto" as a Way to Promote its Use as Natural Stone, Proceedings of Global Stone Congress 2012, (*in this volume of Key Engineering Materials*).

[2] E. Pereira (Coord): Carta Geológica de Portugal à escala 1:200 000, Folha 2, Instituto Geológico e Mineiro, Portugal (2000).

[3] E. Pereira (Coord): Notícia Explicativa da Folha 2 da Carta Geológica de Portugal à escala 1/200 000, INETI, Lisboa, 119 pp. (2006).

[4] M.A.M. Ribeiro: PhD Thesis, Faculdade de Ciências da Universidade do Porto, 231 pp. (1998).

[5] C. Carvalho, S. Aires, F. Noronha, A. Casal Moura, J. Farinha Ramos: "Schist" from Trás-os-Montes and Alto Douro (NE of Portugal): Potential Use as Natural Stone, Proceedings of Global Stone Congress 2012, (*in this volume of Key Engineering Materials*).