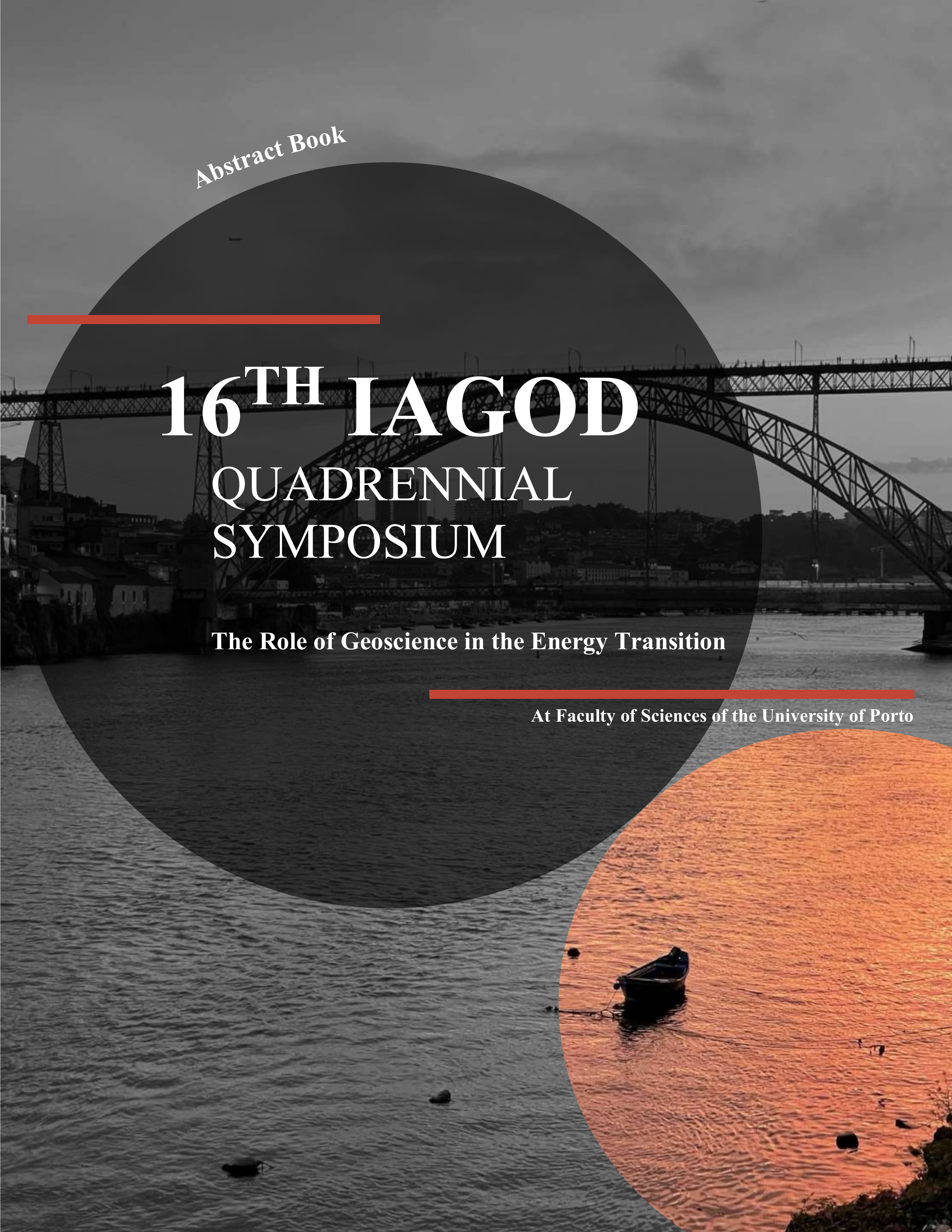

Abstract Book

16TH IAGOD QUADRENNIAL SYMPOSIUM

The Role of Geoscience in the Energy Transition

At Faculty of Sciences of the University of Porto

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Leeb D Hardness Test: *in situ* expedite method to evaluate mineral alterations and uniaxial compressive strength

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Highlight

The Leeb D Hardness test uses the rebound of a semispherical penetrator to estimate the rock hardness. This method can be used in ornamental rocks, such as granites and marbles, as a expedite proxy to identify the main rock-forming mineral phases and mineral alteration processes (e.g. dolomitization and silicification on marbles), as well as to estimate the uniaxial compressive strength, through a correlation of both data.

Introduction

The uniaxial compressive strength (UCS) can be determined through laboratory mechanical tests. However, the uniaxial compressive strength test (UCST) is not simple, and other *in situ* methods can be applied to estimate the UCS value. The most widely non-destructive and portable method is the Schmidt Rebound Hammer Test (SHT), used to estimate surface hardness and rebound, and, therefore, the compressive strength of concrete and rocks, based on the principle that rock hardness correlates positively with compressive strength. Other methods, firstly applied to the hardness of steels, were recently applied also to rocks namely the Leeb D Hardness test (LHT; e.g., Asiri, 2017; Çelik and Çobanoğlu, 2019; Ghorbani et al., 2022). The general principle is quite similar to the SHT, although the equipment is smaller, resulting in lower impact energy and. therefore, reducing surface damage. This method was applied to igneous, metamorphic and sedimentary rocks, and correlation equations between UCST and HLD (leeb harness unit) were proposed by several authors (Asiri, 2017; Corkum et al. 2018; Çelik and Çobanoglu, 2019). In the present work, we compare the results obtained by the LHT and the UCST, both in rocks (*in situ* and in the laboratory) and mineral samples, to constrain their use as a UCS proxy.

Material and methods

The methodology consisted of identifying the lithological features of quarry faces (main lithotypes, mineralogical content, and alteration). The main lithotypes were tested in the quarry face using LHT and were sampled to laboratory testing. Laboratory work consisted in the X-ray diffraction, to identify the mineralogical main phases, as well as physical-mechanical tests, namely LHT and UCST. According to Çelik et al. (2020), the rock test specimens should have a thickness of at least 50 mm to ensure that the LHT is representative. The rock test specimens used for the LHT conducted in the laboratory were subsequently used for the UCST [50x50x50 mm cube]. Leeb D Hardness test was also applied to the main rock-forming mineral specimens (calcite, plagioclase, K-feldspar and quartz) to compare the obtained rock data with the expected values for those mineral phases. The study was conducted in: (1) eight marble varieties identified in two marble quarries [Texugo nº3 and MSB] in the Estremoz Anticline (Ossa Morena Zone [OMZ], Portugal), both exploited by António Galego e Filhos - Mármores S.A.; and (2) a medium-grained gray granodiorite with biotite and amphibole, from Barrocal quarry (Évora Massif, OMZ, Portugal), exploited by Granialpa; leucogranite veins and mafic microgranular enclaves (with tonalite and granodiorite compositions) were also identified.

Results

The LHT measured on mineral phase samples shows an increase in HLD values according to the mineral hardness: calcite 513 ± 57; plagioclase 833 ± 46; K-feldspar 833 ± 71; and quartz 913 ± 66 HLD.

As respect to the marble varieties (1) the white and pink marbles show moderately soft hardness (according to the nomenclature proposed by Ghorbani et al., 2022), with Leeb hardness ranging from 570 to 620 HLD; (2) the dark-grey (Ruivina) and gray-striped (Pele de Tigre) marbles also shows moderate soft hardness values, although with slightly higher values (hardness between 590-650 HLD); (3) marbles with secondary dolomitization, sometimes with silicification, shows moderate soft hardness values, although highest than (1) and (2) varieties (625-700 HLD) and (4) silicified alteration zones with quartz veins show moderate hard hardness, showing typical values above 700 HLD.

In what concerns the UCS, the lowest values were obtained for the pure calcite pink marbles (51 MPa) and for the gray-stripped marbles (54 MPa), following the pink-stripped (94 MPa), the dark-grey Ruivina Marble (101 MPa), the white (113 MPa) and the light pink (122 MPa) marbles. Lithotypes with evidence of late dolomitization and silicification present the highest UCS values (146 MPa). The highest UCS values were obtained in lithotypes with higher dolomite content.

Regarding the igneous-derived rocks from Barrocal Quarry: (1) the granodiorite shows moderate hard to hard hardness (842 ± 60 HLD); (2) the leucogranite veins present similar LHT values (842 ± 45 HLD) and (3) the mafic microgranular enclaves, although with hard hardness values, show lower LHT values (794 ± 59 HLD). According to Carvalho et al. (2023), the Cinza Évora granodiorite (commercial name) shows a UCS of 212 MPa.

Final Remarks

The HLD values obtained for the quartz-feldspar rocks and carbonate-rich (calcite) rocks show clear similarities to those obtained for rock-forming mineral phases. Leeb D Hardness test is also sensitive to the presence of dolomitization and silicification alterations in marbles, as indicated by increased HLD values. Indeed, the use of this technique in marbles can be useful to identify alteration fronts and the nature of the fluids invoved (more silicate or carbonate-rich), as well as meteoric alteration (e.g., granular decohesion, exfoliation on granitoids). The LHT has limitations if the rocks are mainly composed of silicate minerals. Indeed, for values higher than 900 HLD, the equipment scale approaches the maximum limit (1000 HLD), and several silicate mineral phases have hardness values close to this limit. This way, in a granite-like rock, essentially composed of quartz and feldspar, the LHT shows quite similar values.

With respect to the exponential correlation between LHT values and UCS, although the results do not perfectly fit, correlation coefficients (R^2=0.73) are quite similar to those obtained by other studies (Asiri, 2017; Corkum et al. 2018; Çelik and Çobanoglu, 2019), showing that the LHT method can be a good and simpler approach to estimate the UCS.

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