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# Slate as Dimension Stone by Jörn Wichert

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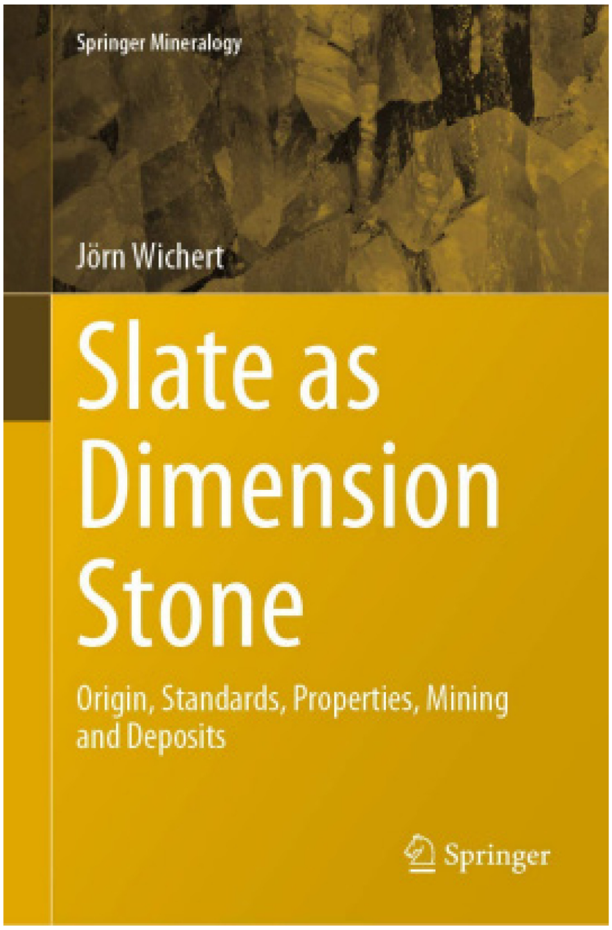


Recently, Springer has published the book *Slate as Dimension Stone*, by Jörn Wichert, Freiberg University. This book was written with the aim to become the definitive compendium of the roofing slate knowledge up to date. It is divided into seven chapters: 1) Slate in Architecture, 2) The Origin of Slate, 3) Methodology and Standards, 4) Properties of Slate, 5) Weathering of Slate, 6) Mining of Slate and Production, and finally, 7) Slate Deposits. This book represents a good approach to the roofing slate world. Graphics (especially geological maps) are accurate and well designed, and language is clear and understandable. The book is mainly focused on geotechnical aspects of underground mining, and on the description of the some of the most important deposits of the world. There is plenty of information regarding roofing slate outcrops in Europe, Northern America and Russia, with detailed geological maps and historical information. However, there are some lacks that move the book away from its objective to become the ultimate encyclopedia for the roofing slate world.

Chapter 1 – *Slate in Architecture*

This chapter gives a short overview of the use of roofing slate in architecture. The length of this chapter (13 pages) is too short, and there is only one reference in the bibliography. Roofing slate architecture has a long tradition and many different styles, but this chapter only scratches on the surface of this extensive topic.

Chapter 2 – *The Origin of Slate*

2.1 Sedimentation
2.2 Metamorphism
2.3 Tectonic and deformation

In this section, the author explains the depositional environments of the sedimentary sequences that will be metamorphized into slate. However, the author adopts the wrong petrological terms coined in the European Norm (EN) 12326 for roofing slates. In this norm, slate is divided into «slate of tectonic compression» and «slate of lithostatic compression». This terminology is strictly commercial, made to distinguish the Brazilian roofing slates from the rest. The difference between these two categories is the relative position between the sedimentation beds and the slaty cleavage plane. If they are parallel, the slate is of "lithostatic compression", and if they are oblique, then the slate is of "tectonic compression". Nevertheless, this is not accurate. A quick view to the existing bibliography highlight the fact that Brazilian roofing slates have a lesser metamorphic degree, as shown by their Kübler Index. There is no need to create new terminology based in an inaccurate understanding of basic metamorphic petrology. See Frey et al. 2007 for the proper slate definition. Besides, the length of this chapter is very short (15 pages) to treat this subject in depth. A good background in metamorphic petrology is missed.

Chapter 3 – *Methodology and Standards*
3.1 Determination of mineralogical composition
3.2 Microporosity and Thermal Expansion
3.3 Determination of the Hydric Expansion
3.4 Determination of the Strength Parameters
3.5 Determination of the Snow Load
3.6 Standards for Roofing and Cladding

This chapter enumerates some of the test methods compiled in the European Standard EN 12326 and the American Standard ASTM C406, together with other test methods (and results) used in geotechnics, useful for mining operations. The results provided are very interesting not just for mining operation but for geothecnics in general. However, this part could have been greatly improved with a deep discussion of the roofing slate standard tests, especially when the author co-authored a paper in 2016 on this subject, not mentioned in the text. See the bibliographic review of this paper for more information.

Chapter 4 – *Properties of slate*
4.1 Petrography and Mineralogy
4.2 Fabric
4.3 Optical properties
4.4 Strength Properties
4.5 Density and Porosity
4.6 Thermal Properties
4.7 Hygric and Hydric Properties
4.8 Moisture Transport Mechanism in Stones

This chapters presents data on different types of roofing slates. For some properties such as pore system, thermal and fluid transmissivity, the author uses data from other publications, such as Kessler 1932. There is interesting information not compiled in any other publication about roofing slates, but some sections have conceptual errors, probably due to the misunderstanding of the slate structure, or just to a defective bibliographic review. Section 4.3, Optical Properties, deals with color and aesthetics of roofing slates. Color in roofing slates is due to mineral composition, which in turn is linked to depositional conditions, and brightness is linked to the metamorphic recrystallization. These two points are missed in this section. Being aesthetics one of the most important values for roofing slates, it is surprising that the author has not delved into this aspect. In section 4.5 Density and Porosity, the author uses Mercury Intrussion Porosimetry (MIP) data to define the pore system. This method is not appropriate to determine the pore system, since the small pore radius access is in the limit of the resolution, and the stress needed to intrude the mercury in the slate generally breaks the probe, making these results not accurate. Perhaps this is the reason of the "interesting phenomenon" described by the author in page 117. Besides, X-axis for the cumulative volume obtained with MIP expresses radius of access to pores, not "pore size diameter". See figure 4.37. In section 4.8, the author applies the water transport mechanisms for other stones to roofing slates. Since slate structure is strongly anisotropic due to the slaty cleavage, and the pore system very low, applying models developed in other rocks is not accurate. Finally, mineral compositions are given in different graphics for each two minerals, which it makes difficult to get the general view of the bulk composition for each roofing slate.

Chapter 5 – *Weathering of Slate*
5.1 Introduction and Environmental Conditions
5.2 Classification of Deterioration Patterns
5.3 Deterioration Caused by Mechanical Processes
5.4 Chemical Weathering
5.5 Oxidation
5.6 Biological Colonization

In this chapter, the author uses the classification for rock pathologies developed by the International Council on Monuments and Sites, ICOMOS, which is a good approach to this subject. Nevertheless, pathologies are not sufficiently explained. The main pathology for the roofing slate market, oxidation, is only superficially treated. This is surprising, since there are several works on iron sulphides oxidation already published, but the author has avoided to mention them. Besides, there is not a word on roofing slate weathering by sunlight (UV radiation exposure). Since roofing slates are in the top of the buildings, their exposure to these radiation is the greatest. A discussion on this process would have improved this chapter.

These first five chapters form about 30% of the book. The rest of the book is for Chapters 6 – *Mining of Slate* and Production and 7 – *Slate Deposits*, in which the author feels much more comfortable with all the geotechnical aspects referring to mining.

Chapter 6 – *Mining of Slate*
6.1 Overview
6.2 Site Investigations
6.3 Rock failures
6.4 Room and Pillar Design and Safety Calculation
6.5 Failure Criteria of Rocks
6.6 Production of Roofing Slate
6.7 Other Slate Products

This chapter is one of the strong points of this book. There is abundant geotechnical information about the specific requirements of a slate mine. However, most of this information is already available in any geotechnics manual. Perhaps a book devoted to slate as dimension stone should have focused more on the stone instead of geotechnics.

Chapter 7 – *Slate Deposits*
7.1 The Slates of Europe
7.2 Slate in Russia
7.3 Slate in Georgia
7.4 The Slates of North America

As pointed before, the book has a detailed description of the main outcrops in Europe, Northern America and Russia. However, no information is found, even a short reference, to the important outcrops of China, Brazil and India. The author mentions the potential of China as the next first producer in the world, once Spanish deposits are depleted, but no more information is given. Also the Brazilian deposits are not described, which is surprising since they have, at least, the same potential than China. These countries represent about 30% of the world production. Other minor producers, such as Scandinavia, Argentina, Japan, South Africa, Vietnam and Australia are neither mentioned. Scandinavian and Argentinian roofing slates are very exclusive, since they are phyllites. These phyllites have reduced productions, but are very appreciated in the roofing slate market. Finally, the description of the Spanish deposits is not as accurate as it should be, especially regarding the historical development.

Finally, the bibliographic review lacks most of the roofing slate papers published in the last 15 years. It is surprising that the author has even avoided citing papers which he has co-authored. Recent (and past) research on several topics has been omitted. Some of the references that are not cited and would have improved the book are (references for the years 2019 and 2020 have been omitted in this review):

**1) Slate in Architecture**

Cárdenes, V., Rubio-Ordóñez, Á., Monterroso, C. and Mateos, F.J., 2014, Guidelines for selecting roofing slate for the restoration of historical buildings and monuments: Two case studies. Journal of Cultural Heritage, v. 15, pp. 203–208.

Gillespie, M.R., Everett, P.A., Albornoz-Parra, L.J. and Tracey, E.A., 2013, A survey of building stone and roofing slate in Falkirk town centre, British Geological Survey.

Pires, V., Amaral, P.M., Rosa, L.G. and Camposinhos, R.S., 2011, Slate flexural and anchorage strength considerations in cladding design. Construction and Building Materials, v. 25, pp. 3966–3971.

**2) The Origin of Slate**

Attewell, P.B. and Taylor, R.K., 1968, A microtextural interpretation of a Welsh Slate. International Journal of Rock Mechanics and Mining Sciences, v. 6, pp. 423–438.

Borradaile, G.J., MacKenzie, A. and Jensen, E., 1991, A study of colour changes in purple-green slate by petrological and rock-magnetic methods. Tectonophysics, v. 200, pp. 157–172.

Ingham, J., 2005, Characterisation of roofing slate by optical microscopy. In: J.J. Hughes, A.B. Leslie and J.A. Walsh (Editors), 10th Euroseminar on Microscopy Applied to Building Materials, Paisley, pp. 18.

Kisch, H.J., 1991, Development of slaty cleavage and degree of very - low - grade metamorphism: a review. Journal of Metamorphic Geology, v. 9, pp. 735–750.

Siddans, A.W.B., 1972, Slaty cleavage — a review of research since 1815. Earth-Science Reviews, v. 8, pp. 205–232.

**3) Methodology and Standards**

Blanchard, I.G. and Sims, I., 2007, European testing of roofing slate. Construction Materials, v. 160, pp. 1–6.

Bortz, S.A. and Wonneberger, B., 2001, Review of durability testing in the United States and Europe. ASTM Special Technical Publication, pp. 94–106.

Cárdenes, V., Cnudde, J.P., Wichert, J., Large, D., López-Munguira, A. and Cnudde, V., 2016, Roofing slate standards: A critical review. Construction and Building Materials, v. 115, pp. 93–104.

Gómez-Fernández, F., Castañón, A.M. and Ward, C.R., 2012, Analysis of the methodology of the petrographic examination test (European Standard EN 12326-2) and the relation between petrography and modulus of rupture for Spanish roofing slates. Engineering Geology, v. 141–142, pp. 114–123.

**4) Properties of Slate**

Boutinguiza, M., Lusquiños, F., Pou, J., Soto, R., Quintero, F. and Comesaña, R., 2012, Thermal properties measurement of slate using laser flash method. Optics and Lasers in Engineering, v. 50, pp. 727–730.

Campos, M., Velasco, F., Martínez, M.A. and Torralba, J.M., 2004, Recovered slate waste as raw material for manufacturating, sintered structural tiles. Journal of the European Ceramic Society, v. 24, pp. 811–819.

Cárdenes, V., Mateos, F.J., Rubio-Ordoñez, A. and Monterroso, C., 2011, Standard tests for the characterization of roofing slate pathologies. Materiales de Construcción, v. 62, pp. 251–268.

Cárdenes, V., Rubio-Ordóñez, Á., Wichert, J., Cnudde, J.P. and Cnudde, V., 2014, Petrography of roofing slates. Earth-Science Reviews, v. 138, pp. 435–453.

Hughes, T., 2004, Testing Roofing Slates. New standards and a new specification regime. The Building Conservation Directory, pp. 80–82.

Van den Abeele, K., Carmeliet, J. and Wevers, M., 1999. Quantification of microdamage in slate tiles: Comparison of nonlinear acoustic resonance experiments with visual and X-ray diagnosis. In: W.Lauterborn and T. Kurz (Editors), 15th International Symposium on Nonlinear Acoustics, Gottingen, Germany, September 01-04, 1999, pp. 307-310.

Wagner, H.W., 2007, The basics of test methods of slates for roofing and cladding. Grundlagen für die Prüfung von Dach- und Wandschiefern. Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, v. 158, pp. 785–805.

**5) Weathering of Slate**

Cann, J.H., 2012, Physical weathering of slate gravestones in a Mediterranean climate. Australian Journal of Earth Sciences, v. 59, pp. 1021–1032.

Cárdenes, V., Paradelo, R. and Monterroso, C., 2009, Passivation techniques to prevent corrosion of iron sulphides in roofing slates. Corrosion Science, v. 51, pp. 2387–2392.

Garabito, J., Rodriguez, A., Garabito, J.C. and Calderon, V., 2017, Durability of slate and zinc sheets in the rehabilitation of historical heritage. A case study. Construction and Building Materials, v. 135, pp. 212–224.

Iglesias, J., Feijoo, J., Taboada, J., Rivas, T. and Modino, M., 2014, Protecting roofing slates against oxidation: Analysis of the chemical interaction between protective treatments and pyrite. Rock Engineering and Rock Mechanics: Structures in and on Rock Masses, pp. 1255–1259.

Walsh, J., 2002, Predicting the service life of natural roofing slates in a Scottish environment, 9th international conference on durability of building materials and components. In House Publishing, Brisbane.

**6) Mining of Slate and Production**

Bastante, F.G., Taboada, J., Alejano, L.R. and Ordóñez, C., 2005, Evaluation of the resources of a slate deposit using indicator kriging. Engineering Geology, v. 81, pp. 407–418.

Boutinguiza, M., Pou, J., Lusquiños, F., Quintero, F., Soto, R., Pérez-Amor, M., Watkins, W. and Steen, W., 2002, $CO_2$ laser cutting of slate. Opticals and Lasers Engineering, v. 37, pp. 15–25.

Gholami, R. and Rasouli, V., 2013, Mechanical and Elastic Properties of Transversely Isotropic Slate. Rock Mechanics and Rock Engineering, v. 47, pp. 1763–1773.

González-Nicieza, C., Taboada-Castro, J., Menéndez-Díaz, A. and Álvarez-Vigil, A.E., 1997, Geological risks in slag heaps of roofing slate in Spain. International Journal of Surface Mining, Reclamation and Environment, v. 11, pp. 145–150.

Haritash, A.K., Baskar, R., Sharma, N. and Paliwal, S., 2007, Impact of slate quarrying on soil properties in semi-arid Mahendragarh in India. Environmental Geology, v. 51, pp. 1439–1445.

Iglesias, C., Martinez, J. and Taboada, J., 2018, Automated vision system for quality inspection of slate slabs. Computers in Industry, v. 99, pp. 119–129.

**7) Slate Deposits**

Bernardos-Sánz, J.U. and López-Mesones, F., 2017, Historical and architectural value of the slates of Bernardos. Naturpiedra.

Brandolini, P., 1988, L'utilizzazione dell'ardesia in Liguria. Studi e ricerche di Geografia, v. 11, pp. 31–85.

Cárdenes, V., Cnudde, V. and Cnudde, J.P., 2015, Iberian roofing slate as a Global Heritage Stone Province Resource. Episodes, v. 38, pp. 97–105.

Cárdenes, V., Ponce de León, M., Rodríguez, X.A. and Rubio-Ordoñez, A., 2019, Roofing Slate Industry in Spain: History, Geology, and Geoheritage. Geoheritage, v. 11, pp. 19–34.

Cárdenes, V., Rubio-Ordóñez, Á., Wichert, J., Cnudde, J.P. and Cnudde, V., 2014, Petrography of roofing slates. Earth-Science Reviews, v. 138,

pp. 435–453.
Gwyn, D., 2015, Welsh Slate: Archaeology and History of an Industry. Royal Commission n the Ancient and Historical Monuments of Wales.
Iglesias Ponce de León, M., 1995, L'ardoise en Espagne: Histoire et economie, Universite de Rennes 2, Rennes.
Jones, J.L., 2005, The Peach Bottom Slate in southeastern Pennsylvania; once the best building slate in the world, Geological Society of America, Northeastern Section, 40th annual meeting, pp. 26.
Jope, E.M. and Dunning, G.C., 2011, The use of blue slate for roofing in medieval England. The Antiquaries Journal, v. 34, pp. 209–217.
McWhirr, A., 1988, The Roman Swithland slate industry. Transactions of the Leicester Archaeological and Historical Society, pp. 1–8.
O'Neill, N., 2014, Capitalism and Class Formation in the Angers Slate Fields, 1750–1891, University of Oregon Graduate School, Oregon, 238 pp.
Piddock, S., 2007, Slate, slate, everywhere slate: the cultural landscapes of the Willunga slate quarries, South Australia. Australasian Historical Archaeology, v. 25, pp. 5–18.

In summary, this book is interesting for the roofing slate world, with important information about underground mining operations, together with detailed description of some of the world's main deposits, but it has some serious lacks and inaccuracies in other fields. This book is an interesting reading for anyone working or just interested in roofing slates, but this reading should be complemented with further bibliography.

(Episodes does not have to share the same opinion as reviewers and we do not take responsibility for reviews and comments.)