Clarifying the Geological Nature of Brazilian Metalutite: Technical Response and Evidence Review

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Introduction and historical context

The technical discussion between the Spanish and Brazilian producers is not new. In 2007, a report commissioned by the Galician Slate Cluster (CPG) concluded that Brazilian rocks could not be considered slate in the strict sense of the word and, therefore, should not be marketed under European Roofing Slate Standards (López- Mesones, 2007).

Brazilian authors responded, arguing that its rocks did indeed have the geological characteristics necessary to be considered slate. The discussion reached the highest levels of the European Council, ending with a consensus based on the geological origin of the rocks. Therefore, the new revision of standard EN 12326 would distinguish between "tectonic slates" (i.e., Spanish slates and, by extension, European slates, as they share a similar geological origin in most cases) and "lithostatic slates," which correspond to Brazilian slates. There was a third group for “carbonated slates”, slates with more than 20% carbonate (the Italian ones). These definitions, still in force today, led to a consensus between the two sides, and the debate paused.

In the following years, the Brazilian material did not have a strong impact on Europe, which is the world’s leading market. The COVID crisis, the increase in the prices of transportation, and other factors hindered the penetration of Brazilian metalutites. However, markets are evolving, and in recent years, the increase in exports of these rocks to the European Community has increased. Recently, the CPG and the National Federation of Roofing Contractors (NFRC), among others, have renewed this technical discussion in the sector by sharing existing technical information, studies and reports that underline the differences between European slate and the Brazilian metalutite with their associates.

Letter from Geologist Cid Chiodi Filho on behalf of the *Minas Gerais Slate Miners Association*

The argument regarding the quality of the Brazilian rock has been addressed in a letter from Brazilian geologist Cid Chiodi Filho, who has extensive experience in various geological topics, including dimension stone consulting, sets out the following points:

- Scientific studies and petrographic analyses from the Laboratoire National de Métrologie et d’Essais (LNE) confirming Brazilian rocks from Minas Gerais meet international standards (EN12326) and fall under the roofing slate classification.
- Analysis of the motivations of current objections by CPG, NFRC and others; as these are non-technical, they fall outside the scope of this technical response.
- Brazilian rock is presented as meeting applicable regulations; commercial considerations are not assessed here.

The letter is completed with some pictures of roofs installed with Brazilian rocks.

Chiodi Filho refers to a publication of mine (Cárdenes et al., 2020), Definition of Roofing Slate Lithotypes for an International Roofing Slate Classification, which proposes a classification for roofing slates. The letter also mentions the standard EN 12326 Slate and stone products for discontinuous roofing and cladding (CEN/TC_128, 2015), which is the most important roofing slate standard, as it applies to the European market, the world's largest market.

This letter is a reaction to the reports published by the Cluster da Pizarra de Galicia (CPG), the NFRC, and others.

Response to the letter. Is Brazilian metalutite a roofing slate?

Yes, insofar as they are a product currently used for roofing. However, there is no doubt that they are different in geological origin, aesthetics, and technological properties from Spanish slates and, by extension, from European slates.

As proposed by Cárdenes et al. (2020), roofing slates can be sorted according to their color (resulting from mineralogical composition) and petrology (reflecting the degree of metamorphism). There are three possible color families (Black/Gray, Green, and Red/Purple) and four rocks (metalutite/low-grade slate, slate s.s., phyllite, and mica-schist). These four rocks are, in fact, quite similar, as they can all be split into tiles or shingles. **They differ in the degree of metamorphism (Figure 1), colloquially explained as the degree of cooking of the rocks in the Earth's oven.** The combination between color family and rock type gives 12 roofing slate lithotypes (Figure 2).

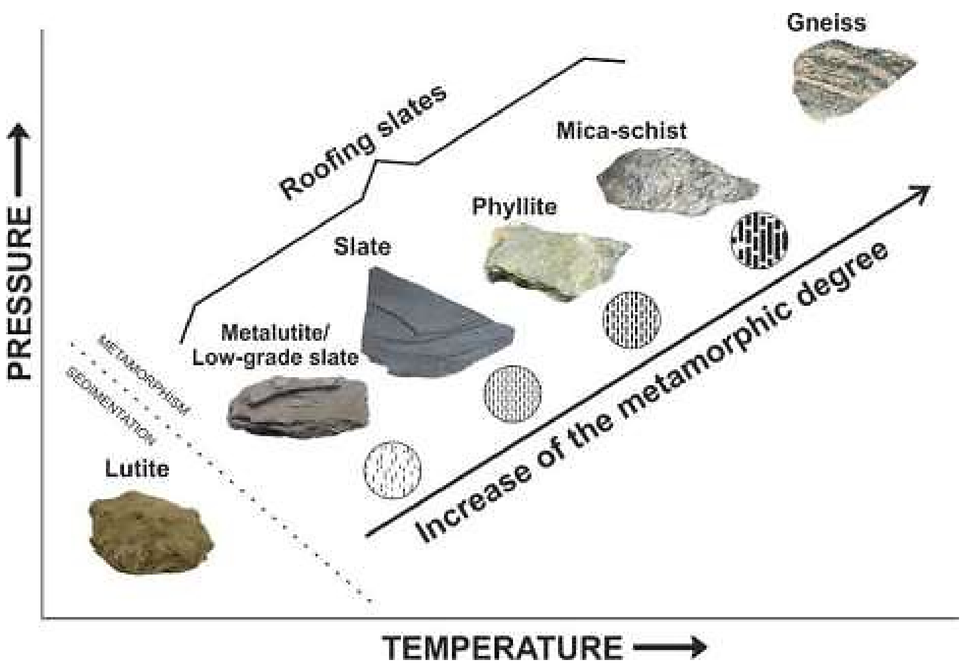

Figure 1: *Metamorphic sequence of the group of rocks used as roofing slates. All originate from a sedimentary parent rock (lutite or mudstone). The Earth's tectonic movement buries the lutite deposits, which are subjected to increased temperature and pressure. These conditions cause a change in the structure and mineralogical composition of the rocks, forming the slaty cleavage, the mineral alignment that allows cleavage. Slaty cleavage is therefore the structure that defines roofing slate. Without it, regular, thin tiles cannot be obtained. The circles below the rocks indicate the arrangement of layered minerals observed at a microscopic scale. Slate cleavage runs north-south in these circles. The increase in metamorphism brings with it crystalline growth. The optimum grade of crystalline growth corresponds to slates s.s., and represents the best mechanical properties for a tile.*

It is also important to remark that there are two different terms that usually are confused as the same: roofing slate and slate. A roofing slate, as defined by Cárdenes et al. (2016), is a metamorphic rock that can be split into thin and regular tiles for roofing. On the other hand, a slate is an "ultrafine or very fine-grained metamorphic rock displaying slaty cleavage", according to the recommendations of the International Union of Geological Sciences (IUGS) Subcommission on the

Systematics of Metamorphic Rocks (Fettes & Desmons, 2011). In turn, slaty cleavage is a “type of continuous cleavage in which the individual grains are too small to be seen by the unaided eye”. Both terms cover different topics. **While roofing slate is a construction term, as it refers to a building material, slate is a type of rock. In other words, not all slates can be used for roofing, and not all roofing slates are slates.**

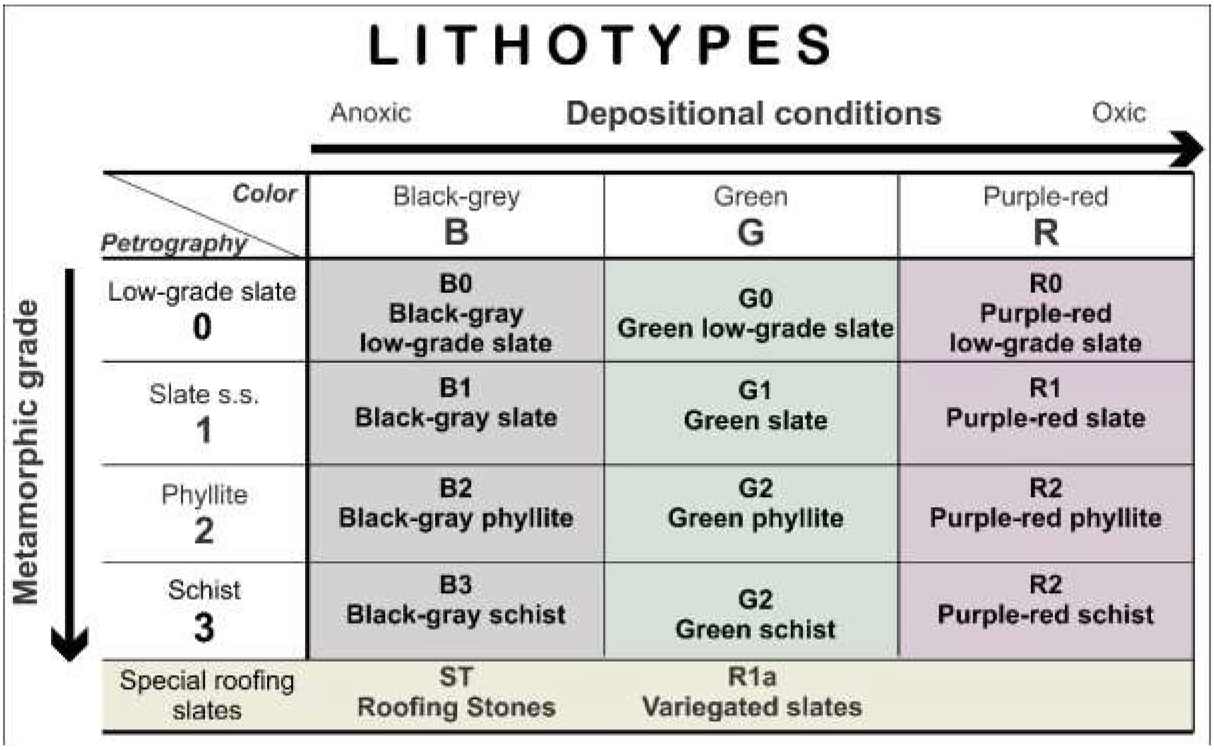

Figure 2: *International Roofing Slate Classification (IRSC). Codes B/G/R correspond to color families, while codes 0/1/2/3 correspond to petrology, or type of rock. The combination of these two groups results in 12 lithotypes. Most of roofing slates traded in the world correspond to lithotype B1 (>90%), i.e., black-gray slates s.s.*

According to this definition, the Brazilian material falls within the “roofing slate” product category (EN 12326) with important nuances. This rock exhibits metamorphic traces but retaining sedimentary characteristics. The degree of metamorphism is clearly lower than that of other roofing slates; therefore, the development of slaty cleavage is not as penetrating as in slates s.s. In fact, this rock splits along the remnants of sedimentary levels. **From a petrological point of view, it is not a slate s.s., nor a mudstone or a shale. In previous publications, this rock has been referred to as “metalutite” (also called “low-grade slate” in that literature)—both labels referring to a metamorphic rock that still retains some sedimentary traces observable under petrographic examination (Figure 3).**

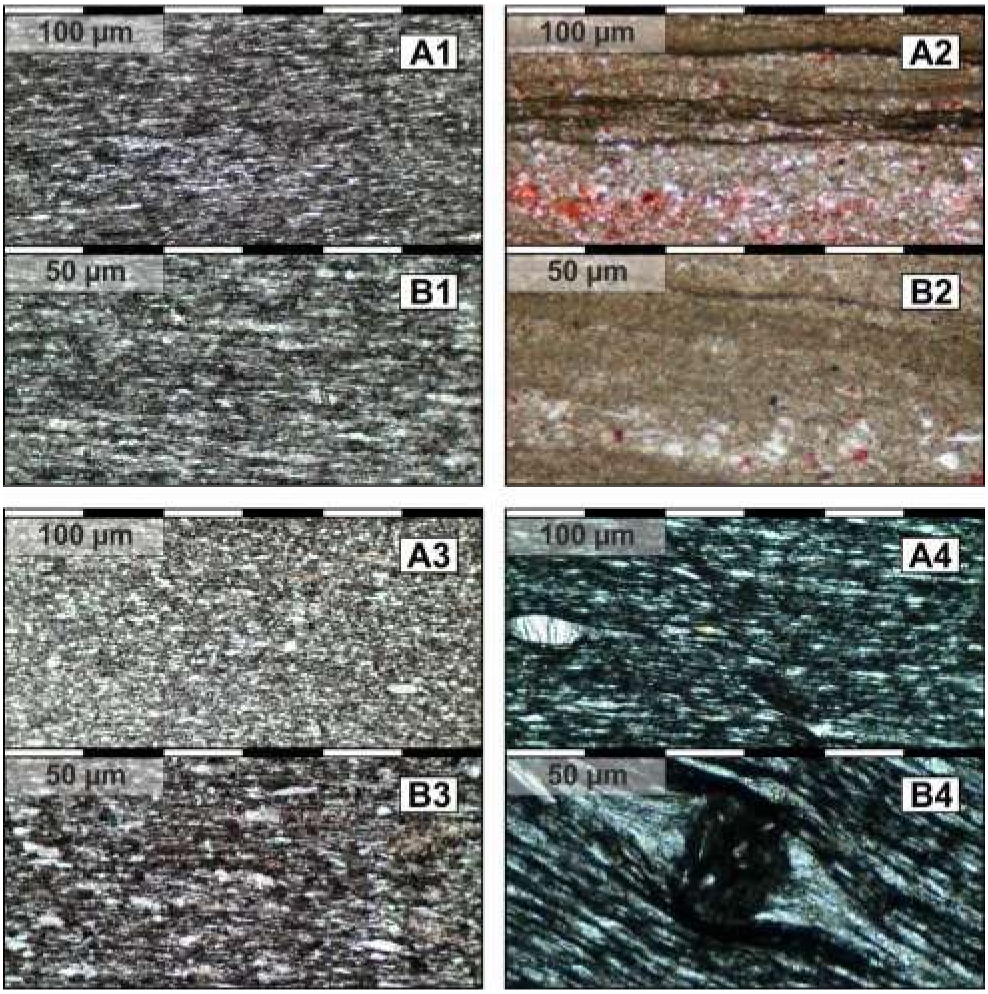

Figure 3. *Petrographic microscope images of selected roofing slates from the world. In all cases the fissility/split plane runs left-right:*
1: Ordovician slate s.s. Minerals are strongly aligned along the slaty cleavage. Angers, France.
2: The dark lines correspond to relict sedimentary planes. Red grains correspond to dyed carbonate grains. Minas Gerais, Brazil.
3: Regular, homogeneous slate s.s. from Newfoundland, Canada.
4: Another slate s.s., showing a big crystal of monacite in B4. La Baña, Spain. Modified from (Cárdenes et al., 2014)

To conclude, Brazilian "slates" are indeed roofing slates insofar as they are used for roofing, but not slates s.s., they correspond to metalutites (or low-grade slates, it is the same), code IRSC 0, while slates s.s. have the IRSC code 1.

Are there differences between the technical performance (test results) of Brazilian metalutites and European slates?

Yes, as are the test results from the ATG certification show. This certification is awarded by the Belgian Union of Technical Qualification in Construction (BUTgb) and is considered, along with the French NF certification, the most prestigious and reliable certification for roofing slates in Europe. However, NF test results are not available on their website, so only ATG reports, which are available online, were used for this comparison.

Test results show some differences between the Brazilian metalutites/low-grade slates, and slates s.s. (Table 1). Basic statistical parameters (average and standard deviation) are summarized in Table 2 for mechanical parameters (Modulus of rupture), Water Absorption, and CaCO3 content. Thermal cycle and Exposure to SO2 are the same for all reports (T1 and S1), so it is not necessary to include them.

Country	IRSC code	ATG Report	Modulus of rupture		WA	CaCO3	TC	Exp. SO2
			Long.	Trans.				
BR	B0	ATG 08/H854	50,1	47,7	0,61	2,7	T1	S1
BR	B0	ATG H854	56,7	58,1	0,44	1,8	T1	S1
BR	G0	ATG 08/H853	49,6	49,4	0,31	0,9	T1	S1
BR	G0	ATG 15/H853	55,9	59,0	0,35	0,9	T1	S1
CA	B1	ATG 08/H768	62,4	57,1	0,21	1,4	T1	S1
CA	B1	ATGH768	67,7	70,8	0,31	0,3	T1	S1
ES	B1	ATG 08/H517	70,1	43,0	0,21	0,1	T1	S1
ES	B1	ATG 08/H518	73,6	70,6	0,55	0,1	T1	S1
ES	B1	ATG 08/H526	55,7	53,0	0,51	0,5	T1	S1
ES	B1	ATGH526	56,9	54,8	0,36	1	T1	S1
ES	B1	ATG 08/H550	61,1	62,3	0,39	0,1	T1	S1
ES	B1	ATG 08/H552	79,2	61,3	0,47	0,1	T1	S1
ES	B1	ATG 08/H683	58,2	43,4	0,29	0,1	T1	S1
ES	B1	ATG 08/H800	67,9	49,4	0,47	0,1	T1	S1
ES	B1	ATGH800	61,2	57,3	0,3	0,5	T1	S1
ES	B1	ATG 08/H848	51,0	48,3	0,25	0,55	T1	S1
ES	B1	ATG 08/H573	75,0	47,0	0,39	0,1	T1	S1
ES	B1	ATG 08/H754	70,0	65,8	0,27	0,6	T1	S1
ES	B1	ATG 10/H896	75,7	60,7	0,19	0,17	T1	S1
ES	B1	ATG 09/H625	59,8	52,2	0,35	0,3	T1	S1
ES	B1	ATGH625	65,5	65,4	0,36	0,4	T1	S1
ES	B1	ATG 10/H664	80,5	62,2	0,23	0,2	T1	S1
ES	B1	ATG 10/H737	74,0	71,2	0,21	0,5	T1	S1
ES	B1	ATG 10/H885	62,7	57,5	0,19	0,3	T1	S1
ES	B1	ATG 10/H890	87,8	68,2	0,3	0,4	T1	S1
ES	B1	ATG 11/H652	64,0	57,1	0,4	0,1	T1	S1
ES	B1	ATG 11/H626	53,2	58,4	0,26	0,67	T1	S1
ES	B1	ATG 11/H625	64,0	57,1	0,4	0,1	T1	S1
ES	B1	ATG 12/H670	82,0	71,0	0,22	0,4	T1	S1
ES	B1	ATG 12/H851	70,5	62,4	0,4	0,4	T1	S1
ES	B1	ATG 14/H571	64,6	58,0	0,22	0,4	T1	S1
ES	B1	ATG 15/H517	67,7	47,5	0,25	0,4	T1	S1
ES	B1	ATG 15/H518	65,5	61,2	0,35	0,35	T1	S1
ES	B1	ATG 15/H550	62,4	60,1	0,25	0,1	T1	S1

ES	B1	ATG 15/H552	72,0	63,6	0,31	0,4	T1	S1
ES	B1	ATG 15/H598	63,6	56,2	0,26	0,3	T1	S1
ES	B1	ATG 15/H599	72,6	67,9	0,31	0,3	T1	S1
ES	B1	ATG 15/H657	65,7	54,3	0,33	0,4	T1	S1
ES	B1	ATG 15/H689	77,7	65,1	0,29	0,5	T1	S1
ES	B1	ATG 15/H695	70,0	51,6	0,3	0,4	T1	S1
ES	B1	ATG 15/H800	61,2	57,3	0,3	0,5	T1	S1
ES	B1	ATG 15/H845	68,4	58,5	0,19	0,4	T1	S1
ES	B1	ATG 15/H848	54,5	56,2	0,26	0,7	T1	S1
ES	B1	ATG 15/H876	74,5	63,2	0,3	0,4	T1	S1
ES	B1	ATG 15/H926	66,1	52,4	0,33	0,3	T1	S1
ES	B1	ATG 15/H572	65,0	56,3		0,35	T1	S1
ES	B1	ATGH930	66,9	54,4	0,2		T1	S1
ES	B1	ATGH517	67,7	47,5	0,3		T1	S1
ES	B1	ATGH518	65,5	61,2	0,4		T1	S1
ES	B1	ATGH599	72,6	67,9	0,3		T1	S1
ES	B1	ATGH657	65,7	54,3	0,3		T1	S1
ES	B1	ATG H941	66,5	61,0	0,31	0,4	T1	S1
UK	R1	ATG 08/H631	91,3	55,1	0,15	0,5	T1	S1
UK	R1	ATGH631	78,4	50,6	0,19	0,4	T1	S1

Table 1. *Data retrieved from ATG certifications (https://butgb-ubatc.be) after the test methods from EN 12326-2. Modulus of rupture values in MPa; WA: water absorption (%); CaCO3: carbonate content (%); TC: thermal cycle; Exp. SO2: Sulfur dioxide exposure test.*

	Modulus rupture (MPa)		WA (%)	$CaCO_3$ (%)
	Long.	Trans.		
Metalutite/Low-grade slate **IRSC code: 0**	53.1 (3.7)	53.6 (5.8)	0.4 (0.1)	1.6 (0.9)
Slate *s.s.* **IRSC code:1**	67.9 (8.3)	58.2 (7.1)	0.3 (0.1)	0.4 (0.2)

Table 2. Statistics for the test results from Table 1. Discussion in the main text.

Test results from Tables 1 and 2 highlight some differences between IRSC 0 (metalutite/low-grade slate) and IRSC 1 (slate s.s.). However, the statistical representativeness of IRSC 0 is lower, as only four certifications were obtained from the BUTgb website, none of which are currently active. **It appears that no IRSC 0 currently holds ATG certification.**

Modulus of rupture

The modulus of rupture expresses the maximum load a tile can withstand before failing. It is closely related to the internal structure and the effect of slaty cleavage. Slaty cleavage is, in fact, a set of parallel planes affecting the entire rock mass created during the metamorphism. Generally, there is another set of planes, corresponding to the original sedimentation, created when the primordial clays were deposited. The intersection between these two planes gives a set of parallel lines, the intersection lineation, well known to slate miners as *grain* or *hebra* in Spanish (Figure 3). This lineation is very important, since to achieve optimal mechanical strength for a tile, it must be trimmed with its length parallel to the grain. This strong structural control is also the reason why there is such a difference between the longitudinal and transverse values for the modulus of rupture[1] in IRSC 1, slates s.s. On the other hand, there is no difference between the

[1] EN 12326 measures the Modulus of Rupture in two perpendicular directions, taking as a reference the length of the tile. As a result, longitudinal and transversal values can be obtained.

longitudinal and transverse values for IRSC 0, due to the lack of development of the intersection lineation. **Furthermore, the overall values of the modulus of rupture of the Brazilian material are significantly lower (Table 2).**

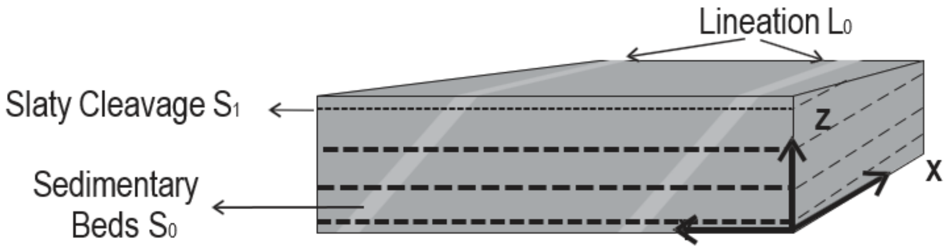

Figure 3. *Relations between Sedimentation and Slaty cleavage planes, and their resulting combination, the Lineation or grain.*

The lineation is usually noticeable on the surface of IRSC 1. Since this structure needs a certain metamorphic grade, it is not present on the surface of the IRSC 0 (Figure 4).

Water absorption

Water absorption is one of the most important characteristics of a dimension stone, as **it determines its vulnerability to weathering**. WA is determined by the structure of the pore system. Roofing slates are, in general, fine-grained rocks, with low WA values. However, there is also a difference in this value between IRSC 0 and IRSC 1. The IRSC 0 lithotype has higher WA values than IRSC 1. This is due to the effect of metamorphic recrystallization. Metamorphism is a geological process that involves the creation of new minerals, which tend to fill empty spaces, or pores, in the rock matrix. Under low-grade metamorphic conditions, the more intense the metamorphism, the thinner the pore system and, therefore, the lower the WA. **Since IRSC 0 has a lower metamorphic development, its pore system is also larger than IRSC 1.**

The technical problem with WA is that it makes it prone to weathering in cold climates. The rock absorbs water, which can freeze. Ice has a volume 9% greater than water, meaning that when it freezes, its volume increases, creating tension in the rock. This process, repeated several times, is known as freeze-thaw and is one of the main processes of stone decay, along with salt crystallization, which follows a similar mechanism. The WA values for both lithotypes are low compared to other dimension stones, but roofing applications require very high WA values.

Figure 4. *Brazilian material (left), corresponding to IRSC 0, and Spanish roofing slate (right), corresponding to IRSC 1. Lineation (hebra) in this last sample runs north-south. On the other hand, no trace of lineation can be observed in the IRSC 0.*

Carbonate content

Carbonate is a group of harmful minerals that can seriously affect the integrity of slate. Typically, it ranges between 0% and 2%, but in some Italian slates (carbonate slates) it can exceed 20%[2]. **The ATG test results show a higher proportion of carbonates in IRSC 0, likely associated with a more extensive pore system.** Carbonate is deposited in the void spaces by meteoric waters. However, the number of results (only four) is not statistically significant. In IRSC 1, the carbonate content ranges between 0.2% and 0.6%.

NF and ATG certification requirements

As pointed before, these two certifications use the EN 12326 test methods, incorporating their own quality thresholds (Table 3).

	NF	**ATG**
Modulus of Rupture	Depends on the width and thickness. For a 30x20x4, it would be 33 Mpa	not defined
WA	<0.4%	<0,6%
Thermal cycle	T1, iron sulphides only in the central part of the tile	T1
SO2 exposure	S1	S1
CaCO3	<1.5%	<5%
C	<1.5%	<2%
Density	>2.60 gr/cm3	

Table 3. *Required parameters for the NF and ATG certifications.*

According to the data used for this report, all IRSC 1 values meet these requirements. On the other hand, the IRSC 0 values for WA and CaCO3 are practically unacceptable. However, more data would be needed to verify the accuracy of this statement.

Conclusions

- Brazilian metalutite is a roofing slate insofar as it is used for roofing, falling within the scope of the EN 12326 standard. However, from a geological and petrological standpoint, **the structure and grade of metamorphism is different than Spanish (and, by extension, European) roofing slates.**

- **According to the International Roofing Slate Classification, Brazilian roofing slate corresponds to a IRSC 0, while Spanish roofing slates corresponds to IRSC 1.**

- **This difference is easily noticeable not just aesthetically but in its technical properties.** A review of the test results from the Belgian ATG certification highlights that values of the Modulus of Rupture, Water Absorption, and Carbonate Content were found to be below the average values for Spanish roofing slates

- **Therefore, the performance of Brazilian roofing slates is expected to be significantly lower that for Spanish roofing slates, especially in humid, cold climates in which freeze-thaw processes are common.**

[2] Italian Ligurian slates are characterized by turning white after a few years while maintaining their structural integrity due to their unique mineralogical arrangement.

- Regarding the ATG test results, only four (all expired) of the 53 results obtained from the ATG website corresponded to Brazilian roofing slates. This leads to two conclusions: **Brazilian companies seem to have difficulty obtaining ATG certification, and the lack of data on Brazilian roofing slates makes it difficult to determine the characteristics and performance of the product that reaches the European market.**

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