



Del Carmen Natural Roofing Slate

**a review of the geology,
test performance and use**

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This report reviews the geology, test performance and use of Del Carmen slate from La Cabrera, north-western Spain. The report principally draws on information and test results from a variety of independent sources on behalf of SSQ Group.

The Del Carmen slate is true geological slate exhibiting a range of properties that make it suitable for use as roofing slate. The supply is well developed with considerable and consistent reserves available for the future.

Regularly tested to British, French, German, Belgian and American standards, a service life in excess of 75 years is expected. Additionally, the Del Carmen slate has very low contents of potentially problematic inclusions such as pyrite and calcite meaning that it will not discolour or suffer from pitting.

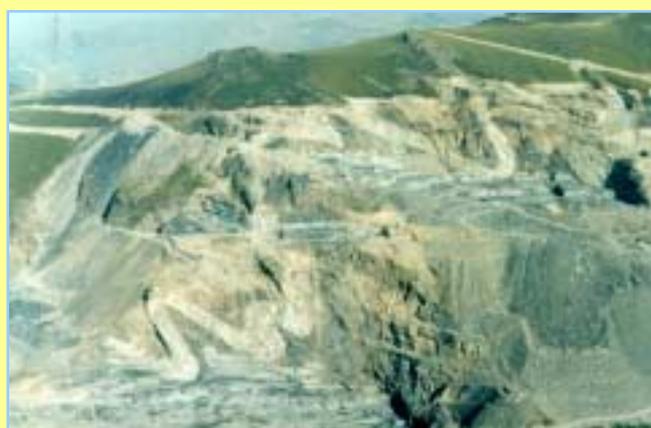


The Geology of La Cabrera and Carbajal de la Romana Quarry

The Cabrera area of north-western Spain includes the quarry of Carbajal de la Romana, which produces Del Carmen slate. The quarry is situated about five kilometres west of the village of La Bana on the Rio Capillo. Its altitude is approximately 1,450 metres above sea level. The geology of this region is extremely complex and has suffered a variety of major phases of tectonic activity, i.e. the upheaval of the rocks as a result of pulling, pushing and shearing forces on a continental scale.

The Del Carmen slate occurs within a sequence of Ordovician age (505 – 438 million years ago). Originally the material that now forms the Del Carmen slate was part of a series of rapidly deposited sediments. Subsidence of the basin into which the sediments were deposited meant that a thick sequence of rock built up.

The sediments were subjected to heat and pressure modification during part of the Hercynian orogeny between 320 and 310 million years ago, which occurred throughout Europe and across other parts of the globe. This folded, tilted, overturned and recrystallised the sediments, metamorphosing them into a range of new rock types. A second series of lesser movements at the end of the Hercynian orogeny overprinted some of the structures formed with additional features that make the Del Carmen slate what it is today.



View of the Del Carmen and nearby La Bana slate quarries

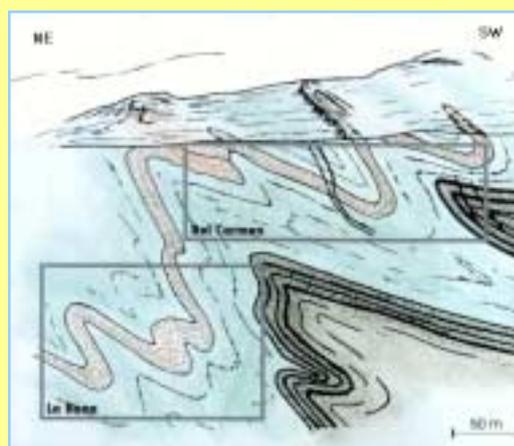


Diagram demonstrating the rock sequence, the most notable feature being the folded band of lighter coloured quartzite

The rock sequence now found at the Carbajal de la Romana quarry and the immediate surrounding area is a mixture of true geological slate, quartzite and fine quartzitic layers of variable grain size (known as a 'turbidite' sequence). Evidence for the previous metamorphic processes is highlighted by the behaviour of the different layers as demonstrated above.

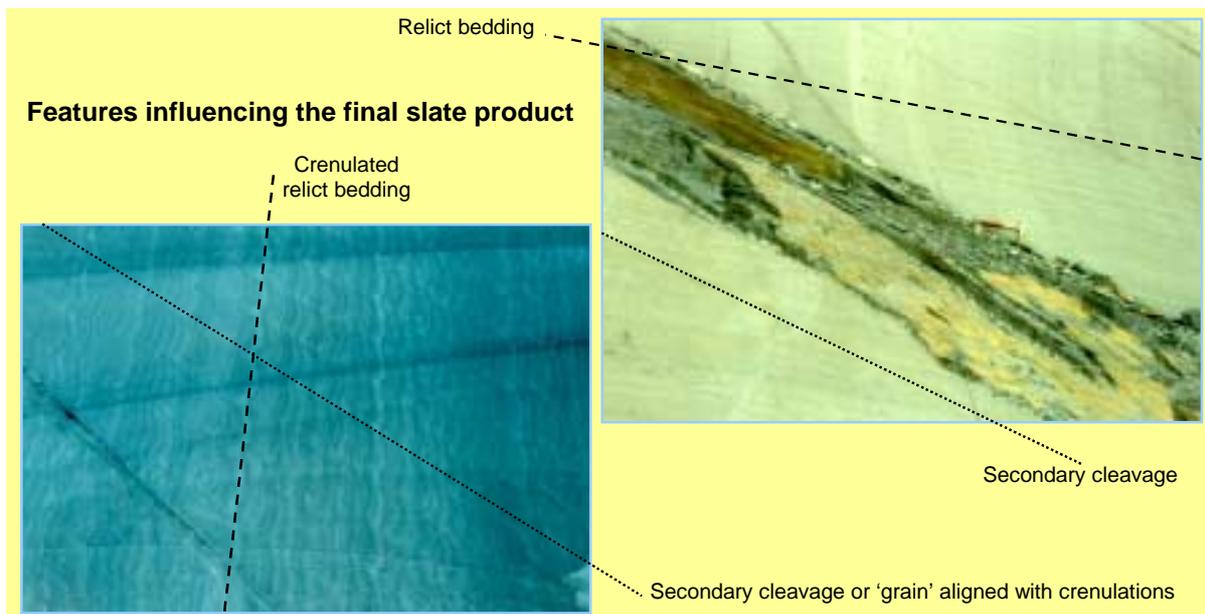
Below, folding and displacement of the rock sequence, slate extraction is occurring below this.



Above, folding of a lighter coloured quartzite band, grey slate is observed below this

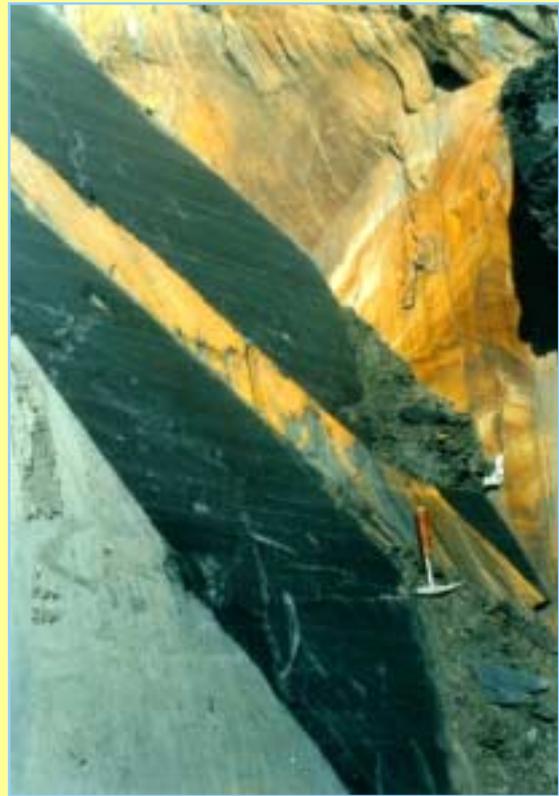
The first stage of metamorphism formed the primary cleavage of the slate whilst the second stage of metamorphism imparted a second, inferior cleavage almost at a right angle to the first. This second cleavage imparts a grain or secondary splitting direction, which is exploited during slate extraction. The second cleavage also imparts a crenulated or wavy structure to the plane of the first cleavage to give the characteristic, faintly rippled texture observed in the finished slate.

The slate sequence is approximately 200 metres thick, 150 metres being blue/black layers, the remaining 50 metres being more greyish layers. Whilst being mostly extremely finely crystalline, the Del Carmen slate exhibits some slightly more coarsely crystalline bands reflecting the original sedimentary conditions at the time of formation. The main cleavage is generally parallel to the relict sedimentary banding, but is sometimes at a slight angle allowing the structures to cut the main cleavage, resulting in apparent banding. This banding may be visible either due to subtle colour variation and/or slight rippling due to the different competency of the layers.





Above, succession of quartzite and finer quartzitic bands known as a 'turbidite' sequence that has been folded. Slate is extracted to the left of the fold



Right, close view of some of the jointing structures within the rock sequence

Other structures influencing the geology include the presence of random quartzitic veining and a series of large fractures or joint sets related to the decompression of the rock. Major faults also cut through the sequence. It is these faults and joint sets that are exploited during quarrying to assist extraction. Where blocks require cutting from the quarry face, this is done using diamond wire cutting equipment to avoid the disruptive effects that blasting may impart.



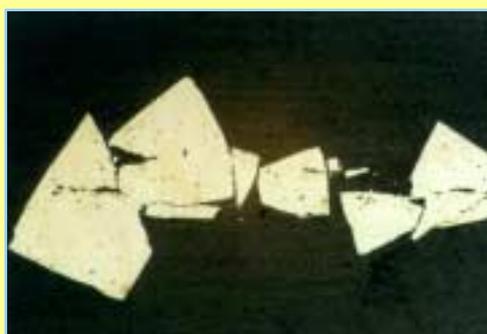
Diamond wire cutting apparatus used at the Carbajal de la Romana Quarry. The machine tracks backwards as the wire cuts through the rock

Mineralogy of the Del Carmen slate

The Del Carmen slate comprises predominantly the phyllosilicate minerals chlorite, muscovite mica and illite, together with quartz and minor feldspar. Traces of calcite and opaques principally as pyrite are also present.

The split face of the slate is the primary cleavage plane. This plane is found to be slightly uneven as a result of the secondary crenulation cleavage, providing a faintly rippled surface.

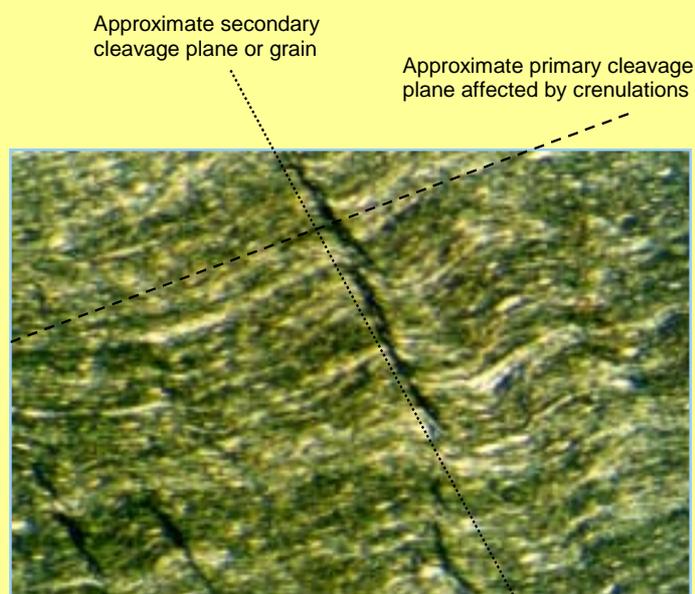
The phyllosilicate minerals have a platy structure and are typically aligned sub-parallel to the primary cleavage with a 'preferred orientation'. Where the crenulation cleavage occurs, the phyllosilicates depart from the general plane to form small wave structures. The quartz and feldspar are almost indistinguishable amongst the phyllosilicates except where they occur in lenses and occasional coarser more silica rich bands. The larger quartz grains are typically flattened and elongated sub-parallel to the primary cleavage, sometimes giving the appearance of a series of discontinuously aligned lenses. The pyrite traces occur as well-formed crystals although some finely disseminated material is present. Calcite occurrence is irregular, usually as small clusters of grains when present.



These two views are photographs taken through the microscope, known as photomicrographs

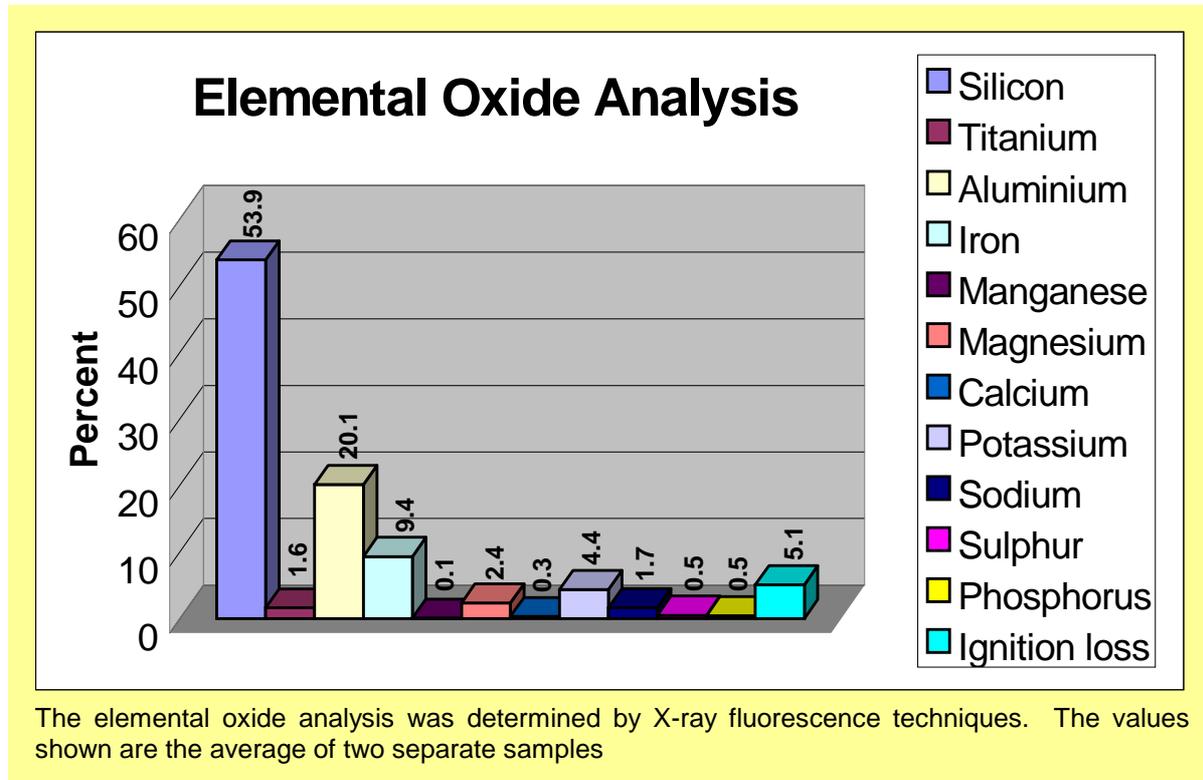
Above, in reflected light, bright, well-formed crystals of pyrite are visible in contrast to the dark matrix of the slate

Right, in plane-polarised light, both the primary cleavage and secondary splitting (grain) planes are visible, these modified by the crenulations



Elemental analysis shows the Del Carmen slate to be rich in silica and aluminium with substantial proportions of iron, potassium, magnesium, sodium and titanium. Lesser proportions of sulphur, phosphorus, calcium and manganese are also present. The loss in weight upon burning suggests that a few percent may comprise carbon.

The titanium may be present as titanium oxide or rutile in the form of sub-micron-sized needles, finely disseminated throughout the slate. The carbon is probably present as graphite, again sub-micron-sized and disseminated throughout the matrix, and is probably responsible for the dark colour.



The Testing of Del Carmen Slate

The Del Carmen slate has been tested to current British, French, German, Belgian and American standards for roofing slate materials. The standards have a number of tests that are similar; however, there are some tests unique to a country as a result of differing climate or perception of the final use.

The most recent results available at the time of writing are summarised in **Table 1**. The Del Carmen slate passed all the different test criteria where given by the five countries.

It must be remembered that slate is a natural product that will vary in its composition and other features; this is particularly relevant for the Del Carmen slate quarry. Test results will vary with time and should be updated regularly to assess trends and whether any significant changes are taking place. The Del Carmen slate is regularly tested and previous reports are available on request.

Table 1, Summary of Test Results for Different Countries

Country	UK	France	Germany	Belgium	USA
Test	Results and Observations				
Water absorption, %	0.3	0.30	0.21	0.28	0.25
Absolute density, Mg/m ³		2.81	2.78	2.80	
Dry density, Mg/m ³			2.81		
Porosity, %		0.8	0.56		
Thermal cycling	Pass	No change		0.02% loss	
Acid resistance ¹	Pass		0.20/0.24 0.17/0.18		
Steps ²		None			
White deposits ³		None			
Pyrite		Non-oxidisable	0.12		
Frost resistance, loss, %		< 0.1	0.01		
Carbon dioxide, %			0.12		
Sulphur, %			0.03		
Sulphate (SO ₄)			0.02		
Calcium carbonate, %		0.3	0.27	0.04	
Bending strength, MPa	Transverse, dry	78	76.1	51.3	65.3
	Transverse, wet		65	44.6	
	Transverse, after frost testing, dry			75.3	
	Transverse, after thermal cycling, dry			73.4	
Depth of softening, mm					0.04
Classification	Pass	Class A	-- ⁴	Pass	Grade S₁

Notes

- 1 The German test is for weight gain after 14 and 28 days, dry and saturated conditions.
- 2 A 'step' is an oblique fracture relative to the cleavage plane with a quartz infill between the two lips of the fracture.
- 3 'White deposits' are thin film deposits that may be affected by changes in colour.
- 4 No acceptance criteria for the German test standards.

The various test results given above are from a variety of independent accredited sources

The Use of Del Carmen Slate

The Del Carmen slate is true geological slate with a well defined cleavage that allows even thickness slates to be prepared that exhibit little evidence of warping or curling. A poorly defined secondary cleavage or grain provides a natural secondary splitting direction.

The geology, examination and testing of the Del Carmen slate indicate a resource that can produce roofing slates of high quality that should be durable under the expected range of conditions found across the British Isles and Europe.

The bulk phyllosilicate and silica minerals are effectively inert, being the weather resistant remains of former rocks. These will resist the potentially daily cycles of wetting and drying and heating and cooling. The combination of these minerals should also provide strength without significant brittleness, making holing smooth with few resultant breakages.

The low absorption will help the slate resist the ingress of water, reducing the subsequent potential for freeze-thaw action. The high flexural strength will also resist expansive forces as well as those expected from strong wind uplift.

Significantly, there is a low pyrite content and this pyrite appears to be non-oxidisable. The proportion of calcite is also very low suggesting that the slate should resist even highly acidic atmospheres.



For roofing, Del Carmen slate is a natural choice



The results suggest that a service life of over 75 years should be expected; however, periodical removal by cleaning of moss, lichen and dirt build-up may considerably increase the potential life span.

Summary of Findings

The Del Carmen natural roofing slate meets all the highest requirements of the British, French, German, Belgian and American roofing slate standards. The findings were as follows:

British	Pass
French	Class A (highest class)
Belgian	Pass
American	Grade S ₁ (highest grade)

The German standard does not include acceptance criteria.

The physical, mechanical and chemical features are equivalent to many of the best roofing slates from around the globe, including those from the UK, America and other locations within Spain.

A service life in excess of 75 years should be expected for a correctly constructed and maintained roof.

SSQ will accept no responsibility for any loss or damage howsoever caused that may arise through reliance being placed on the content of this document. Natural slate resources typically exhibit lateral as well as vertical variations in composition and features and performance must be expected to change with continued quarrying. SSQ Group therefore cannot guarantee that the supplied product will exactly match the various results given in this document. However, SSQ Group, through regular appraisal of its resources, endeavours to ensure that a reasonably uniform product is supplied.

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Appendix A

British Standard Testing BS 680: 1971

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Test report by Sandberg, ref 17337 dated 20.7.99

Appendix B

French Standard Testing Norm

(This appendix consists of 10 pages, including this)

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Test reports by Laboratoire National D'Essais:

Dossier 9080178 – Document CEMATE/1 dated 19/07/99

Dossier 9080178 – Document CEMATE/2 dated 19/07/99

Appendix C

German Standard Testing DIN 52 201

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Test report by Eifelinstitut, ref Nr. 0610-93 dated 27.10.93

Appendix D

Belgian Homologation

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Belgian Agreement Certificate dated 2.4.97

Appendix E

American Standard Testing ASTM C406-89

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Test report by TBV Stangers, ref 202/0698/95/JG/st dated 5.10.95