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NATURAL ENVIRONMENT RESEARCH COUNCIL

GeoReports

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Building Stone Assessment

The BGS Building Stone Assessment service combines geological expertise and building conservation expertise to provide authoritative advice to clients wishing to specify natural stone for repairing or building stone structures. Samples of stone supplied by clients are compared with samples from active quarries held in the BGS Collection of UK Building Stones to identify the closest-matching, currently available stone(s). Using the closest-matching stone type in repairs to stone structures maximises the likelihood that the replacement stone will co-exist harmoniously with the original stone and will weather sympathetically.

Report Id:	GR_213220
Site Address/Location:	Kisimul Castle, Castlebay, Isle of Barra, HS9 5UZ; and Stulaigh, OS Grid Ref [NF 83 23]
Date report commissioned:	09/02/2016
Sample Numbers:	ED11450 and ED11483
Date of Report:	14/03/2015

Building Stone Assessment

Comparison of stone samples from Kisimul Castle (Barra) and the island of Stulaigh (by South Uist)

1 Introduction

BGS has been asked by Jamie MacPherson, of Historic Environment Scotland, to perform a Building Stone Assessment on two samples of stone from the Outer Hebrides, both provided by the client.

- *Sample from Kisimul Castle on Barra* (OS Grid Reference [NL 6651 9796]): a tabular block of greyish-green metamorphic rock c. 20x15x5cm in size, which is understood to be typical of the main decorative stone used in the castle dressings. The BGS sample number ED11450 has been assigned. The stone forming this sample was identified as *mylonite* in a previous BGS report[1].
- *Sample from the island of Stulaigh*, which lies off the east coast of South Uist. A grid reference for the sample has not been provided; Stulaigh is at OS Grid Reference [NF 83 23]). The sample, which is a tabular block of greyish-green metamorphic rock c. 40x12x5cm in size, is assumed to come from a bedrock outcrop on the island. The BGS sample number ED11483 has been assigned.

The objectives of this Building Stone Assessment are to:

- provide detailed petrographic descriptions of both samples, to establish the range and character of their intrinsic properties; and
- compare the geological character of the samples to assess whether Stulaigh could have been the source of the dressing stone used in Kisimul Castle.

A brief summary of key features of the bedrock geology of Barra and South Uist is presented in section 2, to provide context. A petrographic description of each sample, with accompanying photographs, is presented in Appendix 1. The geological character of the samples is compared in section 3, and conclusions are presented in section 4.

1. Everett, P.A., Gillespie, M. R. and Tracey E.A. (2015). *The provenance of building stones in four 'galley castles' in Argyll*. British Geological Survey Commissioned Report OR/15/053.

2 Geological background

Most of the bedrock in the Outer Hebrides, including the rocks that underlie Barra, South Uist and nearby islands, is assigned to the *Lewisian Complex*, a major geological unit of thickly banded and strongly metamorphosed crystalline rocks (*gneiss*) (Figure 1). The Lewisian rocks formed between 3 billion and 1.6 billion years ago (during the Archaean and Proterozoic eons), and as such are some of the oldest rocks on Earth. Most of the gneiss consisted originally of intrusions of light and dark igneous rocks (*granite* and *basalt*, respectively). Strong metamorphism has deformed the intrusions, giving the Lewisian Complex a banded or striped character on a range of scales.

Along much of the length of the Outer Hebrides the Lewisian Complex is bisected by a major geological fault, the *Outer Hebrides Thrust Fault* (Figure 1). This fault, which developed around 2,400 million years ago, dips gently towards the east; the bedrock on one side of the fault (the east side) has been pushed (or ‘thrust’) over the bedrock on the other side (the west). This event, in which vast volumes of rock were displaced relative to each other, deep within Earth’s crust, produced a band of strongly deformed rocks along the line of the fault. The line marking the position of the Outer Hebrides Thrust Fault on Figure 1 is drawn along the western edge of the band of rocks that have been strongly deformed by movement on the fault.

Rocks that have been strongly deformed by faulting are known as *fault rocks*. Fault rocks are classified according to how they have responded to deformation during the faulting episode. *Mylonite* is a type of fault rock that is produced when the rocks are hot and displacement is slow; under such conditions crystals in the rock deform in a ductile (or ‘plastic’) manner and do not break, producing long, thin, intensely stretched layers of rock. By contrast, *cataclasite* is a type of fault rock that is produced when the rocks are cool or displacement is fast; under these conditions the rock deforms in a brittle manner, producing fragments of broken rock within a matrix of finely pulverised rock. *Pseudotachylite* is an extreme form of cataclasite that forms when the heat produced by friction as a fault moves is sufficiently intense to melt rock; the melted rock cools to form a new rock made of glass (pseudotachylite).

Various forms of mylonite and cataclasite crop out along the surface trace of the Outer Hebrides Thrust Fault on Barra and South Uist; collectively, these units of fault rock have been assigned to the *Outer Hebrides Thrust Zone Mylonites Complex* (Figure 1). Previous studies[2] have shown that the principal bodies of fault rock crop out mainly on the east side of the Outer Hebrides Thrust Fault.

[2] e.g. Sibson, R.H. 1977. *Fault rocks and fault mechanisms.* Journal of the Geological Society of London (March 1977), 133(Part 3):191-213.

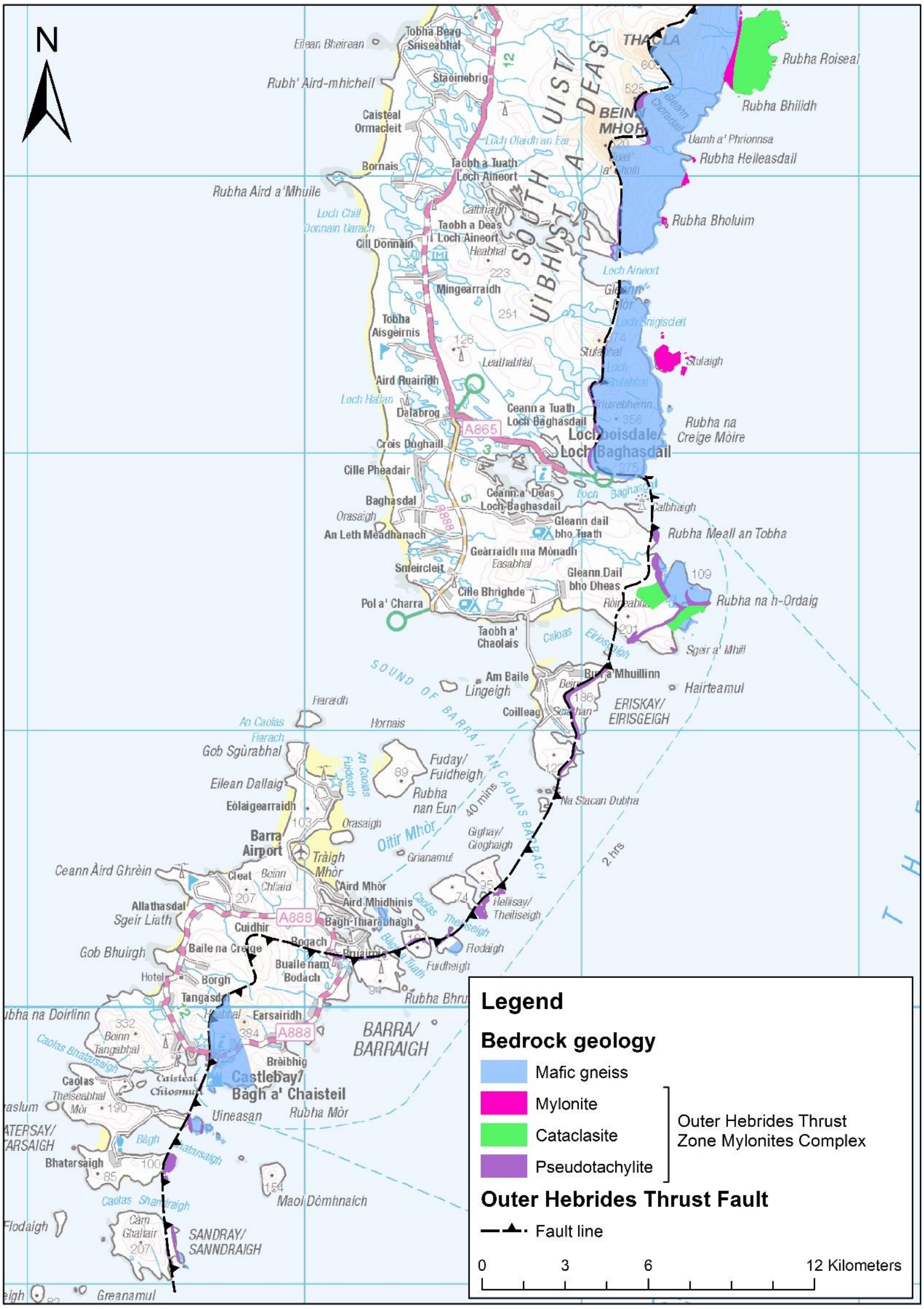

Figure 1. Map showing the position of the Outer Hebrides Thrust Fault at the ground surface, and the locations of the largest bodies of rock assigned to the Outer Hebrides Thrust Zone Mylonites Complex in Barra and South Uist (see text for more details). Many smaller bodies of fault-rock crop out close to the Outer Hebrides Thrust Fault but they are too small to show at this scale. Nearly all of the remaining (uncoloured) bedrock in this map area is assigned to the Lewisian Complex. Derived from the 1:50 000 scale BGS Digital Geological Map of Great Britain (DigMapGB50).

3 Comparison of samples

A photograph illustrating the appearance of both hand specimen samples is presented in Figure 2, and brief petrographic descriptions with accompanying thin section photographs are presented in Appendix 1.

A comparison of the photographs and descriptions confirms that the two samples are closely similar in nearly all respects. Specifically:

- The hand specimen samples are virtually identical in terms of physical form (both preferentially develop tabular blocks of similar thickness and surface character), colour, and fabric (both display the same intense foliation on sawn surfaces).
- Both share near-identical mineralogy, being dominated by quartz, chlorite and epidote in similar proportions. The substantial proportions of chlorite and epidote suggest that the original (pre-deformation) rock was a dark igneous rock such as basalt or gabbro.
- Both share near-identical textural character at the thin section scale, with occasional larger crystals (porphyroclasts) of epidote set in a matrix of intensely foliated, thoroughly recrystallised, very-fine-crystalline quartz, chlorite and epidote, in which quartz is commonly segregated from the other minerals in thin ‘ribbons’. The ribbons in the Stulaigh sample are somewhat thinner and more extended than in the Kisimul Castle sample, suggesting the Stulaigh sample was subjected to slightly more intense deformation.

Figure 2. A photograph of the two hand samples of stone considered in this assessment: sample ED11450 (Kisimul Castle) is to the left and sample ED11483 (Stulaigh) is to the right. The sawn surfaces have been moistened to highlight the strong mylonitic foliation in both samples.

4 Conclusions

This petrographic examination and comparison of samples of stone from Kisimul Castle and the island of Stulaigh has shown that they are essentially identical in terms of hand specimen character, key mineral constituents, and texture at both the macroscopic and microscopic scales.

Both samples consist of mylonite, a type of fault rock that forms under conditions of intense ductile strain deep in Earth’s crust. The BGS geological map of the area indicates that all of the bedrock forming Stulaigh is mylonite forming part of the Outer Hebrides Thrust Zone Mylonites Complex. The rocks of this complex formed approximately 2,400 million years ago as a result of displacement on the Outer Hebrides Thrust Fault, a major crustal discontinuity that today bisects the outcrop of the Lewisian Complex along much of the length of the Outer Hebrides.

The textural similarity of the two samples suggest they both formed under similar geological conditions, and probably at the same time, during movement on the Outer Hebrides Thrust Fault. However, mylonite crops out in many locations near to the trace of the Outer Hebrides Thrust Fault, so the textural similarity alone does not confirm that the sample from Kisimul Castle was sourced from Stulaigh.

Both samples are dominated by the same minerals - quartz, chlorite and epidote - which are present in roughly similar proportions; this indicates that both formed from the same ‘parent’ (pre-deformation) rock type, which was almost certainly a dark igneous rock such as basalt or gabbro.

The part of South Uist that is closest to Stulaigh is underlain by a large body of ‘mafic gneiss’ (Figure 1). This gneiss formed through the metamorphism of dark igneous rock, and this geological character combined with its close proximity to Stulaigh suggests it is this rock that has been strongly deformed by displacement on the Outer Hebrides Thrust Fault to become the mylonite that underlies Stulaigh.

The very close similarity between the sample from Kisimul Castle and the sample from Stulaigh means there is a strong possibility that the Kisimul Castle stone was also sourced from Stulaigh; however, another body of mafic gneiss is mapped around Castlebay on Barra (Figure 1), and the possibility that the Kisimul Castle stone was sourced from a band of mylonite developed within this bedrock unit (which crops out very close to Kisimul Castle) cannot be discounted.

BGS has no record of any historic quarries located within the Outer Hebrides Thrust Zone Mylonites Complex.

Analysis by: **Paul Everett**

Checked by: **Dr Martin Gillespie**

Date: 14/03/2016

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Appendix 1 Petrographic descriptions of samples

Methodology

A brief description is provided of the macroscopic and microscopic character of each sample. The macroscopic description is performed with the unaided eye and using a binocular microscope. The microscopic character is examined using a thin section (a slice of the stone sample cut thin enough to be transparent) and a polarizing microscope. Before preparing the thin section, the stone is impregnated with blue resin to highlight pore spaces. The thin section is cut perpendicular to the main fabric of the stone (where this is visible), and is positioned to be as representative as possible.

Observations are recorded on a Petrographic Description Form designed for building stones, to ensure the description is systematic and consistent with the procedures set out in British Standard BS EN 12407:2000 (*Natural stone test methods – Petrographic examination*). The completed Petrographic Description Forms, with accompanying photographs illustrating the typical character of the stone as it appears in the thin section, are presented below.

Each numbered note below relates to a superscript number in the Petrographic Description Forms.

1 The visual determination of stone colour is based on a simple assessment with the unaided eye in natural light. In stones displaying variable colour, the visual determination records the colour deemed by the geologist to be most representative. The determination of stone colour is made on a broken (not sawn), dry surface.

2 A simple, non-quantitative assessment of the degree to which the stone is cohesive. This property is recorded in terms of four conditions, each representing one segment of a continuum: *strongly cohesive*, *moderately cohesive*, *moderately friable*, and *very friable*. The grains in a *strongly cohesive* stone cannot be disaggregated by hand, whereas the grains in a *very friable* stone can be readily disaggregated by hand.

3 A simple, non-quantitative assessment of stone permeability, presented as one of five conditions (*very low*, *low*, *moderate*, *high*, *very high*) expressed relative to a nominal ‘average’ permeability in building stone samples. The assessment is based on: (i) a water bead test; (ii) the proportion of pore space in the stone; (iii) a visual assessment of the degree to which pore spaces appear connected in the thin section.

4 A record of the constituents (including pore space) in the stone, and their relative proportions, based on microscope examination. Proportions will usually be estimated, expressed in %, and based on a visual assessment of the whole thin section area. Any space created by dissolution within crystals is recorded against 'pore space'. '<' denotes 'less than' and '<<' denotes 'much less than', e.g. '<<1%' reads 'much less than 1%'.

5 A record of the size-range of the crystals in the stone, based on macroscopic examination. If grain-size is variable but there is a broadly uniform 'background' or matrix grain-size, the selected grain-size term describes this character (instead of, for example, porphyroclast size.

6 A record of the distinctive (and potentially diagnostic) textural features in the stone, based on microscopic examination. Where appropriate, qualifying details are recorded in the 'Comments' section.

7 A record of the distinctive (and potentially diagnostic) minerals in the stone, based on macroscopic examination.

8 The determination of stone type follows the classification and nomenclature of the BGS Rock Classification Scheme. This is based on the entries recorded for 'Micro stone constituents' and

'Micro texture'.

Sample ED11450 – Kisimul Castle

Hand specimen observations

Stone colour [1]:	*fresh*	greenish grey	*weathered*	greyish green
	exterior	greyish green		
Stone cohesion [2]:	*fresh*	strongly cohesive	*weathered*	strongly cohesive
Water absorption [3]:	very low			

Thin section observations

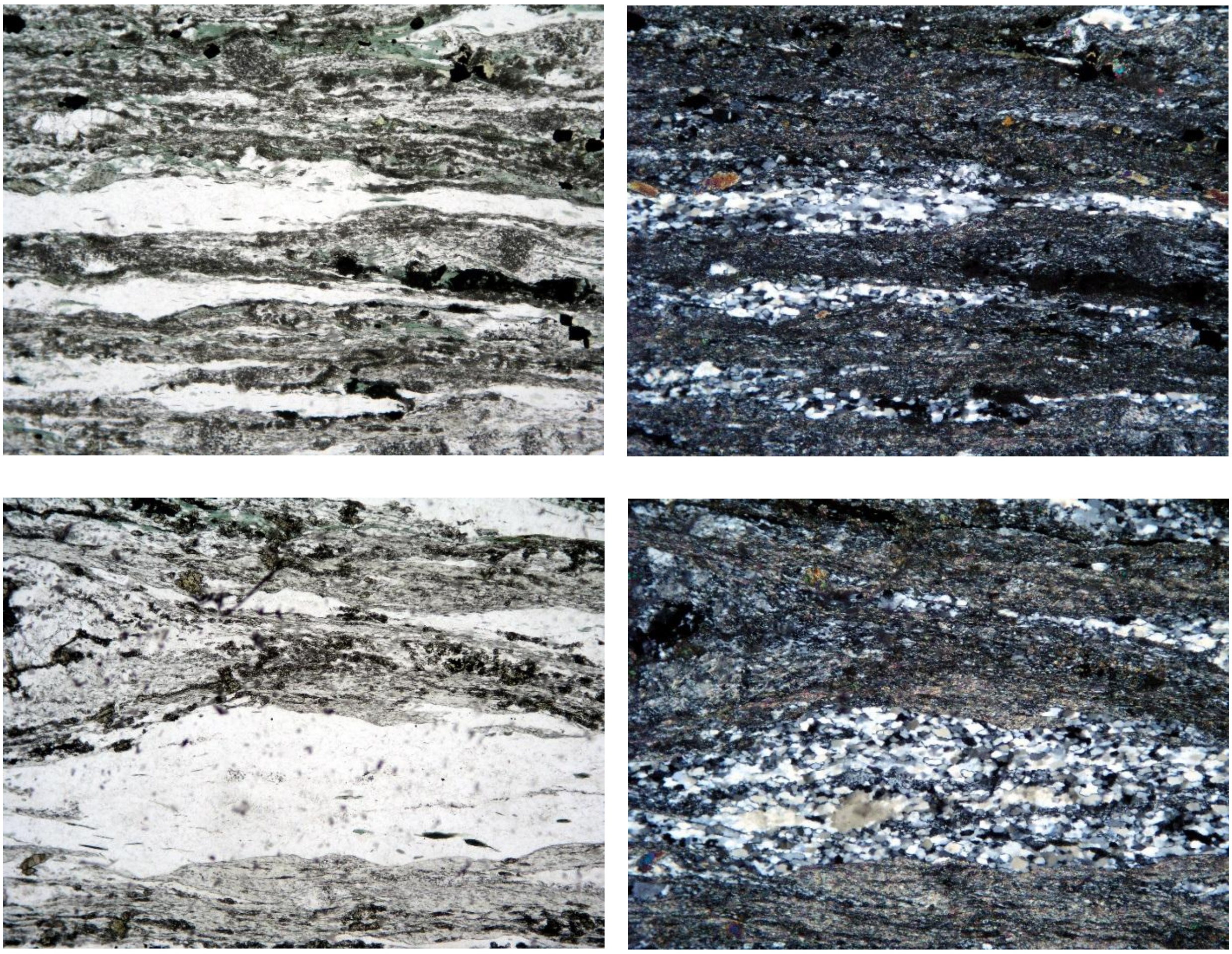
Stone constituents [4]:

Quartz	44%	Opaque oxide	6%
Chlorite	30%	Pore space	<1%
Epidote	20%	Calcite	<1%

Grain-size [5]:	very-fine-crystalline
Stone texture [6]:	very strongly foliated
Key constituents [7]:	quartz, chlorite, epidote
Stone type [8]:	quartz-chlorite-epidote mylonite

Comments

1) The weathered, exterior surface of the sample appears very similar to the fresh stone, and has not experienced significant stone decay.
2) The very strongly foliated character (i.e. intense planar fabric) is defined by thin layers (‘ribbons’) of quartz-rich or chlorite-epidote-rich rock in which the constituent crystals are very small (very-fine-crystalline) and thoroughly recrystallised. This textural character is typical of *mylonite* (i.e. rock that has been strongly stretched in a ductile manner.
3) Several relatively large (medium-crystalline) fragments of quartz, chlorite and epidote have survived the intense deformation and grain-size reduction that the fine-crystalline material has suffered; these *porphyroclasts* give an indication of the size of crystals in the rock before it was deformed by faulting.



Thin section photographs of sample ED11450

The images at left were taken in plane-polarised light: ribbons of dominated by quartz (white) chlorite with epidote (greenish-grey) are thinly interlayered. Black crystals are iron oxide.

The images at right are of the same field of view as those at left, but were taken in cross-polarised light. Under these conditions quartz appears white, grey or black, and the boundaries of numerous individual quartz crystals within each quartz ribbon are evident.

The field of view for all images is c.3.3 mm wide.

Sample ED11483 – Stulaigh

Hand specimen observations

Stone colour [1]:	*fresh*	greenish grey	*weathered*	greyish green
	exterior	greyish green		
Stone cohesion [2]:	*fresh*	strongly cohesive	*weathered*	strongly cohesive
Water absorption [3]:	very low			

Thin section observations

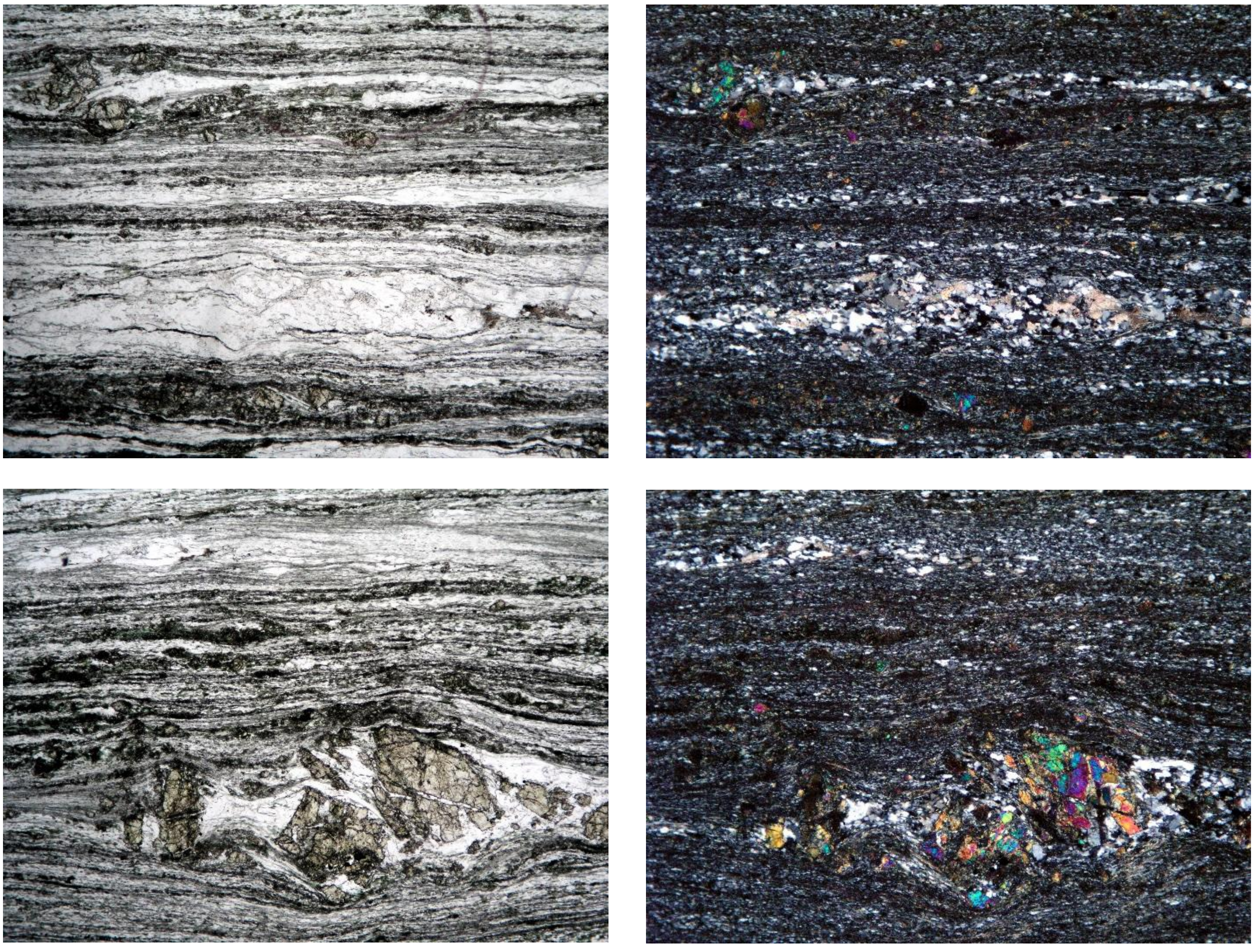
Stone constituents [4]:

Quartz	52%	Opaque oxide	4%
Chlorite	22%	Pore space	<1%
Epidote	20%	Calcite	2%

Grain-size [5]:	very fine-crystalline
Stone texture [6]:	foliated
Key constituents[7]:	quartz, chlorite, epidote
Stone type [8]:	quartz-chlorite-epidote mylonite

Comments

1) The weathered, exterior surface of the sample appears very similar to the fresh stone, and has not experienced significant stone decay.
2) The very strongly foliated character (i.e. intense planar fabric) is defined by thin layers (‘ribbons’) of quartz-rich or chlorite-epidote-rich rock in which the constituent crystals are very small (very-fine-crystalline) and thoroughly recrystallised. This textural character is typical of *mylonite* (i.e. rock that has been strongly stretched in a ductile manner.
3) Several relatively large (medium-crystalline) fragments of quartz, chlorite and epidote have survived the intense deformation and grain-size reduction that the fine-crystalline material has suffered; these *porphyroclasts* give an indication of the size of crystals in the rock before it was deformed by faulting.
4) One thin (<1mm) carbonate vein cuts the thin section. In hand specimen, the vein reacts strongly to 10% HCl, indicating that the carbonate mineral is likely to be calcite.



Thin section photographs of sample ED11483

The images at left were taken in plane-polarised light: ribbons of dominated by quartz (white) chlorite with epidote (greenish-grey) are thinly interlayered. Black crystals are iron oxide.

The images at right are of the same field of view as those at left, but were taken in cross-polarised light. Under these conditions quartz appears white, grey or black, and the boundaries of numerous individual quartz crystals within each quartz ribbon are evident.

The field of view in the lower images includes an obvious porphyroclast of epidote (brightly coloured crystals). This represents a relict crystal that has largely survived the intense deformation associated with faulting, though it has broken into several smaller pieces.

The field of view for all images is c.3.3 mm wide.

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