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STONE ANALYSIS
& MATCHING REPORT

AP 3763
Abbot Hunter's Tower/ Mauchline Castle,
Mauchline

Sample 1

Sandstone

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SITE	Abbot Hunter's Tower/ Mauchline Castle, Mauchline
CLIENT	Wylie Shanks Architects
DATE SAMPLE RECEIVED	02/12/2021
ANALYSIS/EXAMINATION DATES	02/12/2021 – 08/02/2022
ANALYSIS, INTERPRETATION & REPORT BY	Dr Katie Strang and Roz Artis
CLIENT REQUIREMENTS	Petrographic Examination for Stone Source Matching
STRUCTURE DATE	1636
STRUCTURE TYPE	Castle
STONE TYPE	Red Sandstone
LOCATION/ FUNCTION IN STRUCTURE	Stone taken from the dressed opening next to footpath.
CONDITION OF SAMPLE RECEIVED	The sample received consisted of one core of sandstone Size of largest piece = 136.36mm x 87.25mm x 75.84mm Total mass of sample received = 287.54 grams

Method of Examination & Test

A sample comprising of a fragment of weathered sandstone was received for examination and determination of its properties. The stone was stated to have been collected from the Abbot Hunter's Tower with the sample submitted for examination to assist in identifying a suitable source of replacement stone for use in remedial works.

Upon receipt in the laboratory the sample was examined with the aid of a stereo-binocular microscope at magnifications up to x 40. Following the initial examination, one dimensioned sub-sample was prepared and submitted to a range of physical tests to determine the properties of the stone. In addition, a slice was cut through the remaining sample of stone, with the specimen aligned such that the slice extended through the full thickness of the sample.

The slice was prepared for thin sectioning by washing the soiling from the sample, which was then dried to a constant weight prior to the vacuum impregnation of the sub-sample with an epoxy resin, to which a fluorescent blue dye had been added. One side of the resin impregnated slice was polished and mounted onto a glass slide (50mm x 75mm), with the mounted sample ground and polished to give an approximate thickness of 30 microns. Thin section preparation was undertaken by Mr John Fletcher of the British Geological Survey Thin Sectioning Service.

The thin section was submitted to a microscopic examination, which was undertaken with the aid of a polarised light microscope, fitted with a digital camera, to permit recording of photomicrographs, some of which are included in this report, for reference purposes.

The presence of dyed epoxy resin within the sample enables an assessment of the stone fabric to be made, including an assessment of the visual porosity, void size and distribution along with the evaluation of any crack patterns and physical depositional features apparent in the sample under examination. The sample was examined following standard procedures, and in general accordance with BS EN 12407:2000; Natural Stone Test Methods.

This report presents observations from the microscopic examination.

MACROSCOPIC EXAMINATION

In hand specimen the sample showed some slight discolouration on certain exposed stone faces, measuring 2.5YR 6/6 ‘light red’ to 2.5YR 6/4 ‘light reddish brown’ when assessed against the Munsell Soil Colour Charts. The sandstone is generally fine to medium grained, appearing texturally sub-mature to mature and mineralogically mature to sub-mature. It is composed of similar sized, sub-angular to sub-rounded haematite-stained quartz grains, occasional Fe-oxides and lighter coloured grains (possibly feldspar or lighter coloured quartz) bound by occasional and well distributed intergranular quartz overgrowth silica cement. Haematite staining of quartz grains provides the stone with its distinctive red colour in hand specimen. The stone exhibits fine scale laminations/bedding measuring between 1-2mm in thickness. Presence of finer scale laminations can also signify well-spaced bedding planes, as expected from the typical red sandstone used throughout southern and western Scotland. Bedding planes are defined as areas of well cemented quartz and Fe-oxide grains that show a high variability in their size and shape but are generally smaller than the surrounding fine to medium-grained matrix. This greater compaction of small grains within the bedding planes can also influence the porosity, providing horizons of smaller and likely poorly connected pores. Grains are moderately well compacted, showing a range of point and line contacts throughout, leaving a clean and highly accessible pore network, clear of pore filling clays and defined by two main visually apparent pore size classes (ranging between small and medium sized, in relation to a typical sandstone). The stone experienced a moderate water absorption rate when subjected to the water droplet test, signifying a discontinuous internal pore network.

Plate 1. Image of the sample as received. Note the fine laminations in the stone. Scale is in mm.

MICROSCOPIC THIN SECTION EXAMINATION

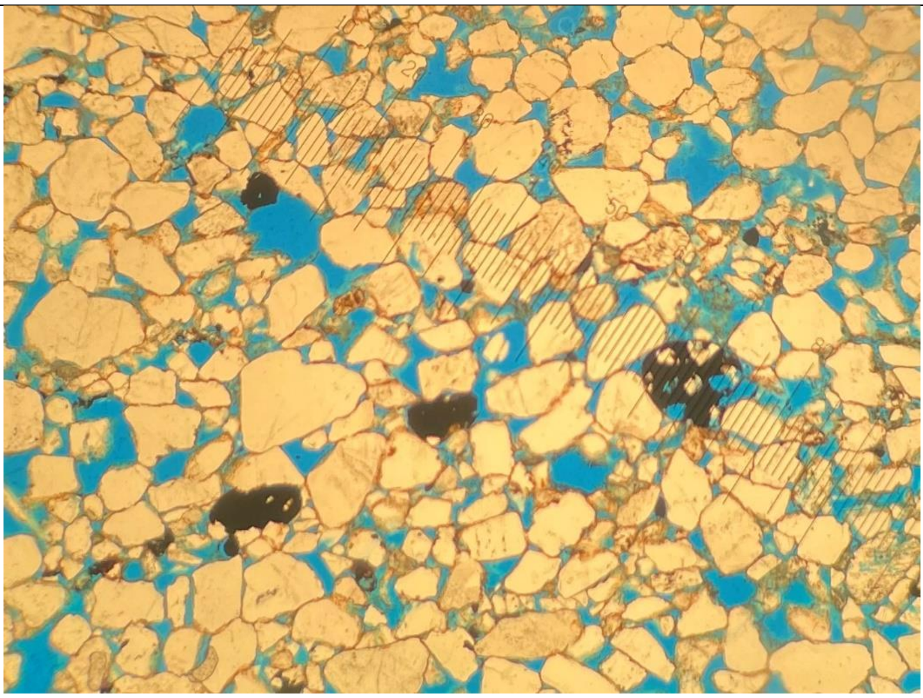
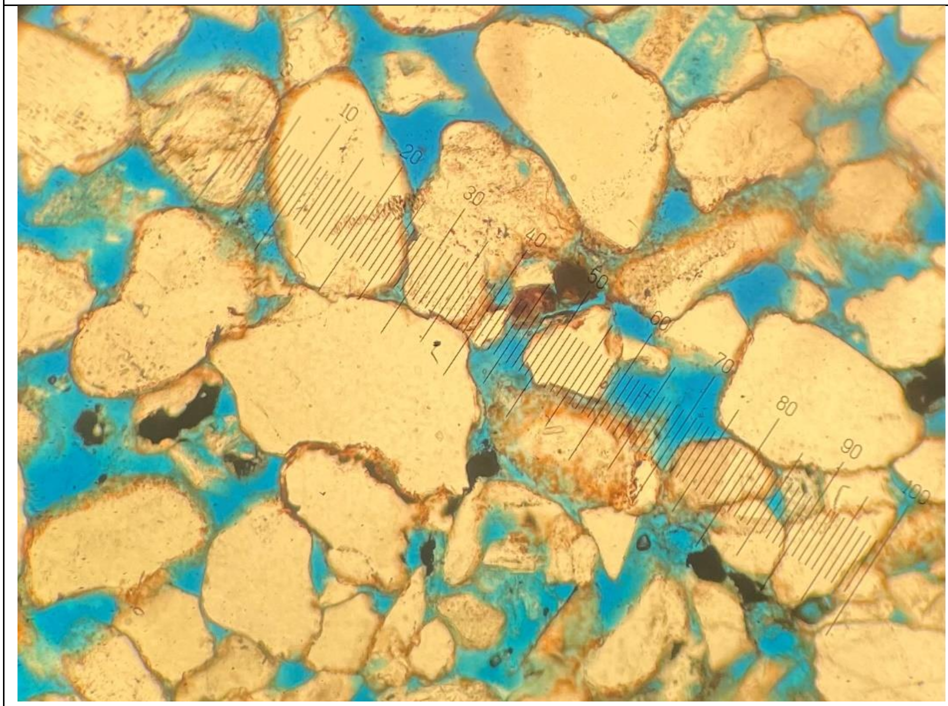
Texture: Bedding planes are evident within the thin section through narrow (1 – 2mm thick) layers that are composed of finer sub-rounded to rounded quartz grains, a low proportion of similar shaped lithic fragments, feldspar grains, Fe-oxides and pore-filling clays. These are separated by beds of a predominantly fine to medium grainsize which measure >3mm. These grains are more compact than the surrounding stone matrix, with smaller pores evident between the grains. The permeability and porosity are decreased in these layers, owing to the increase in grain compaction, pore-filling clays and the decrease in grain and pore size.

Mineralogy: The mineralogy of the stone is dominated by fine to medium-grained, sub-rounded to sub-angular and spherical quartz and feldspar grains, sub-rounded and slightly more elongated lithic fragments, Fe-oxides and pore-filling clays. Bedding planes are composed of a greater proportion of Fe-oxides, pore filling clays and smaller, sub-angular to sub-rounded quartz and feldspar grains. Quartz grains show well-developed hematite rims; these provide the stone with its distinctive red colour. Grains are cemented by silica throughout, with a moderate proportion of pore filling clays and quartz overgrowths present, providing secondary cements. Small quartz grains show a high proportion of point and line contacts, while larger quartz grains also show concave-convex contacts. Lithic fragments have a mixed composition. The stone is relatively ‘clean’ and most grains show low levels of alteration.

Detrital Minerals: Quartz, feldspar, lithic fragments.
Authigenic Minerals: Kaolinite, Fe-oxides.

Porosity and permeability: The stone has a moderate to low visually estimated porosity and moderate to low total estimated permeability. Permeability is likely reduced within the narrow bedding planes due to an increase in the amount of poorly connected smaller pores. This infilling of the porosity with smaller grains also serves to significantly increase the tortuosity of the pore network, which will also impact on moisture movement through the stone. Restrictions to moisture flow within the stone will significantly influence the stone’s weathering behaviour and its overall durability within a building.

Photomicrographs:

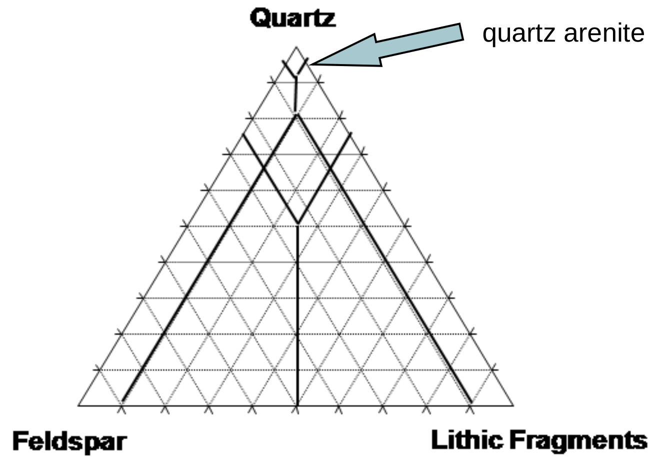
	**Plate 2. Thin section of the sample under plane polarised light. Pore spaces are highlighted in blue, while areas of light blue indicate pore filling clays that have absorbed some of the blue dye. Pores are moderately to well connected, however some regions are completely infilled with cement (both primary and secondary products).** **Field of view is 1.5mm.**
	**Plate 3. Thin section image of the sample under plane polarised light. Pore spaces are highlighted in dark blue, while areas of light blue indicate pore filling clays. There are some concentration of Fe oxides and organic carbonaceous matter within the thin section. Iron-oxide staining can be seen surrounding some of the quartz grains, which imparts the red colour to the stone.** **Field of view is 1.5mm.**

Point Count Data:

Components	Total (%)	Q/F/L (quartz/feldspar/lithic % proportion)
Detrital Components		
Quartz	91	95.8
Feldspar	2	2.1
Lithic fragments	2	2.1
Detrital Clay	0	
Muscovite Mica	0	
Authigenic Minerals		
Quartz Overgrowths	0 (<0.5)	
Indeterminate Clay	2.5	
Carbonate cement	0	
Opaque Minerals inc carbonaceous matter	2.5	
Total	100	100
Porosity	Variable, estimated ~10-14%	

Table 1: Results of modal analysis on the sample received.

Sandstone Classification:



Classification of sandstone after McBride (1963)[1]

[1] McBride, E. F. (1963), A classification of common sandstones. Journal of Sedimentary Petrology 33, 664-669

COMMENTS

Sample AP3763 S1 from Abbot Hunter's Tower/ Mauchline Castle, is most similar to the Permian type deposits like Locharbriggs found in the West of Scotland. It is lighter in colour and shows distinct bedding, indicating it was not sourced in from the same quarries as AP3759, AP3760 and AP3761. It is classified as well graded and mineralogically mature quartz arenite, containing sub-rounded to rounded, moderately compacted quartz grains, feldspar grains, lithic fragments, Fe-oxides and a moderate to low proportion of pore-filling kaolinite clay. The closest matching currently available sandstones are Corncockle, Knowehead, and Locharbriggs quarried in Dumfriesshire. All these replacement stones can be sensitive to sodium chloride salt crystallisation damage due to the high percentage of micro-pores within the stone, and their spatial distribution within bedding planes. This means they may not be suitable for buildings that are at risk of salt crystallisation damage: ie close to heavily salted roads in winter.

In regard to choosing a suitable matching stone, it must be remembered that because stone is a natural material, it can vary in colour and appearance both over time and spatially within a quarry. It is therefore important to check the colour and appearance/obtain representative samples of the stone with the quarry operator in advance of works. Furthermore, each stone type will vary in its weathering behaviour over a period of years in accordance to weather conditions, the stone extraction process, and it’s functionally within a building. This report is therefore not an endorsement of stone quality, nor does it ensure that the listed matching stones will weather in harmony with the original stone. The matched samples are based on thin section petrographic and physical stone testing analysis, taking into account colour, texture, mineralogy, porosity and permeability.

The contact addresses for these quarries are as follows:

Locharbriggs sandstone **Colour:** Reddish – pink - orange **Fabric:** Well bedded sandstone, with evidence of cross-beds in areas. **Grain-size:** Fine to medium grained sandstone. **Permeability:** High permeability parallel to bedding and low permeability perpendicular to bedding. **Distinctive features:** None. **Comments:** May not be suitable for buildings that are at risk of salt crystallisation damage: ie close to heavily salted roads in winter.	**Hutton Stone Co Ltd.** **West Fishwick** **Berwick-upon-Tweed** **Scottish Borders.** **TD15 1XQ** **Tel: +(44) 01289 386056** 

Corncockle sandstone **Colour:** Reddish – orange **Fabric:** Well bedded, laminated sandstone. Beds measure ~1-2mm in thickness. **Grain-size:** Fine to medium grained sandstone, with distinct differences in grain size evident between beds. **Permeability:** High permeability parallel to bedding and low permeability perpendicular to bedding. **Distinctive features:** None. **Comments:** Corncockle may not be suitable for buildings that are at risk of salt crystallisation damage: ie close to heavily salted roads in winter.	**Dunedin Stone** **Dunedin Stone Office** **3 Lower London Road** **Edinburgh** **EH7 5TL** **Scotland** **UK** **There are reserves of this stone, and the quarry is opened as required to replenish stock levels.**

Knowehead sandstone **Colour:** Reddish – orange **Fabric:** Well bedded, laminated sandstone. Beds measure ~1-2mm in thickness. **Grain-size:** Fine to medium grained sandstone, with bi modal grain distribution. **Permeability:** High permeability parallel to bedding and low permeability perpendicular to bedding. **Distinctive features:** None. **Comments:** May not be suitable for buildings that are at risk of salt crystallisation damage: ie close to heavily salted roads in winter.	**Stirling Stone Group** **Wallace House** **Whitehouse Road** **Stirling, FK7 7TA** **Tel: 01786 450560**

Sandstone is a natural material and by the nature of its origin, can be extremely variable within and between quarry faces. Ideally, a considered match should be examined in the same manner as the stone to be replaced. Archive sandstone samples of possible quarries may not be equivalent to the currently extracted product.
As with all quarries the actual properties of the stone available will be dependent on the face, and the bed, being worked at any given time and it is, therefore, always prudent to obtain samples of the current production for comparison with the stone to be matched, prior to ordering supplies for a particular project/application.