

Figure 7. a. Lava or Tuff. Whitwick, Leicestershire (sample 39/13, right). Intermediate to acid lava or tuff. (See Table 5). Sub-rounded to rounded crystals of quartz and plagioclase up to 5mm diameter in a fine-grained matrix. The plagioclase is partly altered to chlorite and epidote and is often cut through by dolomite. Original ferromagnesian minerals (bottom left) are completely altered to chlorite and epidote. The matrix is mainly quartz, with plagioclase K-feldspar, chlorite and epidote. **b. Diorite. Old Cliffe Hill, Markfield, Leicestershire** (sample 38/13, left). Diorite (see Table 6) although quartz, K-feldspar and plagioclase are the main minerals, the rock is much altered from a presumed primary assemblage. Hornblende is mostly altered to chlorite, and there is much epidote and zoisite.

| Sample number | Harden, Northumberland Dacite | | | | Whitwick, Leicestershire Lava or tuff | |
|-----------------------|----------------------------------|--------------------|-------|--------------------|--|--------------------|
| | 23/13 | | 25/13 | | 39/13 | |
| | % | Size μm | % | Size μm | % | Size μm |
| Quartz | 15.12 | 27 | 13.30 | 21 | 37.06 | 50 |
| K-Feldspar | 66.48 | 71 | 74.27 | 75 | 3.75 | 17 |
| Plagioclase feldspar | 15.33 | 35 | 8.47 | 24 | 30.17 | 46 |
| Biotite | 1.42 | 25 | 1.74 | 27 | 0.67 | 17 |
| Muscovite | 0.06 | 17 | 0.60 | 22 | 1.46 | 17 |
| Kaolinite | 0.01 | 19 | 0.14 | 26 | 0.01 | 15 |
| Chlorite | 0.86 | 19 | 0.82 | 19 | 14.58 | 31 |
| Zircon | 0.03 | 37 | 0.02 | 34 | - | - |
| Fe-Ox/CO ₃ | 0.34 | 22 | 0.31 | 21 | 0.21 | 18 |
| Rutile | 0.13 | 18 | 0.06 | 17 | 0.23 | 16 |
| Ilmenite | 0.10 | 23 | 0.17 | 25 | 0.07 | 17 |
| Titanite | - | - | - | - | 0.09 | 16 |
| Apatite | 0.12 | 28 | 0.09 | 27 | 0.12 | 40 |
| Dolomite | - | - | - | - | 0.69 | 64 |
| Epidote | - | - | - | - | 10.91 | 50 |
| Others | <0.01 | <20 | <0.01 | <25 | <0.01 | ≤15 |

Table 5. Modal composition and mean crystal sizes for lavas and pyroclastics.

C. Intermediate and basic igneous rocks

Examples of diorite, gabbro and dolerite are shown in Figures 7b, 8, 9 and 10, with composition details in Table 6. The quartz dolerite Whin Sill examples (Figure 10) show a primary mineral assemblage of plagioclase and pyroxene and a texture typical of dolerite. The diorite

from Old Cliffe Hill (Figure 7b) and the dolerite from Greystone (Figure 8) are completely altered to a secondary mineral assemblage and texture. The gabbro from West of England Quarry retains its primary texture, although the major ferromagnesian mineral, amphibole, is altering to chlorite.

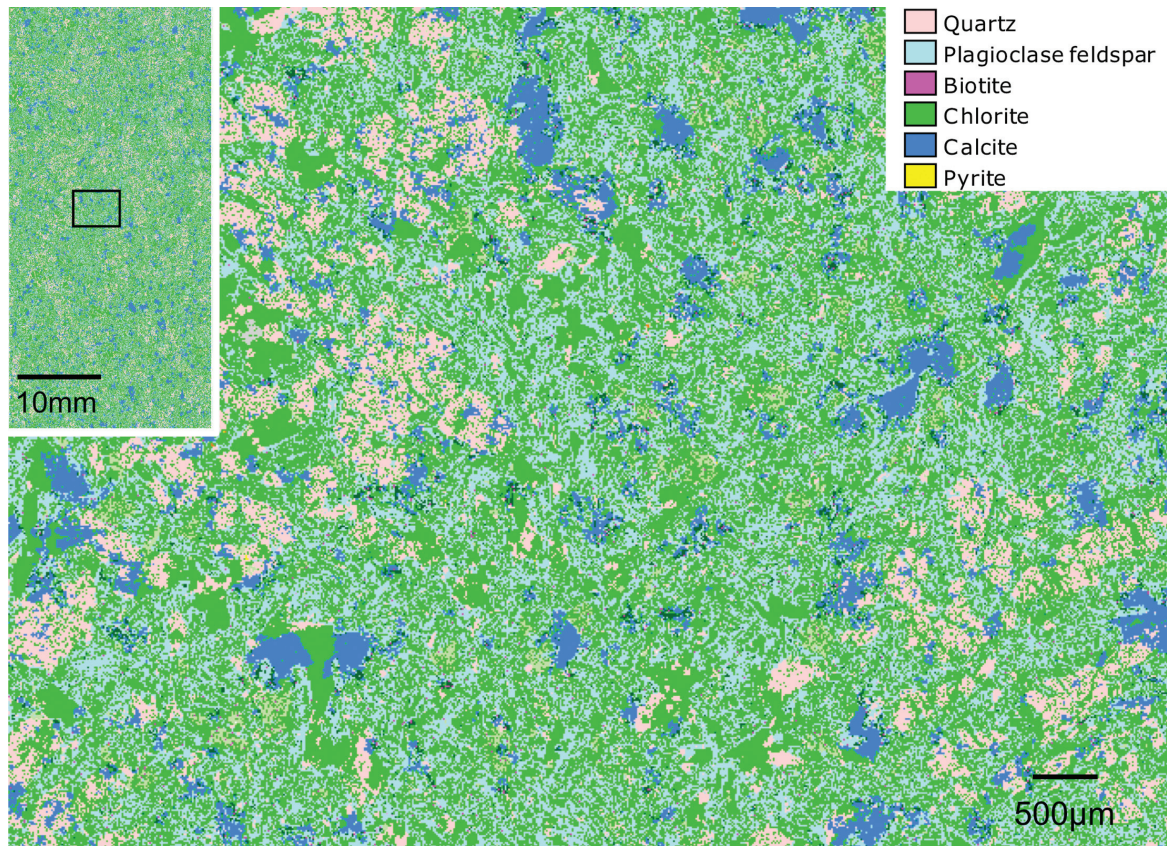


Figure 8. Dolerite. Greystone, Launceston, Cornwall (sample 65/13 (the box inset in the top left image shows the location of the main image)). Dolerite, in which the major primary minerals (plagioclase and pyroxene) are completely altered to a fine-grained interlocking assemblage of albite (plagioclase on key), chlorite, quartz and calcite. (See Table 6).

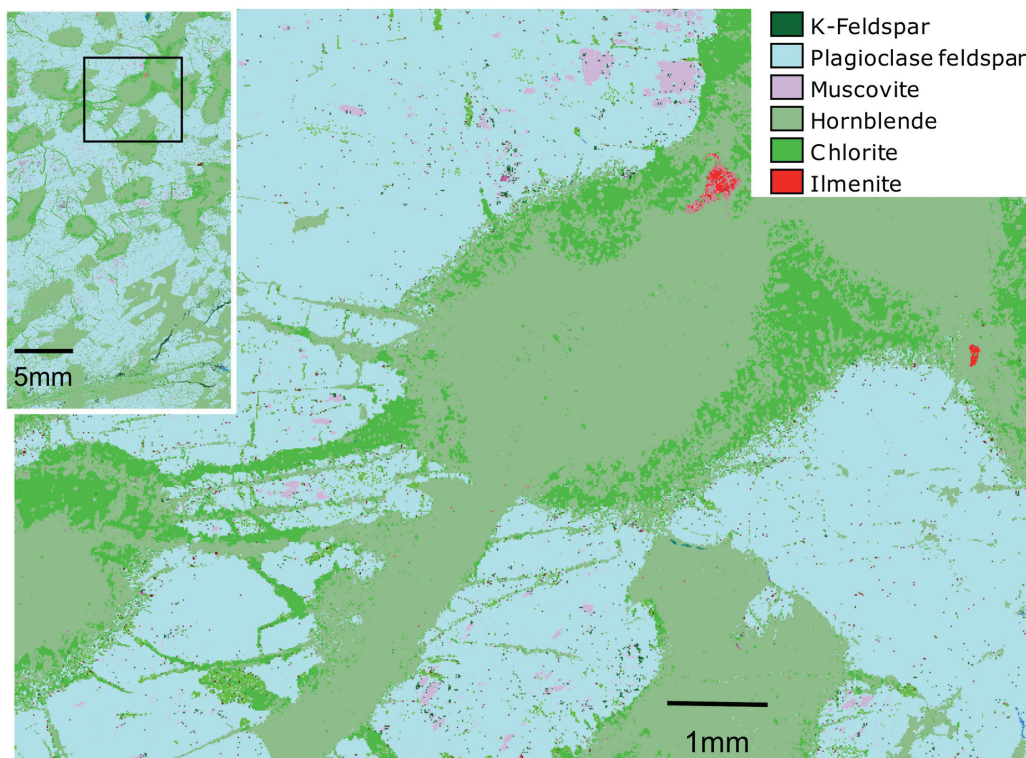


Figure 9. Gabbro. West of England, Porthoustock, Cornwall (sample 63/13 (the box inset in the top left image shows the location of the main image)). Coarse-grained equigranular gabbro made up principally of anbedral hornblende and plagioclase. (See Table 6).The former is partly altered to chlorite, particularly at its margins. Other minerals in the higher magnification field of view are muscovite and ilmenite. Note: the aggregate product from this quarry is a mixture of gabbro and basalt.

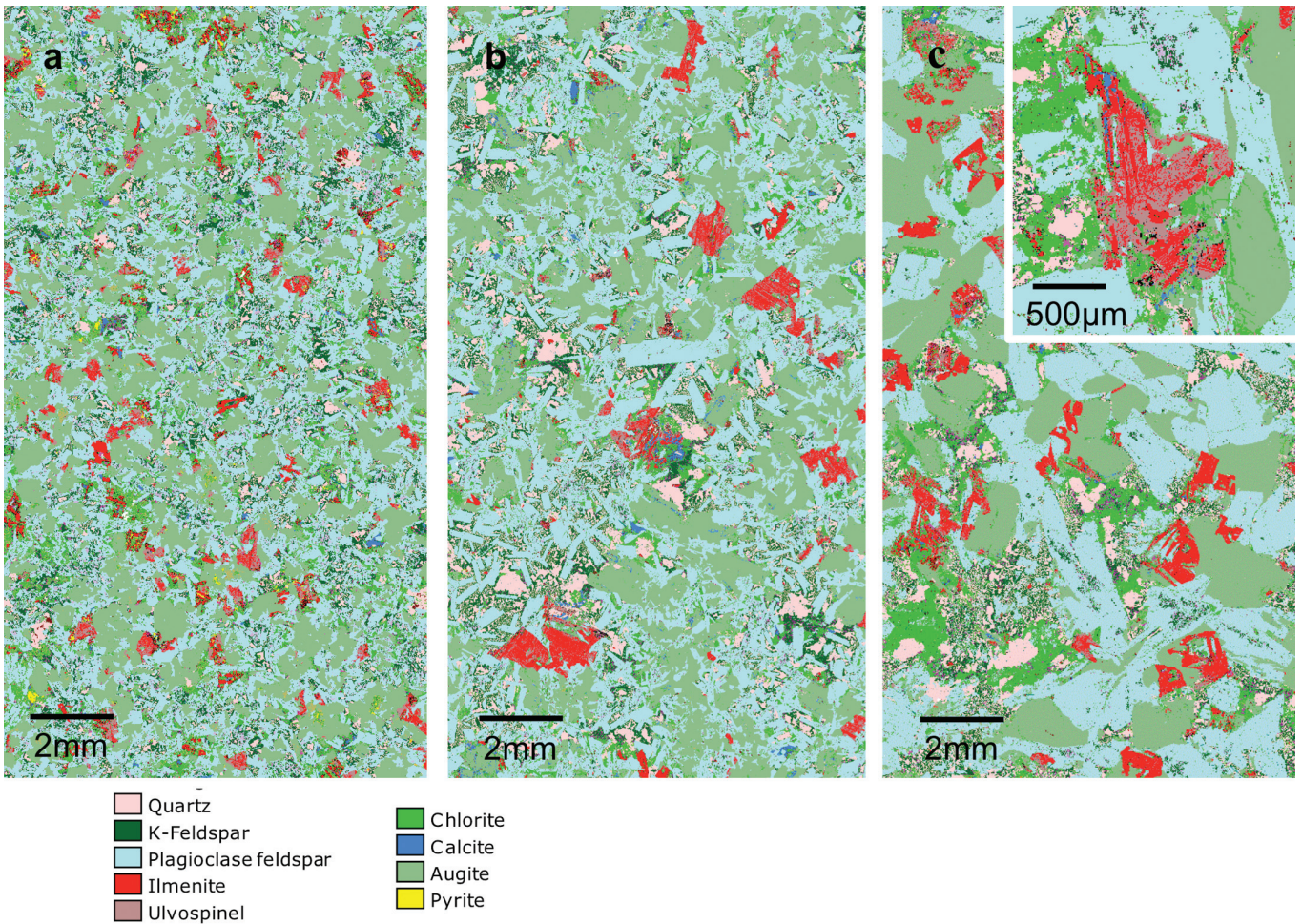


Figure 10. Three samples of Quartz Dolerite (Whin Sill). *a.* Swinburne, Northumberland (sample 21/13). *b* and *c.* Middleton in Teesdale, Co. Durham, fine- (sample 41/13) and coarse- (sample 42/13) grained varieties. (See Table 6). All three show a sub-ophitic texture with plagioclase intergrown with augite. Chlorite and quartz are present as interstitial minerals. The opaque oxides are ilmenite with ulvospinel (see inset image in *c*).

| | Old Cliffe Hill, Markfield, Leicestershire Diorite | | Greystone, Launceston, Cornwall Dolerite | | West of England, Porthoustock, Cornwall Gabbro | | Swinburne, Northumberland Quartz dolerite (Whin Sill) | | Force Garth, Middleton in Teesdale, Co. Durham Quartz dolerite (Whin Sill) | | | |
|---------------------|--|---------|--|---------|--|---------|---|---------|--|---------|-------|---------|
| | Sample number | 38/13 | 65/13 | | 63/13 | | 21/13 | | 41/13 | | 42/13 | |
| | % | Size µm | % | Size µm | % | Size µm | % | Size µm | % | Size µm | % | Size µm |
| Quartz | 16.60 | 73.6 | 12.41 | 36 | - | - | 5.09 | 34 | 9.75 | 52 | 8.51 | 51 |
| K-Feldspar | 14.11 | 31.4 | 1.53 | 20 | 0.95 | 23 | 9.96 | 30 | 7.58 | 34 | 5.06 | 31 |
| Plagioclase | 34.20 | 48.9 | 27.27 | 30 | 55.57 | 177 | 38.03 | 72 | 41.22 | 117 | 36.20 | 162 |
| Biotite | 0.65 | 17.2 | 0.26 | 15 | 0.09 | 17 | 1.13 | 19 | 0.75 | 19 | 0.95 | 20 |
| Muscovite | 2.98 | 26.9 | 0.03 | 15 | 1.59 | 30 | 2.55 | 23 | 0.77 | 20 | 0.36 | 17 |
| Augite | - | - | - | - | - | - | 27.72 | 123 | 24.6 | 132 | 26.44 | 201 |
| Chlorite | 10.89 | 47.9 | 48.04 | 42 | 6.72 | 34 | 8.63 | 29 | 7.79 | 34 | 10.94 | 43 |
| Zoisite | 5.07 | 31.8 | - | - | 1.45 | 26 | - | - | - | - | - | - |
| Zircon | 0.00 | 19.8 | - | - | - | - | <0.01 | 16 | 0.01 | 17 | 0.01 | 17 |
| Fe-Ox/CO3 | 0.11 | 16.8 | - | - | - | - | 0.61 | 17 | 0.32 | 17 | 0.50 | 18 |
| Ilmenite | 0.21 | 44.6 | - | - | 0.01 | 32 | 2.46 | 38 | 3.04 | 59 | 5.92 | 71 |
| Titanite | 1.48 | 48.7 | - | - | 0.02 | 28 | - | - | - | - | - | - |
| Ulvospinel | - | - | - | - | - | - | 1.40 | 32 | 1.85 | 31 | 2.90 | 29 |
| Calcite | 0.02 | 19.0 | 8.40 | 45 | 0.06 | 35 | 0.38 | 40 | 0.63 | 31 | 0.48 | 45 |
| Amphibole | 4.64 | 40.4 | - | - | 33.11 | 131 | - | - | - | - | - | - |
| Ca Fe Al silicates* | - | - | - | - | - | - | 0.43 | 18 | 0.45 | 19 | 0.43 | 18 |
| Mg Fe silicates** | - | - | - | - | - | - | 0.82 | 19 | 0.46 | 17 | 0.47 | 17 |
| Epidote | 8.38 | 35.0 | - | - | 0.36 | 17 | - | - | - | - | - | - |
| Apatite | 0.64 | 43.0 | 0.11 | 16 | 0.05 | 120 | 0.51 | 20 | 0.61 | 21 | 0.72 | 24 |
| Rutile | - | - | 1.91 | 21 | - | - | 0.06 | 17 | 0.02 | 15 | 0.02 | 15 |
| Others | 0.01 | 18.4 | 0.04 | <30 | 0.03 | <40 | 0.21 | <30 | 0.10 | <20 | 0.08 | <30 |

Notes: * Indeterminate composition, probably amphibole. ** Indeterminate composition, possibly orthopyroxene or amphibole

Table 6. Modal composition and mean crystal sizes for intermediate and basic igneous rocks.

D. Carbonate rocks

Samples of aggregates from carbonate rocks are illustrated in Figures 11, 12 and 13 and modal compositions are given in Table 7. With limestones, and to some extent dolostones, the texture is not apparent in the QEMSCAN® images. Individual allochems (intraclasts, oolites, bioclasts, pellets) and the nature of the matrix (sparite, micrite) in limestones are not discernible as they all consist of calcium carbonate (typically calcite or rarely aragonite). Figure 11 compares a QEMSCAN® image with

an equivalent optical thin section. The QEMSCAN® image enables the composition, distribution and amounts of impurities in a limestone or dolostone to be determined and illustrates the porosity along with the nature of any pore fillings. The nature of minor impurities and porosity are important parameters in the assessment of high purity limestones and dolostones for industrial uses such as for lime or dolomitic lime manufacture, including refractory dolomite, and for carbonate powders.

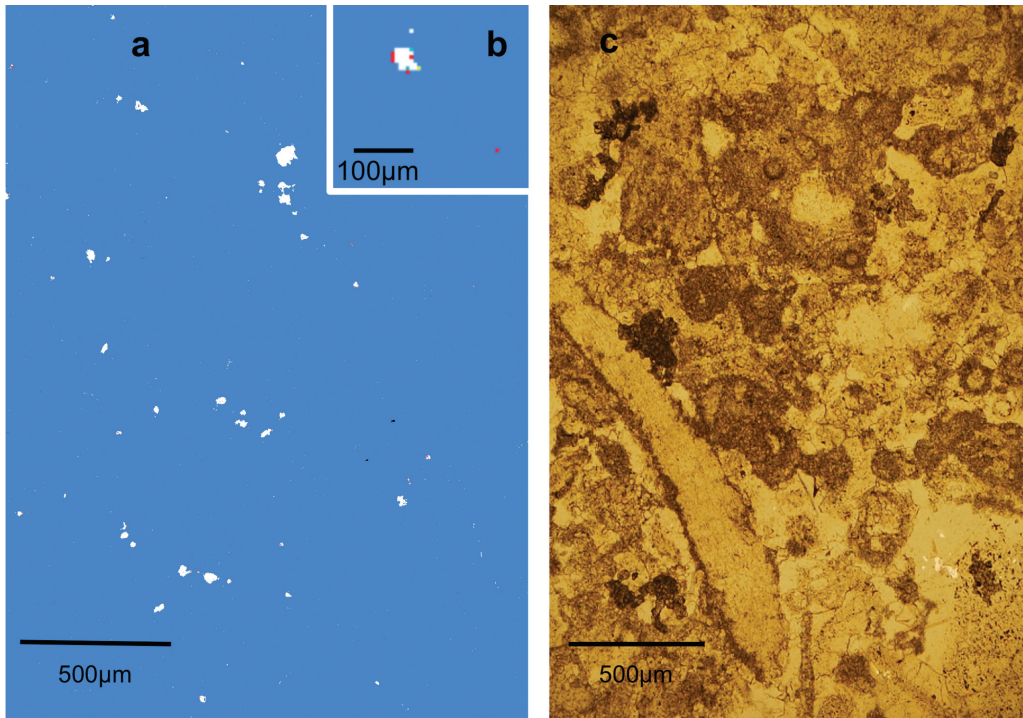


Figure 11. Limestone. Horton, Settle, North Yorkshire (sample 36/13). Very high purity limestone (calcite) (see Table 7). **a and b (inset).** QEMSCAN® image shows calcite (blue), minute black specks (Fe oxides) and quartz (red) with minor porosity (white). **c.** Optical photomicrograph (plane polarised light) showing intraclast and fossil fragments and a mixture of a micritic and sparry matrix.

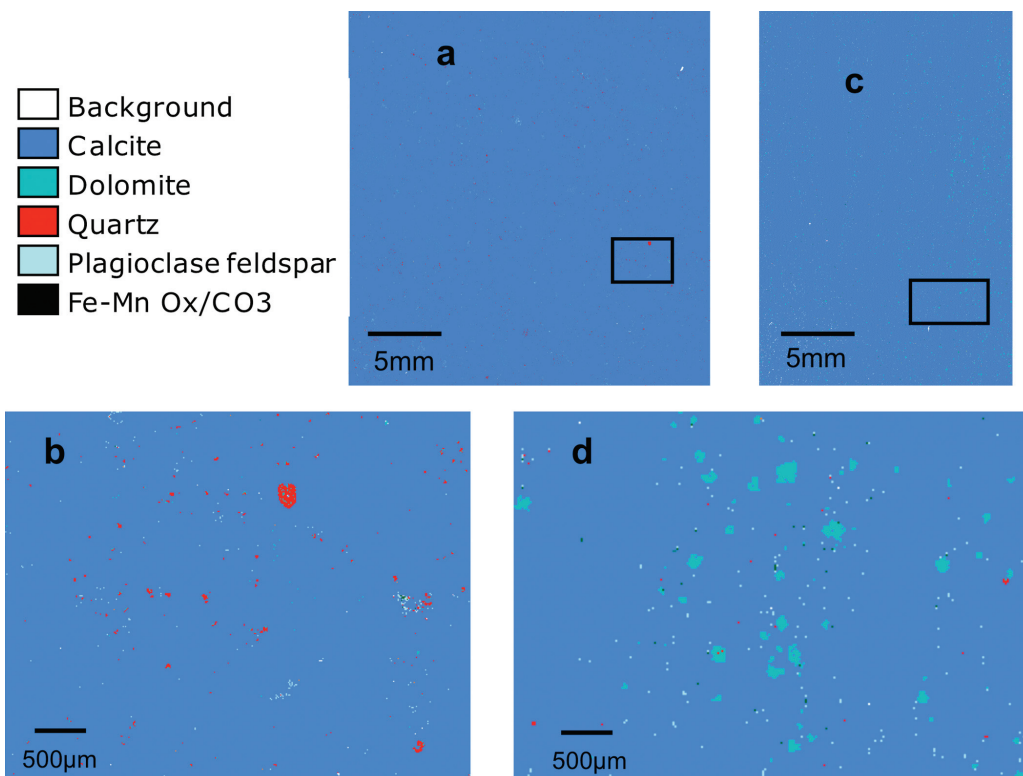


Figure 12. Limestones, a. and b. Battscombe, Cbeddar, Somerset (sample 77/83 (the inset box in image a. shows the location of image b.)). Limestone (see Table 7) with minor impurities of quartz, plagioclase and dolomite distributed fairly evenly throughout. **c. and d. Moorcroft, Plymouth (sample 64/13 (the inset box in image c. shows the location of image d.)).** Medium to high purity limestone with dolomite, plagioclase and quartz distributed fairly evenly throughout. (See Table 7).

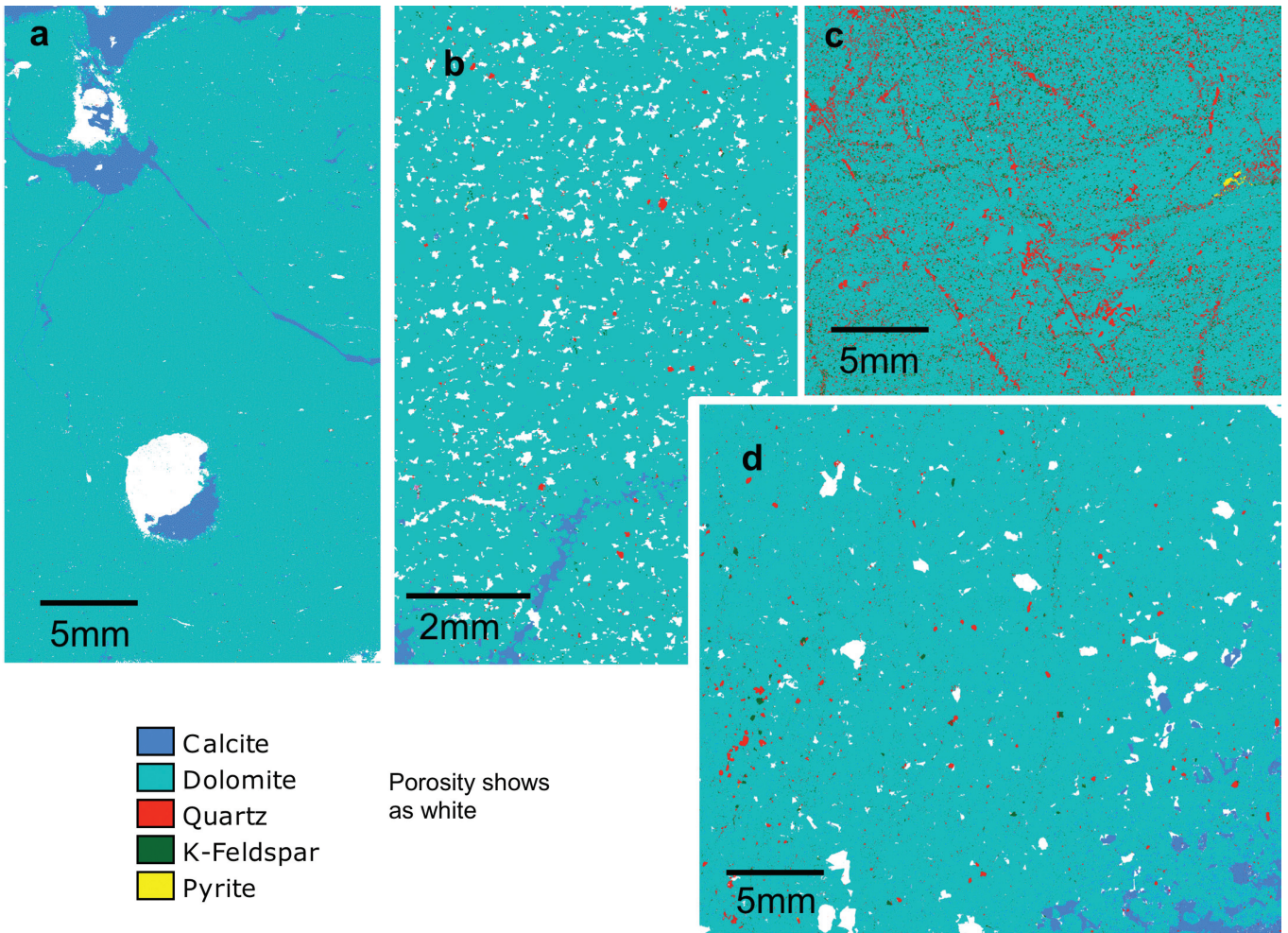


Figure 13. Dolostones. *a. Thrislington, Co. Durham (sample 29/13).* High purity dolostone with dolomite and impurities of calcite in vugs and veinlets *b. Glen, Stainton, Doncaster, South Yorkshire (sample 37/13).* Dolostone with calcite in veinlets, minor quartz and porosity (white). *c. Morefield, Ullapool, Scotland (sample 6/13).* Dolostone with quartz filling fractures, K-feldspar and pyrite. *d. Cloud Hill, Breedon on the Hill, Leicestershire (sample 40/13).* Low purity dolostone with patches of calcite that appear to be filling vuggy porosity, disseminated quartz and K-feldspar. (See Table 7 for all samples).

| | Horton, Settle, North Yorkshire Limestone | Battscombe, Cheddar, Somerset Limestone | Moorcroft, Plymouth Limestone | Thrislington, Cornforth, Co. Durham Dolostone | Glen, Stainton, Doncaster, South Yorkshire Dolostone | Morefield, Ullapool Scotland Dolostone | Cloud Hill, Breedon on the Hill, Leicestershire Dolostone |
|---------------|---|---|-------------------------------|---|--|--|---|
| Sample number | 36/13 | 77/83 | 64/13 | 29/13 | 37/13 | 6/13 | 40/13 |
| | % | % | % | % | % | % | % |
| Calcite | 99.96 | 99.35 | 98.89 | 6.37 | 1.08 | 0.19 | 2.53 |
| Dolomite | <0.01 | 0.10 | 0.63 | 93.51 | 97.98 | 86.41 | 95.88 |
| Quartz | 0.01 | 0.38 | 0.04 | 0.03 | 0.69 | 8.11 | 0.91 |
| K-Feldspar | <0.01 | 0.01 | 0.06 | 0.03 | 0.16 | 4.61 | 0.45 |
| Plagioclase | 0.02 | 0.15 | 0.36 | 0.02 | 0.03 | <0.01 | 0.06 |
| Biotite | nd | <0.01 | <0.01 | 0.01 | 0.01 | 0.08 | 0.07 |
| Muscovite | <0.01 | <0.01 | 0.01 | 0.01 | 0.02 | 0.20 | 0.03 |
| Chlorite | <0.01 | nd | <0.01 | <0.01 | 0.01 | 0.04 | <0.01 |
| Fe-Mn Ox/CO3 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.01 | <0.01 |
| Ti minerals | <0.01 | <0.01 | 0.01 | <0.01 | <0.01 | 0.02 | 0.01 |
| Apatite | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 |
| Fe sulphides | <0.01 | <0.01 | <0.01 | <0.01 | 0.01 | 0.33 | 0.05 |
| Others | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

Notes: nd; not detected.

Fe-Mn Ox/CO3; iron - manganese oxides and or carbonates.

Fe sulphides includes pyrite and marcasite.

Table 7. Modal composition for limestones and dolostones.

The mineralogy and texture of a metamorphosed impure limestone aggregate from Shierglas, Perthshire is illustrated in Figure 14 with the modal composition

included in Table 8. The rock is very heterogeneous containing carbonate poor bands rich in micaceous minerals and calc-silicates (zoisite) along with sulphides.