



**British  
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

# Petrology of the igneous and sedimentary rocks of the Rothbury district (sheet 9), Northeast England

Integrated Geological Surveys (Northern Britain)

Internal Report IR/01/097



BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/01/097

# Petrology of the igneous and sedimentary rocks of the Rothbury district (sheet 9), Northeast England

E R Phillips

The National Grid and other  
Ordnance Survey data are used  
with the permission of the  
Controller of Her Majesty's  
Stationery Office.  
Ordnance Survey licence number  
GD 272191/2001

## *Bibliographical reference*

PHILLIPS, E. R. 2001. Petrology  
of the igneous and sedimentary  
rocks of the Rothbury district  
(sheet 9), Northeast England.  
*British Geological Survey  
Internal Report, IR/01/097*

## BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham and Edinburgh; see contact details below or shop online at [www.thebgs.co.uk](http://www.thebgs.co.uk)

The London Information Office maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

*The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.*

*The British Geological Survey is a component body of the Natural Environment Research Council.*

### **Keyworth, Nottingham NG12 5GG**

☎ 0115-936 3241 Fax 0115-936 3488  
e-mail: [sales@bgs.ac.uk](mailto:sales@bgs.ac.uk)  
[www.bgs.ac.uk](http://www.bgs.ac.uk)  
Shop online at: [www.thebgs.co.uk](http://www.thebgs.co.uk)

### **Murchison House, West Mains Road, Edinburgh EH9 3LA**

☎ 0131-667 1000 Fax 0131-668 2683  
e-mail: [scotsales@bgs.ac.uk](mailto:scotsales@bgs.ac.uk)

### **London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE**

☎ 020-7589 4090 Fax 020-7584 8270  
☎ 020-7942 5344/45 email: [bgs london@bgs.ac.uk](mailto:bgs london@bgs.ac.uk)

### **Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU**

☎ 01392-445271 Fax 01392-445371

### **Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS**

☎ 028-9066 6595 Fax 028-9066 2835

### **Maclea Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB**

☎ 01491-838800 Fax 01491-692345

### *Parent Body*

### **Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU**

☎ 01793-411500 Fax 01793-411501  
[www.nerc.ac.uk](http://www.nerc.ac.uk)

## Summary

This report describes the mineralogy and petrology of a suite of igneous and sedimentary rocks exposed in the Rothbury district (sheet 9), Northeast England. A total of 35 thin sections were examined with the work forming part of the Northeast England regional mapping project as part of a BGS Integrated Geological Survey (North) research programme.

# 1 Introduction

This report describes the mineralogy and petrology of a suite of igneous and sedimentary rocks exposed in the Rothbury district (sheet 9), Northeast England. A total of 35 thin sections were examined with the work forming part of the Northeast England regional mapping project as part of a BGS Integrated Geological Survey (North) research programme.

The report contains a brief description of all the thin sections examined during this study.

## 2 Petrological Descriptions

### 2.1 IGNEOUS ROCKS

**Registered Number:** E686. **Location:** Debdon near Rothbury, Morpeth. **Rock Type:** amygdaloidal, quartz-bearing tholeiitic basalt. **Symbol:** qB<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained (average grain size *c.* 0.2 mm), massive, hypocrySTALLine, inequigranular, anhedral granular, aphyric quartz-bearing tholeiitic basalt (Plates 1a and b). It is composed of inequigranular assemblage of plagioclase, clinopyroxene, orthopyroxene and minor opaque minerals and trace quartz. Hydrothermal alteration resulted in the development of a very fine-grained assemblage of chlorite, carbonate, clay minerals and secondary opaque oxides.

The rock is mainly composed of anhedral to subhedral, randomly orientated lath-shaped plagioclase crystals with intergranular clinopyroxene and subordinate orthopyroxene. Plagioclase forms twinned and simply zoned crystals which are locally randomly orientated in a crudely developed spherulitic texture. Colourless to very pale brown clinopyroxene is fresh and occurs as fractured anhedral crystals which exhibit very little alteration to chlorite. Pyroxene is locally weakly subophitic. Pale brown orthopyroxene is very similar to clinopyroxene in this thin section, but is distinguished by its slightly lower birefringence colours and straight extinction.

The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes. The remainder of the interstitial to intersertal areas are composed of a dusty, locally feldspathic mesostasis and secondary chlorite replacing primary glass. The mesostasis locally contains very fine-grained microlites of feldspar.

One rounded amygdale present within the thin section is composed of very fine-grained to cryptocrystalline, dark green chlorite and minor secondary carbonate. Carbonate is replacing the earlier formed chlorite, the latter forming small aggregates or rosettes of radiating fibrous crystals.

**Registered Number:** E687. **Location:** Debdon near Rothbury, Morpeth. **Rock Type:** weakly plagioclase microporphyritic quartz-bearing tholeiitic basalt. **Symbol:** plmiqB<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained, massive, weakly microporphyritic, hypocrySTALLine, inequigranular, anhedral granular, quartz-bearing tholeiitic basalt which is lithologically similar to sample E686. It is composed of an inequigranular assemblage of plagioclase, clinopyroxene and orthopyroxene with minor to accessory opaque minerals and quartz. Hydrothermal alteration resulted in the development of a very fine-grained assemblage of chlorite, carbonate, zeolite/white mica and secondary opaque oxides.

Phenocrysts are a minor component of the total rock and are mainly composed of plagioclase ( $\leq 1.0$  mm in length) as well as rare, rounded pyroxene microphenocrysts. The rock is mainly composed of anhedral to subhedral, randomly orientated plagioclase laths with intergranular clinopyroxene and subordinate orthopyroxene. Plagioclase forms twinned, simply to rarely oscillatory zoned crystals which are locally randomly orientated in a crudely developed spherulitic texture. Colourless to very pale brown clinopyroxene is fresh and forms anhedral fractured crystals which exhibit very little alteration to chlorite. Pyroxene is locally weakly subophitic. Pale brown orthopyroxene is very similar to clinopyroxene in this thin section, but is distinguished by its slightly lower birefringence colours and straight extinction.

The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes. The remaining interstitial to intersertal areas are composed of a dusty, locally feldspathic mesostasis. Chlorite also occurs as an interstitial to intersertal phase and is probably replacing primary glass and/or the mesostasis.

**Registered Number:** E1187. **Location:** Nether Whitten, Northumberland. **Rock Type:** fine-grained, quartz-bearing tholeiitic microgabbro. **Symbol:** qD<sup>T</sup>.

**Description:** This thin section is of a fine-grained, massive, holocrystalline to weakly hypocrystalline, inequigranular, anhedral granular, aphyric quartz-bearing tholeiitic microgabbro (Plates 1c and d). It is composed of an inequigranular assemblage of plagioclase, clinopyroxene and orthopyroxene with minor to accessory opaque minerals, quartz and apatite. Alteration resulted in the development of a very fine-grained assemblage of chlorite, biotite, carbonate and secondary opaque oxides.

The rock is mainly composed of randomly orientated, anhedral to subhedral plagioclase crystals with intergranular clinopyroxene and subordinate orthopyroxene. Plagioclase forms twinned, weakly zoned, lath-shaped to prismatic crystals which range up to 1.2 mm in length. Untwinned feldspar, possibly including ?K-feldspar, occurs as an interstitial phase. Colourless to very pale brown clinopyroxene is fresh and occurs as fractured anhedral crystals. Pyroxene is locally subophitic and exhibits very little alteration to chlorite and, in some cases, biotite. Clinopyroxene was noted forming aggregates of several granular looking crystals as well as slightly larger single crystals. Pale brown orthopyroxene is very similar to clinopyroxene in this thin section, but is distinguished by its slightly lower birefringence colours and straight extinction. Orthopyroxene was apparently more susceptible to alteration to chlorite, bowlingite and is locally included within clinopyroxene.

Anhedral to locally skeletal opaque minerals are a common minor component and are locally rimmed by dark brown, fine-grained biotite. Trace quartz present within this microgabbro forms anhedral to irregular crystals which occur intergranular to both plagioclase and pyroxene. The remainder of the interstitial to intersertal areas are filled by cryptocrystalline chlorite which may be replacing orthopyroxene and/or primary glass. composed of a dusty, locally feldspathic mesostasis and secondary chlorite replacing primary glass. Trace amounts of secondary carbonate was noted replacing chlorite.

**Registered Number:** E3209. **Location:** River Hart near Longwitten Garden House, Morpeth. **Rock Type:** very fine-grained quartzose sandstone. **Symbol:** not applicable.

**Description:** This thin section is of a very fine-grained, laminated, moderately to well sorted, relatively mature, open to moderately packed, matrix to grain supported quartzose sandstone. The primary sedimentary lamination is defined by a variation in the modal proportion of a very fine-grained, dusty looking chloritic/clay matrix.

Detrital grains are angular to subangular in shape with a moderate to low sphericity. The shape of these grains has, however, been modified due to pressure solution which resulted in grain boundary etching. In the quartz-rich laminae, pressure solution resulted in the main form of cementation. The detrital grains are mainly composed of monocrystalline quartz. Other minor to accessory detrital components include chlorite, biotite, opaque minerals, white mica/muscovite

and altered feldspar. The detrital grains are locally rimmed by an apparently early clay/chloritic rim cement.

**Registered Number:** E13360. **Location:** Silverside Quarries (disused), Northumberland. **Rock Type:** quartz-bearing tholeiitic basalt. **Symbol:** qB<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained, massive, hypocrySTALLINE, originally glassy (glass forming approximately 40% of the total rock), inequigranular, anhedral granular, aphyric quartz-bearing tholeiitic basalt (Plates 2a and b). It comprises an inequigranular assemblage of plagioclase, clinopyroxene, and orthopyroxene with minor to accessory opaque minerals quartz and apatite. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by chlorite, biotite, clay minerals and secondary opaque oxides.

The rock comprises clusters of anhedral to subhedral, randomly orientated to locally radiation lath-shaped plagioclase crystals set in a feldspathic mesostasis replacing primary glass. Plagioclase displays a weakly developed seriate texture and forms twinned, weakly zoned crystals. Both pyroxenes occur intergranular to plagioclase and form anhedral, fractured, granular to elongate crystals. Clinopyroxene ranges from colourless to very pale brown and may locally possess weakly developed simple twins. It is typically fresh, showing very little alteration to chlorite, bowlingite and trace amounts of biotite. Pale brown orthopyroxene is locally included within the slightly coarser grained clinopyroxene and is more susceptible to alteration.

The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes. The remainder of the rock is composed of a dusty, locally feldspathic mesostasis which contains needle-like microlites or opaque oxide. The mesostasis exhibits minor alteration to chlorite.

**Registered Number:** E12879. **Location:** Parkhead Quarry, Netherwittan near Morpeth. **Rock Type:** quartz-bearing tholeiitic basalt. **Symbol:** qB<sup>T</sup>.

**Description:** This thin section is of a medium-grained, massive, holocrystalline to weakly hypocrySTALLINE, inequigranular, anhedral granular, weakly altered, aphyric quartz-bearing tholeiitic basalt. It is composed of an inequigranular assemblage of plagioclase, clinopyroxene, and orthopyroxene with minor to accessory opaque minerals and quartz. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by chlorite and carbonate.

The rock is mainly composed of anhedral to subhedral, randomly orientated plagioclase with intergranular clinopyroxene and subordinate orthopyroxene. Plagioclase forms twinned, simply zoned, lath-shaped to prismatic crystals which range up to c. 0.6 mm in length. Untwinned feldspar also occurs as an intergranular phase. Colourless to very pale brown clinopyroxene and orthopyroxene occur intergranular to plagioclase and form clusters of several granular crystals as well as slightly larger single crystals. The larger pyroxene crystals are locally subophitic to ophitic. Clinopyroxene exhibits varying degrees of alteration to a very fine-grained to cryptocrystalline chloritic mosaic ( $\pm$  biotite). Chlorite within the pseudomorphs after pyroxene was observed partially replaced by secondary carbonate. Orthopyroxene is locally included within clinopyroxene and was apparently more susceptible to alteration.

The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes. The remainder of the interstitial to intersertal areas are filled by a dusty looking mesostasis and chlorite.

**Registered Number:** E12880. **Location:** Causey Park Quarry, between Felton and Morpeth. **Rock Type:** glassy tholeiitic basalt. **Symbol:** B<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained, massive, hypocrySTALLINE, inequigranular, originally glassy (mesostasis forms approximately 40% of the total rock) aphyric tholeiitic basalt. It comprises an inequigranular assemblage of plagioclase, clinopyroxene, and



orthopyroxene with minor to accessory opaque minerals and quartz. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by chlorite and carbonate.

The rock is mainly composed of clusters of randomly orientated to weakly radiating plagioclase crystals set in a glassy feldspathic mesostasis. Plagioclase forms anhedral to subhedral, twinned, simply to rarely oscillatory zoned, lath-shaped to prismatic crystals. The mesostasis possess a dusty appearance in plane polarised light and contains elongate needles of opaque minerals.

Both pyroxenes range from colourless to very pale brown and form aggregates of several, granular-looking crystals as well as slightly larger single, anhedral crystals. Clinopyroxene and orthopyroxene occur intergranular to plagioclase. The larger pyroxene crystals may be weakly subophitic.

The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes. Anhedral granular to rod-shaped opaque crystals are a common minor phase within this basalt.

**Registered Number:** E12881. **Location:** Causey Park Quarry, between Felton and Morpeth. **Rock Type:** fine-grained, quartz-bearing tholeiitic basalt. **Symbol:** qB<sup>T</sup>.

**Description:** This thin section is of a fine-grained, massive, holocrystalline to weakly hypocrystalline, inequigranular, anhedral granular, aphyric quartz-bearing tholeiitic basalt. It is composed of an inequigranular assemblage of plagioclase, clinopyroxene, and orthopyroxene with minor to accessory opaque minerals, quartz and apatite. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by chlorite, carbonate and biotite.

The rock is mainly composed of randomly orientated to weakly radiating plagioclase laths with intergranular clinopyroxene and subordinate orthopyroxene. Plagioclase forms anhedral to subhedral, twinned and zoned (simple to rarely oscillatory zoned), lath-shaped crystals. An untwinned feldspar with a shadowy to sweeping extinction also occurs as an intergranular phase. Colourless to very pale brown pyroxene occurs intergranular to plagioclase and form clusters of several granular crystals as well as slightly larger single crystals. These larger crystals are locally subophitic. Both pyroxenes exhibit minor alteration to chlorite and carbonate, with orthopyroxene apparently being more susceptible to alteration.

The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes. The remainder of the interstitial to intersertal areas are filled by a dusty looking mesostasis. This mesostasis exhibits patchy alteration to chlorite and carbonate.

**Registered Number:** E12882. **Location:** Swarland hall, south of New Lodge. **Rock Type:** xenolithic, fine-grained, quartz-bearing tholeiitic basalt. **Symbol:** qB<sup>T</sup>.

**Description:** This thin section is dominated by a xenolithic fragment (1.0 to 1.5 mm in size) of a fine-grained, massive, hypocrystalline, inequigranular, anhedral granular, aphyric quartz-bearing tholeiitic basalt. This xenolith is included within a slightly coarse grained basalt which is lithologically similar to the previously described thin sections.

The basaltic xenolith is composed of an inequigranular assemblage of plagioclase and clinopyroxene with minor to accessory opaque minerals and quartz. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by chlorite and carbonate. The rock is mainly composed of randomly orientated to weakly radiating plagioclase laths or needles set within a dusty brown coloured (under plane polarised light) mesostasis.

Plagioclase forms anhedral to subhedral, twinned, simply zoned, lath-shaped to elongate crystals which range up to *c.* 0.3 mm in length. Colourless to very pale brown clinopyroxene occurs intergranular to plagioclase and forms elongate, fractured crystals which are variably altered to a cryptocrystalline, turbid chloritic/clay assemblage. Pseudomorphs after pyroxene are present and

probably include orthopyroxene. Radiating/spherulitic aggregates of pyroxene ( $\pm$  plagioclase) were recorded within this basalt.

Anhedral rod-shaped and needle-like crystals of opaque minerals are a common minor phase. The trace amounts of quartz present within this basalt occur as small rounded spots within the mesostasis.

**Registered Number:** E12883. **Location:** Swarland Hall, south of New Lodge. **Rock Type:** tholeiitic basalt. **Symbol:** B<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained, massive, hypocrySTALLine, inequigranular, anhedral granular, weakly amygdaloidal, aphyric tholeiitic basalt. It comprises an inequigranular assemblage of plagioclase, clinopyroxene, and orthopyroxene with minor to accessory opaque minerals and quartz. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by chlorite and carbonate.

The rock is mainly composed of randomly orientated, anhedral to subhedral plagioclase laths with subordinate intergranular clinopyroxene set within a glass groundmass. Plagioclase forms twinned, simply zoned, lath-shaped to prismatic crystals and also occurs as an interstitial phase. Colourless to very pale brown clinopyroxene forms clusters of several anhedral, granular-looking crystals. Clinopyroxene exhibits varying degrees of alteration to a very fine-grained to cryptocrystalline, turbid chloritic assemblage. Orthopyroxene is locally included within clinopyroxene and was apparently more susceptible to alteration. Orthopyroxene is distinguished from clinopyroxene by its slightly lower birefringence colours and straight extinction.

The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes. The remainder of the interstitial to intersertal areas are filled by a dusty looking mesostasis which is variably altered to chlorite.

**Registered Number:** E13107. **Location:** Coal House, Riding Moor. **Rock Type:** weakly plagioclase microporphyritic tholeiitic basalt. **Symbol:** plmiqB<sup>T</sup>.

**Description:** This thin section is of a fine-grained, inequigranular, massive, hypocrySTALLine, anhedral granular, aphyric to weakly microporphyritic quartz-bearing tholeiitic basalt. It comprises an inequigranular assemblage of plagioclase, clinopyroxene, and orthopyroxene with minor to accessory opaque minerals and quartz. Alteration resulted in the development of a very fine-grained chlorite dominated assemblage.

The rock is mainly composed of randomly orientated plagioclase laths with intergranular pyroxene and an interstitial to intersertal mesostasis. The remaining interstitial areas are composed of a dark green chloritic assemblage. Plagioclase forms anhedral to subhedral twinned, lath-shaped crystals (typically  $\leq 0.5$  mm in size) as well as occasional small microphenocrysts. An untwinned feldspar with a sweeping extinction also occurs as an intergranular phase. Colourless to very pale brown pyroxene occurs intergranular to plagioclase and forms anhedral granular crystals as well as slightly larger ( $\leq 0.3$  mm in size), subophitic to ophitic single crystals. Orthopyroxene is locally included within, or surrounded by several crystals of clinopyroxene and was apparently more susceptible to alteration. Chlorite and carbonate pseudomorphs after orthopyroxene have been recognised within this basalt.

Anhedral crystals of opaque minerals are a common minor to accessory phase. The trace amounts of quartz present within this basalt occur intergranular to plagioclase and both pyroxenes.

**Registered Number:** E13108. **Location:** Coal House, Riding Moor. **Rock Type:** quartz-bearing tholeiitic basalt. **Symbol:** qB<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained, massive, hypocrySTALLine to weakly holocrystalline, inequigranular, anhedral granular, weakly altered, aphyric quartz-bearing tholeiitic basalt. It comprises an inequigranular assemblage of plagioclase and pyroxene with

minor to accessory opaque minerals and quartz. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by chlorite, bowlingite and carbonate.

The rock is mainly composed of randomly orientated plagioclase laths with granular looking interstitial pyroxene (mainly clinopyroxene). The remaining interstitial to intersertal areas were originally filled by a dusty looking mesostasis which is variably replaced by a dark green chloritic assemblage. However, traces of a dusty brown coloured mesostasis are present. Plagioclase forms anhedral twinned, lath-shaped to prismatic. An untwinned feldspar also occurs as an interstitial phase.

Very pale brown pyroxene is intergranular to plagioclase and forms anhedral locally subophitic to ophitic crystals. Anhedral opaque crystals are a common minor to accessory phase within this basalt. Trace amounts of quartz occurs intergranular to plagioclase and pyroxene.

**Registered Number:** E13109. **Location:** Cragside Rothbury. **Rock Type:** sericitised quartz-bearing tholeiitic microgabbro. **Symbol:** qD<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained, massive, holocrystalline, inequigranular, anhedral granular, highly altered, aphyric quartz-bearing tholeiitic microgabbro. It was originally composed of an inequigranular assemblage of plagioclase and pyroxene with minor to accessory opaque minerals, quartz and apatite. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by sericitic white mica as well as chlorite, bowlingite, amphibole, epidote and biotite.

The rock is mainly composed of randomly orientated plagioclase laths with intergranular, locally subophitic pyroxene (mainly clinopyroxene) and plagioclase. Plagioclase is variably altered to, or pseudomorphed by very fine grained sericitic white mica. However, relict anhedral twinned plagioclase is present. The remaining interstitial to intersertal phases are replaced by cryptocrystalline to very finely microcrystalline chlorite, bowlingite and trace amphibole.

Very pale brown pyroxene is intergranular to plagioclase and forms anhedral, fractured, elongate to equant crystals. Very fine-grained, fibrous reaction rims of chlorite ( $\pm$  amphibole) are developed locally enclosing rounded to irregular relict pyroxene crystals. Possible orthopyroxene has been completely replaced by chlorite, bowlingite and, in some cases, fine-grained possibly actinolitic amphibole. Anhedral to skeletal opaque crystals are a common minor to accessory phase within this microgabbro. Trace amounts of quartz occurs intergranular to plagioclase and pyroxene.

**Registered Number:** E13110. **Location:** Cragside Rothbury. **Rock Type:** sericitised quartz-bearing tholeiitic microgabbro. **Symbol:** qD<sup>T</sup>.

**Description:** This thin section is of a fine- to medium-grained, massive, holocrystalline, inequigranular, anhedral granular, highly altered, aphyric quartz-bearing tholeiitic microgabbro which is petrographically similar to sample E13109. This microgabbro was originally composed of an inequigranular assemblage of plagioclase, clinopyroxene and orthopyroxene with minor to accessory opaque minerals, quartz and apatite. Alteration resulted in the development of a very fine-grained secondary assemblage dominated by sericitic white mica as well as chlorite, bowlingite, carbonate, epidote and biotite.

The rock is mainly composed of randomly orientated plagioclase laths with subordinate intergranular, locally subophitic pyroxene (mainly clinopyroxene) and plagioclase. Plagioclase is variably altered to, or pseudomorphed by very fine grained sericitic white mica. However, relict anhedral twinned and zoned plagioclase is present. The remaining interstitial to intersertal phases are replaced by cryptocrystalline to very finely microcrystalline chlorite, bowlingite and trace amphibole.

Very pale brown pyroxene (mainly clinopyroxene) is intergranular to plagioclase and forms anhedral, fractured, elongate to equant crystals. Very fine-grained, fibrous reaction rims of chlorite ( $\pm$  amphibole, biotite) are developed locally enclosing rounded to irregular relict

pyroxene crystals. Pyroxene (including orthopyroxene) is pseudomorphed by chlorite, bowlingite, biotite and carbonate. Anhedral to skeletal opaque crystals are a common minor to accessory phase within this microgabbro. Trace amounts of quartz occurs intergranular to plagioclase and pyroxene. Quartz was also noted occasionally forming slightly coarser grained poikilitic intergranular crystals. Traces of a pale brown, interstitial to intersertal mesostasis has also been recorded within this microgabbroic rock.

**Registered Number:** E13111. **Location:** Newtown Rothbury. **Rock Type:** quartz-bearing tholeiitic microgabbro. **Symbol:** qD<sup>T</sup>.

**Description:** This thin section is of a fine-grained, massive, holocrystalline, inequigranular, anhedral granular, aphyric quartz-bearing tholeiitic microgabbro (Plates 2c and d). It is composed of an inequigranular assemblage of plagioclase and clinopyroxene with minor to accessory opaque minerals, quartz and apatite. Minor alteration resulted in the development of a very fine-grained secondary assemblage of chlorite, bowlingite, amphibole, biotite, carbonate and sericitic white mica.

The rock is mainly composed of randomly orientated plagioclase laths ( $\leq 0.8$  mm in length) with intergranular, locally subophitic clinopyroxene and plagioclase. Plagioclase forms anhedral to weakly subhedral, twinned crystals which exhibit very little alteration to sericitic white mica. Plagioclase and an untwinned feldspar (?K-feldspar) with a sweeping to undulose extinction also occur as intergranular phases. Very pale brown pyroxene is fresh and occurs as single ( $\leq 0.6$  mm in size) anhedral, weakly subophitic crystals as well as intergranular aggregates of several granular-looking crystals. Clinopyroxene was also noted enclosed within or rimmed by a pale brown-green coloured amphibole (rare). It is possible that amphibole may have formed a primary phase (minor/trace) within this microgabbro and is locally pseudomorphed by chlorite and biotite.

Orthopyroxene has been completely replaced (pseudomorphed) by chlorite, bowlingite and, in some cases, biotite. Anhedral to skeletal opaque crystals are a common minor to accessory phase within this microgabbro. Trace amounts of quartz occurs intergranular to plagioclase and pyroxene.

**Registered Number:** E13112. **Location:** Ponting Burn, Newtown Rothbury. **Rock Type:** altered quartz-bearing tholeiitic microgabbro. **Symbol:** qD<sup>T</sup>.

**Description:** This thin section is of a fine-grained, massive, holocrystalline to weakly hypocrySTALLINE, inequigranular, anhedral granular, highly altered, aphyric quartz-bearing tholeiitic microgabbro. It is composed of an inequigranular assemblage of sericitic white mica, chlorite, bowlingite, plagioclase, clinopyroxene and orthopyroxene. Minor to accessory phases present include opaque minerals, quartz and apatite. Alteration resulted in the sericitisation of feldspar and replacement of pyroxene by a cryptocrystalline assemblage of chlorite and bowlingite.

The rock is mainly composed of randomly orientated sericitised plagioclase laths with subordinate intergranular, pyroxene and minor to trace amounts of a pale pinky brown mesostasis. The remaining interstitial to intersertal areas are filled by a cryptocrystalline chloritic assemblage. Minor relict clinopyroxene is present forming anhedral, fractured, locally weakly subophitic crystals. Relict crystals of orthopyroxene are distinguished by its straight extinction.

Anhedral to occasionally skeletal opaque crystals are a common minor to accessory phase within this microgabbro. Trace amounts of quartz occurs intergranular to plagioclase and pyroxene.

## 2.2 TUFFACEOUS SANDSTONE

**Registered Number:** E18133. **Location:** 1200 yards east at 30° south of Norwick Hall, Northumberland. **Rock Type:** highly altered tuffaceous sandstone. **Symbol:** not applicable.

**Description:** This thin section is of a medium-grained, massive, immature, poorly sorted, open packed, matrix-rich, matrix supported, altered tuffaceous rock or sandstone. The exact nature of the protolith to this sample is uncertain due to the intensity of alteration which resulted in the variable modification/overprinting of the primary texture of the rock.

Although highly altered the original clastic texture of the rock can still be recognised in plane polarised light. However, this texture is lost under crossed polarised light due to the fact that the primary mineral phases have been replaced by a cryptocrystalline possibly clay-rich assemblage. Recognisable clasts range up to *c.* 3.0 mm in length and exhibit a weakly/patchily developed preferred shape alignment. These clasts are composed of a colourless cryptocrystalline assemblage which is isotropic under crossed polarised light. Originally these clasts appear to have included siltstone and/or mudstone lithic clasts which are variably altered to, or rimmed by opaque oxide.

The matrix to the rock is green-brown in colour and contains small ( $\leq 0.1$  mm in length), broken crystal fragments of possible feldspar. Overall the matrix possesses a tuffaceous, silty appearance.

## 2.3 METASOMATIC ROCKS AND HORNFELSES

**Registered Number:** E19037. **Location:** Whitehouse Quarry, Ewesley, Northumberland. **Rock Type:** altered basalt/metabasalt. **Symbol:** B.

**Description:** This thin section is of a fine- to very fine-grained, crudely foliated, highly altered or metamorphosed (or metasomatised), basaltic rock. It is composed of an inequigranular assemblage of chlorite, quartz, and amphibole with minor to accessory opaque minerals, epidote and carbonate.

The rock is mainly composed of a cryptocrystalline to very finely microcrystalline assemblage of chlorite and amphibole with irregular patches and veinlets of anhedral granular quartz ( $\pm$  plagioclase). Aggregates of anhedral, relict plagioclase laths are present within this highly altered basaltic rock. The quartz patches and veinlets also contain minor to trace epidote and anhedral to weakly subhedral amphibole crystals which are up to 0.3 mm in length. Amphibole, is green in colour with a variably developed pleochroism. Anhedral epidote crystals vary from colourless to pale yellow and exhibit a moderately well developed pleochroism.

The matrix to the rock is composed of a turbid chloritic/amphibole rich assemblage which possesses a weakly developed foliation defined by dark coloured seams of veinlets. Relict plagioclase crystals and lenticular quartz veinlets may also be aligned within the plane of the foliation.

**Registered Number:** E19037A. **Location:** Whitehouse Quarry, Ewesley, Northumberland. **Rock Type:** epidote-pyroxene-amphibole-bearing skarn. **Symbol:** not applicable.

**Description:** This thin section is of a fine- to medium-grained, crudely banded, metasomatised basaltic rock. It is mainly composed of an anhedral granular assemblage of epidote, amphibole and clinopyroxene (Plates 3a and b). The remainder of this inequigranular assemblage includes minor to accessory carbonate, chlorite, plagioclase and opaque minerals. Chlorite and plagioclase occur as intergranular phases.

Epidote ranges from colourless, to pale yellow through to bright yellow and exhibits a well developed pleochroism. It forms anhedral to occasionally subhedral crystals which may possess one or two well developed crystal faces. Subhedral to weakly euhedral, rod to lozenge-shaped epidote crystals have been recorded included within rounded (3.0 to 4.5 mm in diameter) to irregular pockets of coarse-grained carbonate.

Clinopyroxene is colourless to pale green and forms anhedral granular crystals which are probably diopsidic in composition. Pale green amphibole forms acicular to prismatic crystals

which have been variably replaced by dusty looking to turbid carbonate. A weakly developed banding within this thin section is defined by alternating pyroxene and amphibole-rich layers.

**Registered Number:** E19037B. **Location:** Whitehouse Quarry, Ewesley, Northumberland. **Rock Type:** epidote-carbonate metasomatised mudstone. **Symbol:** not applicable.

**Description:** This thin section is of a fine-grained, foliated, altered mudstone (Plates 3c and d) which contains distinct patches of epidote-chlorite-carbonate ( $\pm$  quartz, plagioclase). The host, possibly originally carbonaceous mudstone possesses a variably developed foliation which is defined by lenticular patches of chloritic material. These lenticular patches may also contain a cryptocrystalline assemblage of chlorite, carbonate, quartz and biotite. Epidote forms anhedral crystals which possess a well developed pleochroism which ranges from colourless to bright yellow. The associated chlorite is bright green in colour and exhibits anomalous blue birefringence colours under crossed polarised light.

**Registered Number:** E19037C. **Location:** Whitehouse Quarry, Ewesley, Northumberland. **Rock Type:** very fine-grained biotite-hornfels. **Symbol:** not applicable.

**Description:** This thin section is of a very fine-grained to cryptocrystalline, hornfelsed metasedimentary rock which is composed of a fine granular assemblage of quartz, carbonate, biotite, white mica, chlorite and opaque oxide (Plates 4a and b).

Biotite is red brown in colour and is disseminated throughout the rock. Biotite also occurs in thin veinlets which appear to have accommodated some shear deformation; the latter indicated by the presence of a arcuate to curved fabric defined by deformed biotite flakes. A weakly developed, possibly tectonic fabric, present within the matrix of the hornfels is defined by shape aligned very fine-grained (sericitic) white mica flakes. The presence of finely disseminated opaque gives the rock a slight dusty appearance in plane polarised light. Thin, wispy looking seams of very fine-grained, granular biotite may preserve a weakly developed sedimentary lamination or cross lamination.

**Registered Number:** E19037D. **Location:** Whitehouse Quarry, Ewesley, Northumberland. **Rock Type:** biotite-rich hornfelsed basaltic rock. **Symbol:** not applicable.

**Description:** This thin section is of a fine- to very fine-grained, hornfelsed basaltic rock (Plates 4c and d). The exact nature of the protolith to this hornfels is, however, uncertain due to the intensity of recrystallisation associated with subsequent thermal metamorphism. An igneous origin for the rock is suggested by the presence of 1.5 to 2.5 mm long pseudomorphs after lath-shaped feldspar crystals. They are composed of fine-grained albitic plagioclase, with feldspar also noted forming rounded patches or pockets within the matrix. These feldspathic patches also contain very fine-grained biotite.

The bulk of the rock is composed of a cryptocrystalline to very fine-grained mosaic of biotite, quartz and feldspar which contains finely disseminated, dusty looking opaque oxide. The hornfels is massive to weakly foliated with thermal metamorphism resulting in the overprinting of the original texture of the rock.

## 2.4 LIMESTONES

**Registered Number:** E20248. **Location:** The Glebe, 1 mile southwest of station, Rothbury, Northumberland. **Rock Type:** sandy limestone or highly calcareous sandstone. **Symbol:** not applicable.

**Description:** This thin section is of a medium-grained, clast supported, fragmentary, calcareous, closely packed, micritized, sandy limestone or highly calcareous sandstone (Plates 5a and b). The rock is mainly composed of micritic or micritized, subangular to subrounded, moderate to low sphericity carbonate clasts. Minor detrital monocrystalline quartz clast are angular to subrounded in shape with a moderate to low sphericity. The shape of these quartz clasts has been

modified due to grain boundary etching accompanying the recrystallisation of the adjacent matrix. Locally quartz possesses weakly developed crystal faces due to the development of diagenetic quartz overgrowths. Minor to trace amounts of detrital plagioclase and microcline were also recorded.

Carbonate clasts are typically massive to weakly texturally zoned. The original clasts have been replaced by a cryptocrystalline to micritic mosaic. The original clasts probably included shell fragments, echinoderm/crinoid fragments, calcareous algae and coral. Localised pressure solution along inter clast grain boundaries resulted in the truncation of clasts and the formation of thin pressure solution seams marked by a brown coloured staining/clay.

The cement to this clastic rock is composed of fine-grained sparry carbonate. The carbonate minerals present within this rock have not been established due to the thin section is unstained.

**Registered Number:** E20249. **Location:** The Glebe, 1 mile southwest of station, Rothbury, Northumberland. **Rock Type:** fine-grained limestone. **Symbol:** not applicable.

**Description:** This thin section is of a fine-grained, variably recrystallised limestone which contains calcispheres, algal bioclasts, shell fragments and rounded clasts composed of micritic carbonate (Plates 5c and d). Trace amounts of diagenetic quartz were also recorded within this limestone. The rock is mainly composed of micritic to finely microcrystalline, massive carbonate with occasional small patches of very fine-grained sparry carbonate. The carbonate minerals present within this rock have not been established due to the thin section is unstained.

## 2.5 QUARTZ-ARENITE

**Registered Number:** E47001. **Location:** Ashington New Moor borehole GSN 61 SW 24, 178 m @ 347° from level crossing, depth 83.21 metres [NZ 2645 8963]. **Rock Type:** quartz-rich sandstone (quartz-arenite). **Symbol:** not applicable.

**Description:** This thin section is of a medium-grained, moderately sorted, moderately packed, relatively mature, clast supported, quartz-rich sandstone (quartz-arenite). A distinguishing feature of this sandstone is the presence of irregular, embayed and plastically deformed mudstone lithic clasts or clay filled voids/pore spaces (Plates 6a and b). These clay-rich features occur in distinct horizons and are embayed against neighbouring more rigid quartzose clasts.

Detrital grains are angular to locally subrounded in shape with a low to moderate sphericity. The shape of these clasts has, however, been modified due to grain boundary etching and the development of quartz overgrowths. The clast assemblage is dominated by monocrystalline quartz. Minor to accessory detrital components include muscovite, opaque minerals, microcline, zircon and plagioclase. Traces of secondary opaque oxides and carbonate were also noted.

Minor to trace amounts of a cryptocrystalline, possibly chloritic cement or matrix has been recorded filling intergranular pore spaces. The main form of cementation within this sandstone is a result of pressure solution and the development of quartz overgrowths.

**Registered Number:** E47002A. **Location:** Ashington New Moor borehole GSN 61 SW 24, 178 m @ 347° from level crossing, depth 188.06 metres [NZ 2645 8963]. **Rock Type:** fine-grained quartzose sandstone (quartz-arenite). **Symbol:** not applicable.

**Description:** This thin section is of a fine-grained, closely packed, matrix-poor, weakly laminated, clast supported, quartz-rich sandstone (quartz-arenite). The primary sedimentary lamination present within this sandstone is defined by a slight change in grain size, but is characterised by the variation in modal detrital biotite and, to a lesser extent, muscovite.

Detrital grains are angular, subangular to rarely subrounded in shape with a low to moderate sphericity. The shape of the grains has, however, been modified due to grain boundary etching and the localised development of quartz overgrowths. The clast assemblage is dominated by

monocrystalline quartz with subordinate to minor variably altered feldspar and biotite. Other minor to accessory detrital components include plagioclase, microcline, muscovite and chlorite.

Traces of a colourless cryptocrystalline chloritic or clay cement or matrix has been noted filling intergranular pore spaces. The main form of cementation is due to pressure solution of quartz and the development of interlocking grain boundaries. Traces of secondary carbonate and kinking of detrital micas have also been noted.

## 2.6 VEIN MINERALS

**Registered Number:** E47002. **Location:** Ashington New Moor borehole GSN 61 SW 24, 178 m @ 347° from level crossing, depth 188.06 metres [NZ 2645 8963]. **Rock Type:** carbonate vein. **Symbol:** not applicable.

**Description:** This thin section is of a zoned carbonate vein. It is mainly composed of anhedral to weakly euhedral crystals of carbonate with an 'outer' zone of an opaque mineral. The type of carbonate present within the vein is uncertain as the thin section is unstained.

## 2.7 SILTSTONE

**Registered Number:** E47003. **Location:** Fox Covert borehole GSN 61 NW 34, depth 187.28 metres [NZ 2713 9397]. **Rock Type:** siltstone. **Symbol:** not applicable.

**Description:** This thin section is of a massive, fine-grained siltstone which possess a dusty brown coloured (plane polarised light) clay-rich matrix. This siltstone contains small angular detrital grains of quartz, feldspar, white mica, chlorite and opaque minerals.