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Descriptions of two thin sections from the glacial sediments exposed at Great Orton, Cumbria

Geology and Landscape North Programme

Internal Report IR/07/010

BRITISH GEOLOGICAL SURVEY

GEOLOGY AND LANDSCAPE NORTH PROGRAMME

INTERNAL REPORT IR/07/010

Descriptions of two thin sections from the glacial sediments exposed at Great Orton, Cumbria

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Keywords

Report; keywords.

Front cover

Cover picture details, delete if no cover picture.

Bibliographical reference

E.R. PHILLIPS 2007. Descriptions of two thin sections from the glacial sediments exposed at Great Orton, Cumbria. *British Geological Survey Internal Report*, IR/07/010. 15pp.

Keyworth, Nottingham British Geological Survey 2007

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) as part of their strategic Geology and Landscape Northern Britain programme. It describes the micromorphology of a thin section of glacial sediment and mineralogy and petrology of a granitic erratic from Great Orton, Cumbria, northwest England. The work forms part of a multidisciplinary Southern Scotland Project.

Contents

Summary

This report describes the micromorphology of a prepared sample of Quaternary glaciogenic sediment and a glacial erratic exposed near Great Orton, Cumbria, on the southern side of the Solway Firth. The work forms part of the Southern Scotland Project of the Geology and Landscape Northern Britain Programme. The first part of the report provides a detailed description of a single thin section of an unconsolidated, sandy, silty clay present near the base of the section. The remainder of the report describes the mineralogy and petrology of a large granitic erratic found within the glaciogenic sequence and now located at the entrance to the Watchtree Nature Reserve at Great Orton.

1 Introduction

This first part of this report describes the micromorphology of a sample of sandy, silty mud which forms part of the Pleistocene glaciogenic sequence present at Great Orton, Cumbria on the southern side of the Solway Firth. The remainder of the report describes the mineralogy and petrology of a large granitic erratic boulder which is now sited at the entrance to the Watchtree Nature Reserve.

The glaciogenic sediments at Great Orton were exposed in a temporary section which was dug at the airfield. The section was visited by Jon Merritt, Charlotte Vye and Andrew McMillan as part of a commercial site investigation project. The exposed sequence was approximately 1 m thick and dominated by a red-brown (Munsell colour code 2SYR 3/6 dark red), stiff to very stiff, sandy diamicton. The upper 30 cm has been worked and contains field drains. The till is cut by a number of evenly spaced (*c*. 2 m spacing) subvertical, north–south-trending wedge-shaped features filled with pale grey (Munsell colour code 10R 7/1 light grey) silty sand. The till contains small pebble to cobble sized clasts of subrounded granitic rock (up to 20 cm in length), sandstone and Jurassic siltstone and mudstone, as well as possible wacke sandstone lithic fragments derived from the Southern Uplands. Immediately below the diamicton is a 5 cm thick layer of laminated or foliated, relatively soft, pale grey (Munsell colour code 10YR 5/1 grey) silty clay which, in the field, was thought to be glacitectonic in origin. This foliated layer is underlain by a 50 to 60 cm thick unit of grey to pale brown clay to silty clay. This clay-rich layer is laterally impersistant and wedges out, resulting in till resting directly on bedrock. The upper 20 to 30 cm of this clayey layer contains numerous fragments of oxidised pale red-brown clay and pockets of red sandy clay; the latter being lithologically similar to the matrix of the overlying diamicton. A weakly to moderately developed bedding-parallel fissility or foliation increases in intensity upwards. The lower 20 to 30 cm of the clay layer is pale brown (Munsell colour code 10YR 4/4 dark yellowish brown) in colour and contains fragments of the Jurassic bedrock. Subhorizontal fractures within the clay-rich layer are lined by a thin coating of manganese oxide and/or iron oxides. These fissures appear to have developed along the platy fabric developed within the upper part of the silty clay layer and overlying thin glacitectonic unit. This foliation wraps around the included fragments of bedrock and oxidised red-brown clay. The lower part of the clay layer appears to grade into the underlying weathered bedrock. The bedrock is composed of a micaceous silty mudstone containing small shelly fragments. The mudstone possesses a variably developed irregular to wavy bedding.

Micromorphology is a relatively new and, currently, still developing technique and refers to the examination of Quaternary and other glacial sediments in thin section (see van der Meer, 1987, 1993; Menzies, 2000). A single large format thin sections of unconsolidated sediment collected from near to the base of the temporarily exposed sections at Great Orton was examined during this study. A standard size thin section of a large granitic erratic was also examined. This large granitic erratic is now located at the entrance to the Watchtree Nature Reserve at Great Orton.

2 Micromorphology of the glacial sediments

One sample of the glaciogenic sediments were collected from a temporarily exposed section at Great Orton [NY 31077 53972]. The sample was obtained using 10 cm square, aluminium kubiena tin which was pushed into the face of the exposure. Once the sample was removed from the exposed face it was double sealed in plastic bags and stored at 4°C to prevent it from drying out prior to sample preparation. The sample was taken from the upper part of the silty clay layer which locally separates the diamicton from the underlying Jurassic mudstone bedrock.

2.1 ANALYTICAL TECHNIQUES

A single large format thin section was prepared by Mr D. Oates at the British Geological Survey's Thin Sectioning Laboratory (Keyworth) following the procedures for sample preparation of unconsolidated or poorly lithified materials. The thin section was examined using a standard Zeiss petrological microscope and Zeiss projector enabling the analysis of both large and small-scale microscopic textures and fabrics. An annotated scanned image (Figure 1) of the thin section has been used to describe the main microscopic features developed within this Quaternary deposits.

2.2 TERMINOLOGY

The description and interpretation of the micromorphology and deformation structures developed within glacial deposits is a relatively recent and still developing technique (see van der Meer 1987, 1993; Seret 1993; van der Meer *et al*., 1990; van der Meer *et al*., 1992; van der Meer and Vegers, 1994; Menzies, 2000). Although repetitive features have been recognised by several workers (see van der Meer, 1987, 1993 and references therein), a standard nomenclature has yet to be formalised. The terminology used in this report is that proposed by van der Meer (1987, 1993) and Menzies (2000), and is based upon nomenclature developed by pedologists (for references see van der Meer, 1993). A definition of the terms used for the various textures and fabrics, and their proposed mode of formation is given below.

Plasmic fabric - The arrangement of high birefringent clay plasma/domains which are visible under the microscope (under cross polars) because of the similar extinction of similarly orientated domains. These fabrics are only observed when the sediment is clayey. Sediments which contain a limited amount of fines or relatively high proportion of carbonate within the matrix do not exhibit a well-developed plasmic fabric.

Unistrial plasmic fabric - A planar plasmic fabric defined by relatively continuous domains which is typically observed defining discrete shears. Interpreted as developing in response to planar movement (van der Meer, 1993).

Skelsepic plasmic fabric - A plasmic fabric in which the orientated domains occur parallel to the surface of large grains. Interpreted as developing in response to rotational movement (van der Meer, 1993).

Lattisepic plasmic fabric - A plasmic fabric defined by short orientated domains in two perpendicular directions. In many cases this fabric is found associated with a skelsepic plasmic fabric. Therefore, lattisepic plasmic fabrics are also interpreted as having developed in response to rotational movement (van der Meer, 1993).

Omnisepic plasmic fabric - A plasmic fabric in which all the domains have been reoriented. Interpreted as developing in response to rotational movement (van der Meer, 1993).

Till 'pebbles' - Formed by rotational movement (van der Meer, 1993). They are subdivided into three types: Type (1) consists of till which lack an internal plasmic fabric. They are defined by encircling voids and the shape of the 'pebbles' becomes progressively angular and flatter with depth; Type (2) is characterised by 'pebbles' of fine-grained material which were part of the original sediment host. They are recognised by an internal plasmic structure and are not defined by voids; Type (3) form isolated 'pebbles' of either till or fine-grained sediments and are usually interpreted as having formed by reworking of the till. They may or may not contain internal plasmic fabrics.

Other microscopic features - These include: the circular arrangement of clasts (skeleton grains) with or without a 'core stone', interpreted as having formed in response to rotation (van der Meer, 1993); pressure shadows which are also interpreted as having formed in response to rotation (van der Meer, 1993); dewatering structures associated with shearing; microboudinage; microscopic-scale primary sedimentary structures (e.g. lamination, cross-lamination….etc); water-escape structures associated with forceful dewatering; and crushing of clastic grains.

2.3 THIN SECTION DESCRIPTION

Collectors Number: not assigned. **Registered Number:** E74789. **Location:** [NY 31077 53972] temporary section, Great Orton. **Lithology:** silty clay partially derived from degraded Jurassic mudstone bedrock.

Description: This thin section is of a fine-grained, silty clay containing fragments or patches of a similar silty clay or mudstone which have been stained by Fe-oxides and Mn-oxide (Figure 1). This staining appears to mainly pick out partially 'digested' or 'reconstituted' fragments of micaceous, locally shelly Jurassic mudstone. This results in an overall mottled to blotchy appearance to the sediment. The bedrock fragments are locally micaceous and contain elongate flakes of muscovite and biotite. Small angular grains of quartz, opaque oxide and tourmaline are also present. Intergranular pockets of amorphous hematitic oxide occur within the lithic clasts and probably developed during Fe-oxide staining. Shell fragments present within the bedrock lithic clasts have been completely decalcified and are now preserved as open casts. The preservation of these open voids suggests that decalcification occurred after the incorporation of the rock fragments into the glacial deposits, possibly due to the removal of calcite by mildly acidic groundwater associated with the overlying marsh.

The host glacial sediment appears to have been largely derived from the mudstone bedrock making it locally difficult to distinguish included lithic fragments from the host silty clay. Although the lighter coloured clasts do possess sharp contacts, highlighted by later alteration, the margins of some rock fragments are gradation with the surrounding sediment. This relationship supports the conclusion that the host sediment is, at least in part, derived from the underlying bedrock with the disaggregation of the ?poorly lithified mudstone possibly being aided by the potentially high water content of the host glacial sediment. The sample also contains thin stringers to irregular patches of fine- to coarse-grained sand. These stringers are typically associated with water-escape/fluid flow features.

The host silty clay possesses a patchy, but locally well-developed developed plasmic fabric defined by optically aligned clay plasma and shape-aligned detrital white micas. This fabric appears to largely occur parallel to bedding/layering within the glacigenic sequence, but is locally observed wrapping around included mudstone lithic clasts. A weak, locally developed lamination in the silty clay matrix also wraps around the included rock fragments (see Figure 1). Thin veinlets and rounded to irregular pockets of variably Fe-stained clay cutan are common within the silty clay. The clay cutan is highly birefringent and possesses a well-developed plasmic fabric which typically mimics the shape of the vein or void. This fabric is apparently unrelated to the plasmic fabric present within the host sediment and probably developed in response to the 'plastering' of the clays onto the margins of these fluid flow features during water-escape. However, a number of the larger, open clay cutan-lined voids may represent features left by more recent plant roots. These clay-lined voids also tend to be more prone to alteration/staining and are surrounded by a haloe of Fe-stained (or Mn) sediment (see Figure 1).

The sample contains, or is apparently cut by, a number of diffuse zones or veinlets of massive to weakly laminated silt and clay (Figure 1). The right-hand side of the sample is cut by a near vertical, irregular, sand, silt and clay filled fracture. These diffuse features typically contain the clay-cutan filled water escape features and are, therefore, thought to have developed in response to the injection of fluidised sediment into the basal layer of the Quaternary sequence exposed at Great Orton. Also present within these fluidised zones are thin stringers or irregular patches, up to 1. 6 mm wide, of matrix supported sand. Sand grains (≤ 0.6 mm in diameter) are angular to rounded in shape and mainly composed of monocrystalline quartz. Other minor to accessory detrital components present include polycrystalline quartz, granitic rock fragments, felsite/chert, plagioclase, K-feldspar, amphibole and a clast of a very fine-grained to cryptocrystalline ?basaltic rock. Detrital micas, derived from the underlying bedrock are common within the silty clay. Although aligned parallel to the plasmic fabric present within the sediment, the micas show very little evidence (e.g. kinking) of having been deformed.

3 Petrography of the glacial erratic

This section describes the mineralogy and petrology of a large granitic erratic boulder which is now sited at the entrance to the Watchtree Nature Reserve. The erratic is lithologically similar to the granitic rocks which form the Criffle-Dalbeattie Granite Pluton exposed to the northwest of the Great Orton site, to the west of Dumfries in southwest Scotland.

3.1 THIN SECTION DESCRIPTION

Collectors Number: PX502. **Registered Number:** E74778. **Location:** [NY 3040 5390] large granitic erratic, Great Orton, Cumbria. **Lithology:** foliated, K-feldspar macroporphyritic biotite-granite.

Mineralogy:

***Major* –** quartz, K-feldspar, plagioclase, biotite

***Accessory* –** apatite, titanite, opaque minerals, muscovite, zircon, ?allanite

***Alteration* –** chlorite, epidote, sericite/clay minerals

Description: This thin section is of a coarse- to very coarse-grained, inequigranular, anhedral granular, foliated, K-feldspar macroporphyritic biotite-granite (Figure 2). The rock is mainly composed of an inequigranular assemblage of quartz, K-feldspar, plagioclase and biotite with trace amounts of muscovite. Accessory minerals include apatite, titanite, opaque minerals, muscovite, zircon and possible allanite. The accessories tend to be spatially related to, or included within biotite. A moderately well-developed pre-full crystallisation fabric is defined by variably shape-aligned plagioclase, biotite ad to a lesser extent K-feldspar.

Plagioclase forms equant to lath-shaped, twinned (simple and multiple) and zoned (oscillatory and gradational) crystals which exhibit preferential sericitisation of their cores. Plagioclase ranges in size up to 2.8 mm in size and forms anhedral to subhedral crystals. These occur as single isolated crystals and in clusters of several variably aligned laths. A small number of the larger laths are curved or bent and possess a sweeping to undulose extinction due to intracrystalline deformation. K-feldspar is much coarser grained than plagioclase forming large (up to ≥ 8.0 mm in size), anhedral poikilitic crystals which contain smaller chadacrysts of plagioclase and biotite. The plagioclase chadacrysts are enclosed within a variably developed myrmekitic or granophyric rim composed of finely intergrown feldspar and quartz. K-feldspar is perthitic and possesses an undulose to shadowy extinction, as well as variably developed microcline twins. The more elongate K-feldspar crystals are shape-aligned parallel to the foliation defined by biotite and plagioclase.

Biotite is the only ferromagnesian mineral present within this granitic rock and is pale brown to brown in colour with a moderately developed pleochroism. It forms anhedral to weakly subhedral crystals which are variably aligned parallel to the pre-full crystallisation fabric. This fabric is locally defined by thin stringers or poorly developed domains of aligned, variably deformed biotite flakes. Intracrystalline deformation of biotite resulted in the development of an undulose to sweeping extinction. Biotite is variably altered to pale green chlorite. Traces of small muscovite flakes, where present, are typically associated with biotite.

Earlier formed plagioclase, K-feldspar and biotite form an open framework or crystals. The remaining interstitial to intersertal areas are largely filled by anhedral, variably strained quartz. Quartz crystals are irregular in shape with locally serrated grain boundaries. Intracrystalline deformation of quartz, probably due to minor sub-solidus deformation, resulted in the development of subgrains and diffuse deformation twins. However, new grain development is absent within the quartz crystals suggesting that dynamic recrystallisation during sub-solidus deformation was limited. The subgrains and deformation twins are variably shape-aligned parallel to the fabric developed within this granite. Although foliated, the intensity of solid state/intracrystalline deformation within quartz and feldspars within the granite support the conclusion that foliation development occurred prior to full crystallisation. There is no obvious evidence for the collapse of the primacryst framework suggesting that alignment of both feldspars and biotite largely occurred in response to passive rotation. Foliation development within the granite, therefore, occurred during emplacement and not in response to any subsequent deformation event.

4 Glossary

Micromorphology – A term used to describe the study of unconsolidated glacial sediments in thin section using a petrological microscope.

Plasmic fabric – The optical arrangement of high birefringent clay plasma/domains which are visible under crossed polarised light using a petrological microscope.

Unistrial plasmic fabric – A planar plasmic fabric defined by relatively continuous domains which is typically observed defining discrete shears (van der Meer, 1993).

Skelsepic plasmic fabric – A plasmic fabric in which the orientated domains occur parallel to the surface of large grains (van der Meer, 1993).

Lattisepic plasmic fabric – A plasmic fabric defined by short orientated domains in two perpendicular directions (van der Meer, 1993).

Omnisepic plasmic fabric – A plasmic fabric in which all the domains have been reoriented (van der Meer, 1993).

Grain size – (a) clay < 0.0039 mm in size; (b) silt, 0.0039 to 0.0625 mm in size; (c) fine sand, 0.0625 to 0.25 mm in size; (d) medium sand, 0.25 to 0.5 mm in size; (e) coarse sand, 0.5 to 1.0 mm in size; (f) very coarse sand, 1.0 to 2.0 mm in size; (g) granules 2.0 to 4.0 mm in size; (h) pebbles 4.0 to 64 mm in size.

Rounded – Describes the smoothness of the surface of a grain. The terms well-rounded, rounded, subrounded, subangular, angular, very angular are used to describe the increasingly angular/irregular/rough nature of the surface of detrital grains.

Sphericity – Describes how closely a detrital grain approximates to a sphere. The terms low sphericity, moderate sphericity and high sphericity are used to describe how spherical (ball-like) the detrital grains are.

Sorting – Well sorted describes a deposit in which all the detrital grains are of approximately uniform size. In reality most fragmentary deposits contain a range of grain sizes and can be described as moderately sorted, poorly sorted or in extreme cases unsorted.

Packing – Describes, as the term suggests, how closely the individual detrital grains are packed together within a fragmentary deposit. The term closely packed is used where all the grains are in contact and there is very little obvious matrix or cement; moderately packed and open packed are used with an increase in the porosity, matrix and/or cement.

Clast- supported – Describes a fragmentary deposit where all the detrital grains are in contact.

Clay cutan – a modified texture, structure or fabric of a unconsolidated material (e.g. soil) caused by the concentration of optically aligned, highly birefringent clay plasma.

Matrix-supported – Describes a fragmentary deposit where the detrital grains are, to varying degrees, isolated/supported within a finer grained matrix.

Cement-supported – Describes a fragmentary deposit where the detrital grains are, to varying degrees, isolated/supported within the cement.

Cement – The material bonding the fragments of clastic sedimentary rocks together and which was precipitated between the grains after deposition.

Porosity – The volume of voids expressed as a percentage of the total volume of the sediment or sedimentary rock.

Matrix – Material, usually clay minerals or micas, forming a bonding substance to grains in a clastic sedimentary rock. The matrix material was deposited with the other grains or developed authogenically by diagenesis or slight metamorphism. Also used more generally for finer grained material in any rock in which large components are set.

Detritus – A general term for fragmentary material, such as gravel, sand, clay, worn from rock by disintegration. Detrital grains in clastic sediments or sedimentary rocks may be composed of single mineral grains (e.g. monocrystalline quartz, plagioclase), polycrystalline mineral grains (e.g. polycrystalline quartz) or lithic fragments including sedimentary, igneous and metamorphic rock fragments.

Crystallinity – (a) *holocrystalline*, an igneous rock composed of 100% crystals; (b) *holohyaline*, an igneous rock composed of 100% glass; and (c) *hypocrystalline*, intermediate between the two end-members and can be described more precisely by stating the relative proportions of crystals and glass.

Microcrystalline – crystals can be identified with a petrological microscope. Crystals only just large enough to show polarisation colours (less than 0.01 mm in size) are called microlites.

Cryptocrystalline – crystals are too small to be identified even with the petrological microscope.

Grain size – (a) coarse-grained, crystals > 5.0 mm in size; (b) medium-grained, crystals 1.0 to 5.0 mm in size; (c) fine-grained, crystals < 1.0 mm in size.

Equigranular – all crystals are approximately the same size.

Inequigranular – crystals of substantially different grain size. Common variety, *porphyritic* texture consists of large crystals of a particular mineral or minerals set in a finer grained groundmass. Porphyritic texture can be subdivided into: (a) *microporphyritic*, phenocrysts equal to or less than 2.0 mm in size; and (b) *macroporphyritic*, phenocrysts greater than 2.0 mm in size.

Seriate texture – continuous range in crystal size of principal minerals.

Trachytic texture – sub-parallel alignment of microcrystalline feldspar in the groundmass of a holocrystalline or hypocrystalline rocks. Sub-divided into *pilotaxitic texture* and *hyalopilitic texture* depending on whether the material between the feldspar is crystalline or glassy. Trachytoid texture, alignment of tabular, bladed or prismatic crystals which is visible to the naked eye. The terms flow and fluxion texture are sometimes used as synonyms for trachytic and trachytoid textures. However, they are best avoided due to their genetic implications.

Andesite – An intermediate volcanic rock, usually porphyritic, consisting of plagioclase (frequently zoned from labradorite to oligoclase), pyroxene, hornblende and/or biotite.

Basalt – A volcanic rock consisting essentially of calcic plagioclase and pyroxene. Olivine and minor feldspathoids may also be present.

Basaltic andesite – A volcanic rock with plagioclase compositions expected for andesites but containing ferromagnesian minerals more commonly found in basalts.

Dacite – A volcanic rock composed of quartz and sodic plagioclase with minor amounts of biotite and/or hornblende and/or pyroxene.

Gabbro – A coarse-grained plutonic rock composed essentially of calcic plagioclase, pyroxene and Fe-oxides. If olivine is an essential constituent it is referred to as an olivine-gabbro – if quartz, a quartz-gabbro.

Peridotite – A collective term for ultramafic rocks consisting essentially of olivine with pyroxene and/or amphibole.

Dolerite – A rock of intermediate grain size between a basalt and gabbro (i.e. synonym for microgabbro), and composed of essentially plagioclase, pyroxene and opaque minerals. Often contains an ophitic texture. If olivine is present may be called an olivine-dolerite; if quartz, a quartz-dolerite.

Felsite – A rock term initially used for the microcrystalline groundmass of porphyries. Now commonly used for microcrystalline rocks of granitic composition (i.e. dacite to rhyolite).

Rhyolite – A collective term for silicic volcanic rocks consisting of phenocrysts of quartz and K-feldspar, often with minor plagioclase and biotite, in a microcrystalline or glassy groundmass.

Olivine-basalt – A commonly used term for a basalt containing olivine as an essential constituent.

Granite – A medium- to coarse-grained plutonic rock consisting essentially of quartz, K-feldspar and plagioclase in variable amounts usually with hornblende and/or biotite.

Accessory – A minor constituent of rocks which is present only in small amounts, for example the minerals apatite, zircon, titanite.

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

MENZIES, J. 2000. Micromorphological analyses of microfabrics and microstructures indicative of deformation processes in glacial sediments. *In* Maltman, A. J., Hubbard, B. & Hambrey, J. M. (eds) *Deformation of Glacial Materials*. *Geological Society, London, Special Publication*. **176,** 245-257.

OSTRY, R.C. & DEANE, R.E. 1963. Microfabric analyses of till. *Geological Society of America Bulletin*. **74,** 165-168.

PASSCHIER, C.W. & TROUW, R.A.J. 1996. *Microtectonics*. Springer.

SERET, G. 1993. Microstructures in thin sections of several kinds of till. *Quaternary International*. **18,** 97-101.

VAN DER MEER, J.J.M. 1987. Micromorphology of glacial sediments as a tool in distinguishing genetic varieties of till. In *INQUA Till Symposium, Finland 1985*. KUJANSUU, R. & SAARNISTO, M (editors). Geological Survey of Finland, Special Paper **3,** 77-89.

VAN DER MEER, J.J.M. & LABAN, C. 1990. Micromorphology of some North Sea till samples, a pilot study. *Journal of Quaternary Science*. **5,** 95-101.

VAN DER MEER, J.J.M., RABASSA, J.O. & EVENSON, E.B. 1992. Micromorphological aspects of glaciolacustrine sediments in northern Patagonia, Argentina. *Journal of Quaternary Science*. **7,** 31-44.

VAN DER MEER, J.J.M. 1993. Microscopic evidence of subglacial deformation. *Quaternary Science Reviews*. **12,** 553-587.

VAN DER MEER, J.J. M. & VEGERS, A.L.L.M. 1994. The micromorphological character of the Ballycroneen Formation (Irish Sea Till): a first assessment. *In* WARREN & CROOT (eds.) *Formation and Deformation of Glacial Deposits*. Balkema, Rotterdam. 39-49.

VERNON, R.H. 1989. Porphyroblast-matrix microstructural relationships: recent approaches and problems. *In* DALY et al. (eds). *Evolution of metamorphic belts*. Geological Society of London Special Publication. **43,** 83-102.

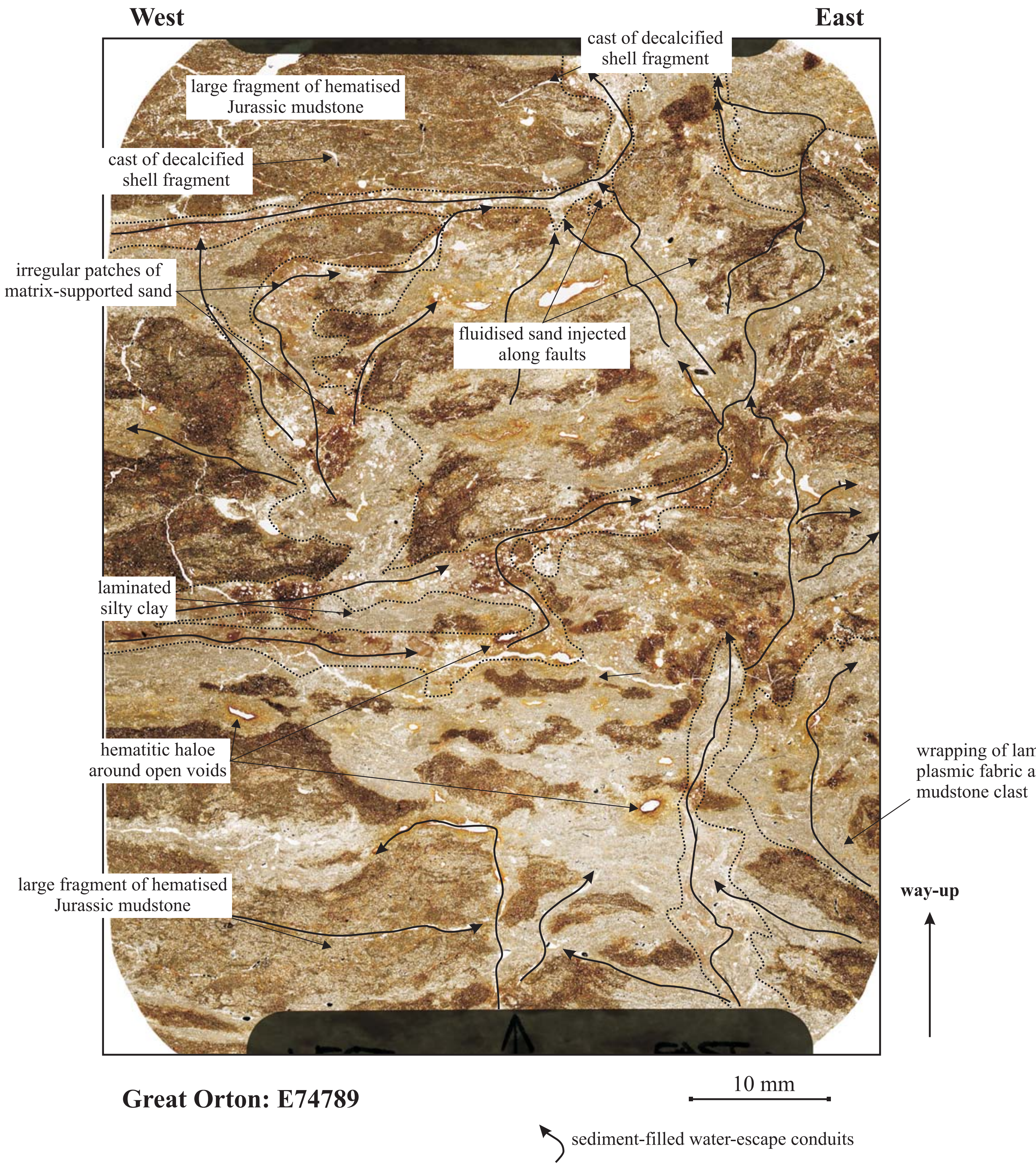

Figure 1. Annotated scanned image of a large format thin section taken from sample E74789.

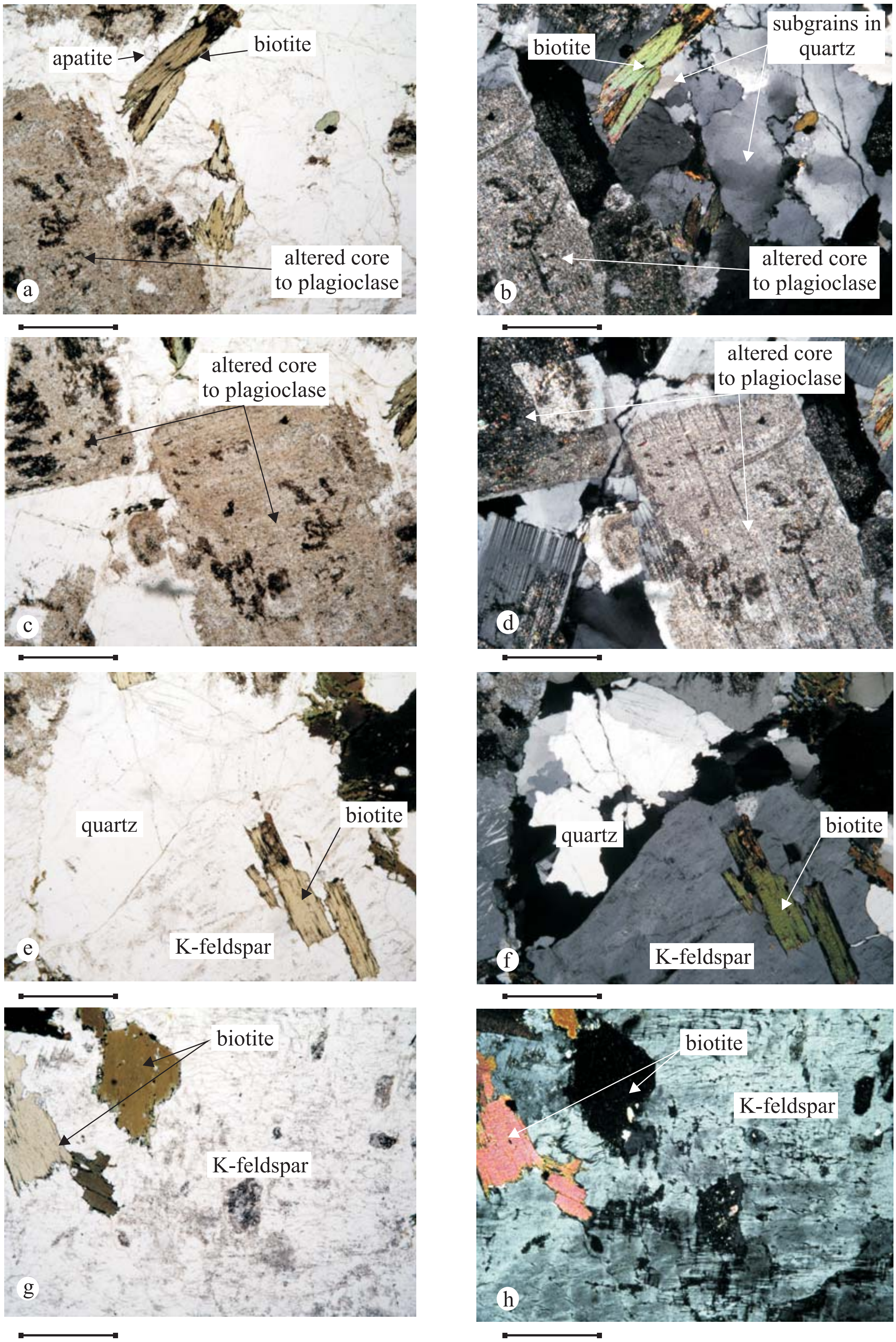

Figure 2. Photomicrographs of the glacial erratic composed of foliated biotite-granite (sample E74778; a, c, e and g - plane polarised light; b, d, f and h - crossed polarised light; scale bar = 1 mm).