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An assessment of the need for a resurvey of the Cheviot Hills

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An assessment of the need for a resurvey of the Cheviot Hills

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1 Introduction

This report is an assessment of the currently available maps of the Cheviot Hills, the extensive upland area that lies partly within the Northumberland National Park, and extending across the Scottish border into the Borders Region. The task was initiated by B Young under the Northern England Responsive Surveys Project, though responsibility for the geology of the Cheviot massif falls within the remits of both this project, and those covering the Southern Uplands terrane evolution and the Quaternary geology of Southern Scotland.

The Cheviot Hills are underlain mostly by Lower Devonian igneous rocks belonging to the Cheviot Volcanic Formation and the Cheviot Pluton. The solid geology is generally poorly exposed and obscured by a variable cover of Quaternary deposits. The igneous rocks crop out over an area of about 730 km², comparable in size to the recently remapped Borrowdale Volcanic Group in the English Lake District.

The aims and objective of this report are:

1. To review the available published and unpublished data on the area;
2. To assess the quality of the existing maps and their fitness for purpose;
3. To consider whether a resurvey of the area is required and to provide an outline of how that might be achieved in a cost-effective and efficient manner.

2 Existing information

2.1 GEOLOGICAL MAPS

2.1.1 One-inch and 1:50 000-scale maps

The Devonian igneous rocks of the Cheviot Hills are depicted on four Scottish and on four English, one-inch and 1:50 000-scale geological maps. Details of these are listed in Table 1 and shown in Figure 1. Sheets such as The Cheviot (E5) straddle the England – Scotland border but only show geology of the English part. Surprisingly, the Geological Survey still has no mainstream 1:50 000-scale maps of this part of the country that show the geology both sides of the border. The Scottish part of the Cheviot Hills were last surveyed in the latter part of the nineteenth century, whereas those parts in England have been surveyed three times, the last during the 1920s.Two of the Scottish Sheets are currently out of print and a third is a Provisional Edition.

2.1.2 Six-inch and 1:10 000-scale maps

Details of the six-inch clean-copy coverage of the area are shown in Table 2. As reported, much of the solid and drift geology of the area covered by the Northumberland New Series was surveyed in some detail, though by contrast, the Roxburgh sheets show little detail in either the solid or drift.

The solid and drift geology of approximately 13 km² of 1:10 000-scale quarter sheet NT 81 NE was mapped in 1981 by P M Allen as part of the Mineral Reconnaissance Programme work in the area (Cameron et al., 1988). The carefully prepared field slips, including detailed drift lines positioned with the aid of aerial photographs, were not clean-copied. To my knowledge there are no other areas of modern mapping within the Cheviot Hills. NT 81 NE is on the Scottish side of

the border where previous mapping is poor in detail, and therefore does not allow assessment of the suitability of the 1920s mapping on Sheet 5, The Cheviot.

2.2 GEOLOGICAL SURVEY PUBLICATIONS

Descriptions of the English parts of the area are contained in memoirs of the Geological Survey (Carruthers et al., 1930; 1932; Miller, 1887; Table 1). There are no Survey memoirs covering the Scottish sheets.

The Cheviot Hills are included within two Regional Guides: The south of Scotland (Greig, 1971) and Northern England (Taylor et al., 1971).

2.3 RESEARCH PUBLICATIONS

A list of publications is included in the bibliography. Interpretation of bulk-rock geochemical and radiogenic isotope data for the Devonian igneous rocks of the Cheviot Hills formed part of a wider investigation of the Scottish Devonian volcanic rocks by Thirlwall (1979 and subsequent papers).

2.4 POPULAR PUBLICATIONS

The most detailed general account of the geology of the Cheviot Hills is by Robson (1976) who also gives details of access to this generally remote area (p 4). The field guide 'Northumbrian Rocks and Landscape' (Scrutton, 1995) contains details of excursions to Upper Coquet Dale and Harthope Burn by P M Allen.

2.5 GEOPHYSICAL AND GEOCHEMICAL DATA

There is full coverage of gravity and aeromagnetic data for the area. These data were interpreted by Lee (1982).

Stream sediment geochemical data are summarised by the Geochemical Atlas for Southern Scotland (British Geological Survey, 1993). Detailed work on the Kingsseat area is contained in Cameron et al. (1988). Cameron et al. (1988) also reported that 86 rock samples from the Kingsseat area were analysed for standard major, minor and trace element compositions. Presumably full listings of these data are accessible in BGS archives. Thirlwall (1979) analysed 40 rocks from the Cheviot Volcanic Group; these data are listed in the thesis.

2.6 THIN-SECTIONS

In the British Geological Survey sliced rock collection there are about 150 thin sections of igneous rocks from the Cheviot Hills. Of these about one-third are from the Cheviot Pluton. The distribution of the sliced rocks is very uneven, with about one half from the area of modern mapping on NT 18 NE.

2.7 AERIAL PHOTOGRAPHS

BGS holds no aerial photographs for this area. Coverage of the area in Scotland is held by the Royal Commission on the Ancient and Historical Monuments of Scotland. These flight lines also extend across the border to cover a substantial part of the remaining upland area. For the English area collections are held by the National Monuments Record (NMR), Swindon (web site www.english-heritage.org.uk)

2.8 ROBSON'S DATA

The late Dr D A Robson (University of Newcastle upon Tyne) carried out a considerable amount of work in the Cheviot Hills and surrounding areas, summaries of which are contained in a number of published works (e.g. Johnson, 1995; Robson, 1976). Field data supporting these publications are contained in his personal effects, now in the care of Mr Peter Robson. Included are six-inch field maps of much of the area: these are annotated with field observations. There are also data from an extensive ground magnetic survey, part of which was published by Robson (1991). These papers have been loaned to BGS by Peter Robson as they offer potentially important information relevant to any resurvey.

3 The need for a resurvey

The Cheviot Hills are the last remaining area of Siluro-Devonian volcanic rocks in Britain for which there are no modern geological maps. Maps of those parts of the Cheviot Hills in Scotland are clearly not of a quality that is appropriate for the twenty-first century, and are in any case mostly out of print. Though the maps of the area on the English side of the border appear to contain much detail, the interpretation of igneous rocks, and in particular of volcanic successions has changed much over recent years, so much so that the present maps are inadequate to provide the basis for a modern interpretation of the geology (see following sections). Part of the area is within the Northumberland National Park and as such offers significant outdoor leisure and educational opportunities. Moreover, an understanding of the geology of the Devonian massif is critical to the development of models of the northern margin of the Northumberland basin during Carboniferous times. Therefore, in my view, there is a strong case for revision survey of the Cheviot Hills.

The objectives for the resurvey would be:

1. To produce modern geological maps of the Cheviot massif that can be fed into both the digital geological map of the region and to contribute towards new printed cross-border maps.

2. To produce a facies-based interpretation for the development of the Cheviot volcanic rocks.

3. To produce modern accounts of the geology suitable for the user community.

3.1 WHAT SHOULD BE IMPROVED?

3.1.1 Nomenclature

At a very basic level, the nomenclature of the igneous rocks present on the published maps does not conform with current BGS practice. For example, terms such as 'mica-felsite', 'mica-porphyrite', 'hypersthene-augite-porphyrite' and 'tholeiite' are outdated terms. The term 'ash' is used incorrectly.

In broad terms, the rock names can be brought up to date without field or laboratory work, though in many instances this must be a best estimate. Some of the petrographical descriptions given in the memoir (Carruthers et al., 1932) are sufficiently detailed and a basic revision has been done for DigMap Version 1. However, in common with many ancient volcanic areas, all the clastic volcanic rocks have been classified previously as pyroclastic. Recent work in many such areas indicates that many of these rocks are probably sedimentary and should be classified using the volcaniclastic sedimentary rock scheme. This problem is linked to the interpretation of these rocks and is discussed further below.

Modern lithostratigraphical and lithodemic nomenclature has also been applied to the Cheviot igneous rocks within the DigMap Project. The contemporaneous volcanic rocks at Eymouth are now given formation status within the Reston Group. The present scheme for the Cheviots should be reviewed during any new work carried out on the area.

3.1.2 Cheviot Volcanic Group

BGS work on volcanic successions in North Wales and the Lake District has shown how a multidisciplinary approach to their mapping can reveal much about the nature of the volcanism and the environment of deposition. The Cheviot Volcanic Group is reported to be a subaerial, sheeted succession dominantly of andesite with some mapped intercalations of volcaniclastic rocks. There are many apparent similarities with both the Eycott and Borrowdale volcanic groups in the Lake District and thus has associated similar problems of interpretation. The andesite sheets of the Cheviot Hills are traditionally interpreted wholly as a lava pile, but are they? Could they be sills, a question that has had a profound influence on the interpretation of the Lake District rocks. A critical examination of the characteristics of the andesite sheets is thus essential to any facies interpretation of the Cheviot volcanic succession.

The volcaniclastic rocks give a great deal of information both on the depositional environment and on the nature of the explosive volcanism. The deposits of subaerial explosive volcanism have poor preservation potential in the stratigraphical record, with contemporaneous erosion processes resulting in the re-sedimentation of these products. Thus, in understanding the Cheviot volcanism the examination of the clastic rocks and modern interpretation of the pyroclastic and sedimentary facies present is critical to determination of the facies model for the volcanism. Robson (1976) indicated that a wide range of lithologies are present, from fine-grained bedded rocks to coarse breccia. Though exposure is generally poor, there are sections through the volcaniclastic rocks in the major streams particularly in the south-west of the massif.

3.1.3 Cheviot Pluton and minor intrusions

This granitic intrusion crops out over an area of some 52 km². Exposure is generally poor though the lithologies can be seen in stream sections and in the tors. The current edition of Sheet 5 shows the granite undivided. On the basis of field and petrographical characteristics Jhingran (1942) divided the granite outcrop into three main lithological subunits. These divisions have been included subsequently in Robson's (1976) map and in general accounts of the Cheviot granite (e.g. Le Bas, 1982). Interpretation of the geophysical data by Lee (1982) require the intrusion to comprise facies with distinct physical properties. The resurvey should test Jhingran's interpretations and make new maps as appropriate.

Contact metamorphism of the andesitic country rocks is known to occur in a zone 1 (Cameron et al., 1988) to more than 2 km wide around the granite. The abundance of metamorphic biotite gives these rocks a distinctive hue. However, on Sheet 5 only a few symbols are used to indicate this widespread aureole which is not otherwise delimited. Magnetometer data has been used by Robson (1991) to delimit the aureole and to identify roof pendants of meta-andesite within the granite outcrop. The new map should attempt to show the extent of the aureole.

The English maps depict abundant minor intrusions, mostly dykes, within the Cheviot massif. Few are shown on the Scottish maps. The recent mapping by P M Allen (section 2.1.2) also identified an intrusion not hitherto depicted on Survey maps. The course of the Acklington dyke (of the Mull dyke swarm) has been proved across the massif with the aid of magnetometer traverse surveys (Robson, 1964); the course differs in detail from that on the survey maps.

3.1.4 Structure

Robson (1976) provided new information on the structure of the andesite outcrop with generalised dips of the strata, mostly obtained from aerial photograph interpretation. The amount

of data suggests that the andesite sheets form significant, perhaps trap-like, landforms. He also identified a number of approximately northerly trending anticlinal and synclinal structures. A brief examination of Robson's map shows that there are abrupt locally changes in strike and/or dip direction. The interpretation of such data is potentially important to our understanding of the development of the volcanic field and of the subsequent deformation history. There is a clear parallel here with how the understanding of the Borrowdale Volcanic Group (BVG) in the Lake District changed as a result of the recent BGS resurvey programme in that area. Previous interpretations of the BVG showed many tectonic folds in these very competent strata. There, it was shown (e.g. Petterson et al., 1992; Branney and Kokelaar, 1994) that the abrupt localised changes in structural dip resulted from block faulting contemporaneous with the volcanism. The new Lake District maps show fewer folds and an extensive pattern of faults.

An investigation of the structure of the Cheviot Block would therefore be a major aim of a resurvey. An understanding of this is very significant as the Cheviot Block had a profound influence on the development of the Northumberland Basin during Carboniferous times.

3.1.5 Quaternary geology

Like others upland areas of northern Britain, The Cheviot Hills were subjected to repeated episodes of glaciation and deglaciation during Quaternary times. The landforms present thus owe much to the processes that operated during this period. Though Quaternary deposits are shown on all the published maps, there is some doubt about the quality of this seen from today's perspective. For example, no mass-movement deposits are shown. Some recent work in the area by Harrison (e.g. 1989; 1993) indicates that these deposits are the most important valley floor deposits and are especially widely developed here compared with contiguous upland areas. Particular features of the upland landscape are the granite tors and the particular abundance of glacial meltwater channels. Beyond the massif are glacial lake deposits and large spreads of sand and gravel, the latter forming a large resource. Our understanding of the Quaternary geology of the Cheviot area would be greatly enhanced by targeted mapping and expert analysis of the landforms and deposits.

3.2 METHODOLOGY

In order to achieve the objectives to produce a fully integrated set of maps, description and interpretation, the resurvey would require a multidisciplinary approach. The area for resurvey is substantial: there are 38 10 000-scale quarter sheets, 25 of which comprise more than 75% igneous rocks. In view of the size of the area, it is essential that full aerial photograph cover is obtained at an appropriate scale.

The survey team should develop its own methodology for achieving the objectives, but the following might form a brief outline:

1. Collect and collate all currently available data and materials using suitable GIS and databases;

2. interpretation of satellite images to identify major regional lineaments in particular;

3. re-examination and, if required, re-interpretation of the geophysical and geochemical data, and thin-sections prior to fieldwork;

4. interpretation of solid and drift deposits from the aerial photographs;

5. use the field slips, clean copy maps and Robson's data for the Northumberland area to provide the basis for the resurvey and to identify targets for detailed study;

6. ongoing targeted fieldwork programme to address the mapping, stratigraphical and process-orientated problems posed by these rocks;

7. the large tracts of upland area in the Scottish part would require rapid field survey, particularly of the better exposed areas;

8. integrate old and new data to produce deliverables.

3.2.1 Resourcing

The resurvey objectives outlined above could be achieved within a four- to five-year period, given the following staffing:

Two mapping geologists with allocations of 70-90 days per year each; they should have experience in mapping ancient volcanic terrains.

Expert advice and targeted work for the project duration from experienced Quaternary geologist(s). The project team should consider University collaboration as an option here (possibly Mike Hamblyn/Phil Gibbard, Cambridge for Quaternary studies in the Bowmont valley, for example).

Expert contributions on remote sensing, geophysics and geochemistry.

A substantial OR budget would be required to purchase complete coverage of satellite and aerial photographs of the area.

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Table 1 Geological Survey 1:50 000 and one-inch-scale geological maps of the Cheviot Hills

Sheet no.	Sheet name	Date of last survey	Map types available*	Approx. area (km²) of Devonian igneous rocks	Comments	Memoir
E3	Ford	1921-5	S; S&D	110	Some detail shown of granite/ volcanic relationships; little detail in Cheviot Volc Gp which is probably poorly exposed. Drift generalised in upland area	Clough, 1888; Carruthers et al., 1932 (combined sheet explanations)
E5	The Cheviot	Publ. 1932	S&D	285	Considerable detail shown in the solid reflecting localised detail on the component 6-inch maps. Drift includes peat, glacial deposits and alluvial deposits	
E6	Alnwick	1921-5	S&D; SwD	45	Solid much obscured by drift; some detail locally reflecting detail on six-inch maps. Drift includes peat, glacial deposits and alluvial deposits	Carruthers et al., 1930
E8	Elsdon	Publ 1951	S&D; SwD	5	Only very small area of Devonian igneous rocks along northern margin	Miller, 1887
S17E	Jedburgh	Publ. 1937; (1982 rep)	D; S	60	Solid very generalised. Drift includes peat, glacial deposits and alluvial deposits	No memoir
S18	Morebattle	Publ. 1883	S (out of print)	182	Solid very generalised; drift shown is mainly alluvium	No memoir
S25	Kelso	Publ. 1879	S (out of print)	2	Solid very generalised; drift alluvium only	No memoir
S26	Berwick upon Tweed	Provisonal Edn 1969	S&D (Prov)	45	Solid and alluvium taken from 1886 edition; with lines added for boulder clay and gravels in SW part only	No memoir

* definitions of S, S&D etc are as given in the BGS Catalogue of Geological Maps and books for 2001 (p17).

Table 2 Six-inch-scale geological maps of the Cheviot Hills in the BGS archive.

Map series	Map no.	Date	Solid geology	Drift geology
Roxburgh	10	Dates not given on clean copies	No detail shown	As for Sheet 15 etc
	11		Map not in cabinet	
	15		No detail shown	Look very generalised; alluvial deposits from original survey. Also boulder clay and gravel spreads appear to have been added later at unknown date. Hand written note dated 1971: "brought up to Provisional Standard" (S Monro added keys to maps)
	16			
	17			
	21			
	22			
	23		Little detail apart from a few minor intrusions	
	27W part			
	28			
	29NW part			
	34N part			
	35			
Northumberland NEW	9SW	1927	Mostly drift covered; solid poorly exposed?	
	10	1926-8	Mostly drift covered; solid poorly exposed?	
	14	1928	Some detail shown in volcanic rocks	Full drift mapping: peat, glacial deposits, river deposits
	15	1928		
	16SW part	1929		
	19E part	1928		
	20	1928	Considerable detail in volcanic and minor intrusive rocks	
	21W part	1929		
	25S part	1929		
	26	1929		
	27W	1929		
	31	1929		
	32	1929		
	33W part	1929		
	38N	1938	Small outlier of Cheviot Volc Fm	
	39N	1929	Mostly drift covered; solid poorly exposed?	
	40N	1929	Mostly drift covered; solid poorly exposed?	
Northumberland OLD	20W part	1923-4	Some detail shown in volcanic rocks	Full drift mapping: peat, glacial deposits, river deposits
	25W part	1926	Mostly drift covered	
	30	1907	Only the 1907 version is available in the cabinet, on which there is much less detail than the later surveys of the rest of the area. Check field slips.	

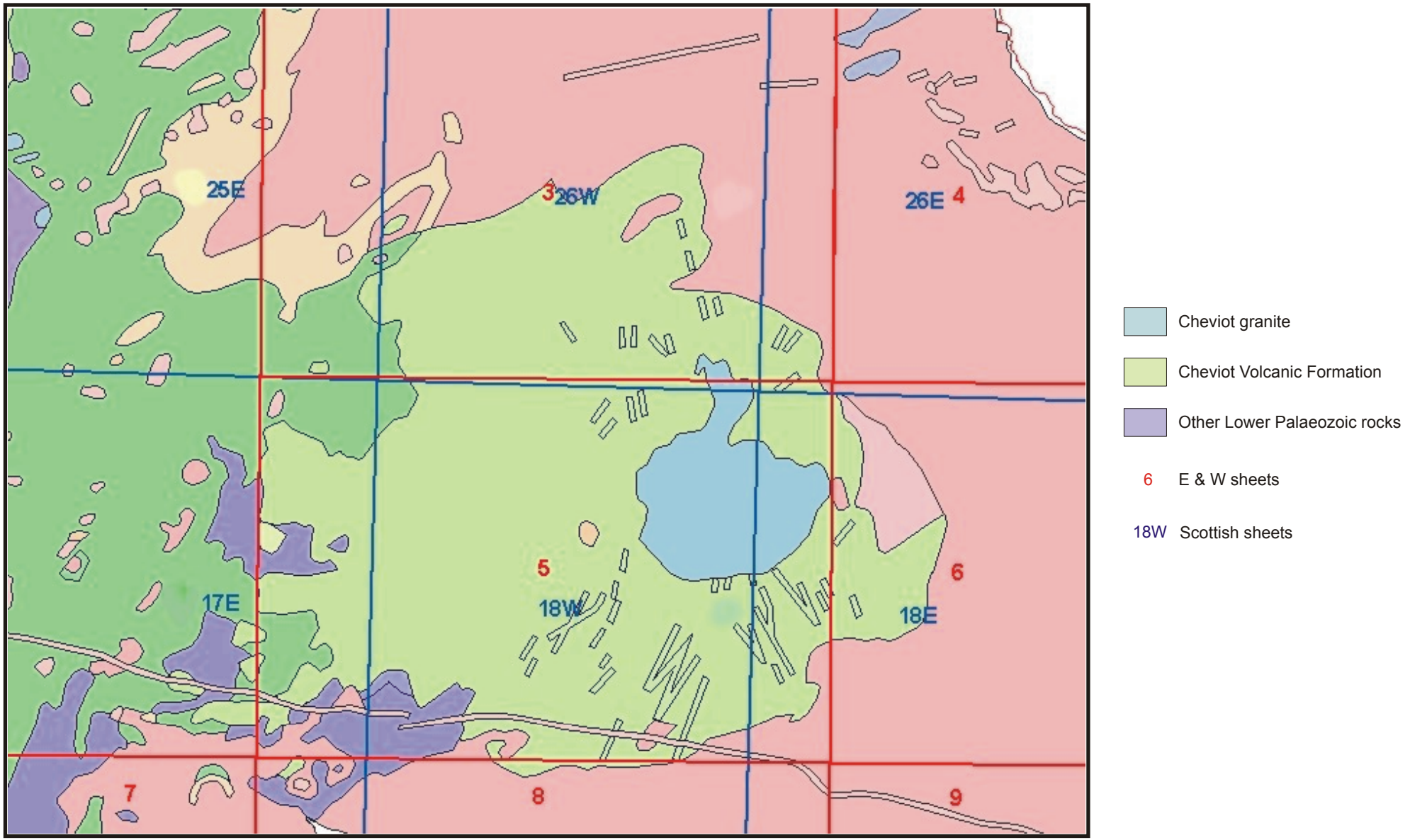

Figure 1. Map of the Cheviot massif showing the BGS 1:50 000 scale geological maps