

BOWNESS KNOTT

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OS Grid Reference: NY112156

Introduction

Bowness Knott is bisected by the nearly NE-trending contact between the Ennerdale intrusion to the east and the Skiddaw Group rocks to the west (Figure 4.33). The GCR site provides excellent sections through this contact and allows an examination of the relationship of the intrusion to the regional deformational events.

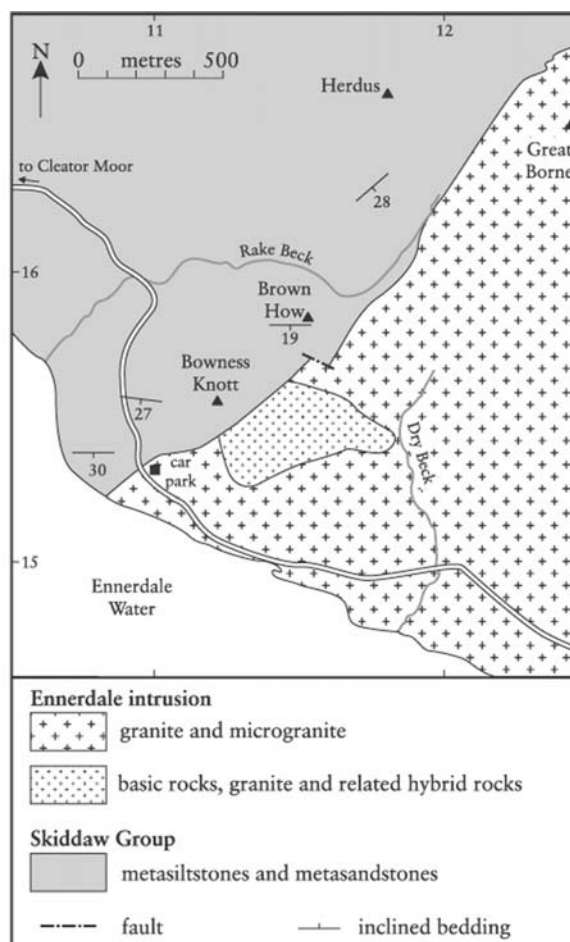


Figure 4.33: Map of the Bowness Knott GCR site.

The Ennerdale intrusion (previously referred to as the Ennerdale 'Granophyre') is one of the major igneous bodies of the Lake District and as such it is a surface expression of the Lake District batholith (Bott, 1974). The intrusion crops out between Buttermere in the north and Wasdale in the south, a distance of *c.* 14 km with an average width of *c.* 4 km. It consists predominantly of a relatively uniform pink or grey medium- to fine-grained granite. There are also a number of localized zones of more basic and related hybrid rocks, notably at Burtness Combe above Buttermere, Bowness Knott, the Bleng Valley and at Mecklin Wood in Wasdale.

The body was first mapped by the early surveyors of the Geological Survey (Ward, 1876). The first comprehensive account was given by Subsequent detailed accounts were given for those parts of the mass within the Gosforth (37) and Whitehaven (28) geological sheets by Trotter *et al.* (1937) and Eastwood *et al.* (1931) respectively. More recently, the mass and its regional setting were described by Clark (1963) who included petrochemical and petrogenetic discussion.

There has been a number of studies on the radiometric age of the intrusion (Brown *et al.*, 1964; Rundle, 1979; Hughes *et al.*, 1996) and on the geophysical characteristics (Bott, 1974; Lee, 1986; Evans *et al.*, 1994). Many of these studies have focused on the regional setting of the mass, and its age relative to the other igneous complexes and the regional tectonism of the Lake District.

Description

Bowness Knott (333 m) lies on the north side of Ennerdale Water guarding the entrance to the main valley (Figure 4.34). It has steep crag and scree-covered slopes to the west and south, falling off more gently to the east, where available exposure is masked by recent afforestation. To the north the ground flattens off with the minor top of Brown How before rising steeply to Herdus and Great Borne. Rake Beck, which rises between these last two hills, flows steeply down to Brown How where it turns through a right angle and continues down the north side of Bowness Knott.

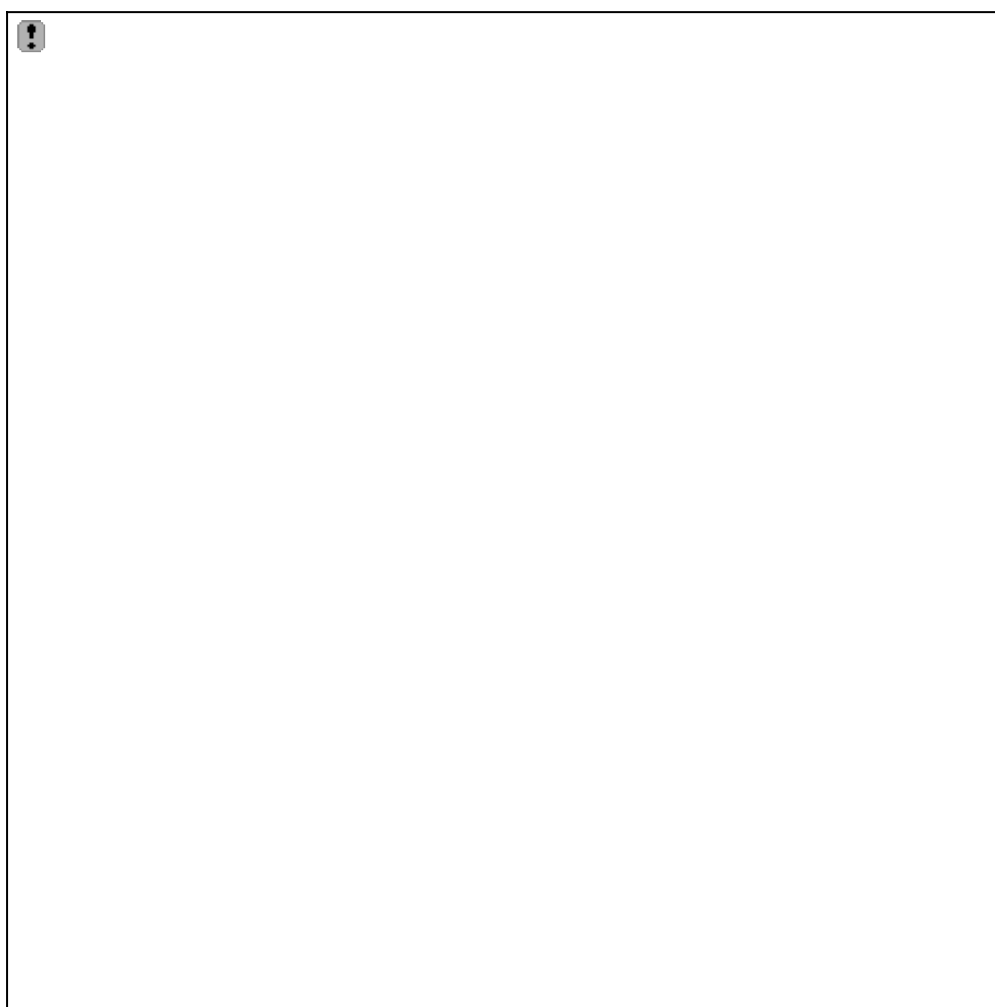


Figure 4.34: Bowness Knott from the west with the low summit of Brown How to the left.
(Photo: D. J. Fettes.)

The contact between the Ennerdale intrusion and the country rocks is steep or near vertical in this area. It runs up a gully near the eastern end of the crags on the south side of Bowness Knott, across the shoulder east of the top, east of Brown How and up the east side of Rake Beck. Over most of its length the contact can be localized to a few metres, though it is only exposed on the south slope of Great Borne. Its trend is parallel to one of the principal joint directions in the intrusion and the country rock.

The country rocks belong to the Buttermere Formation of the Skiddaw Group and are believed

to be of late Arenig or early Llanvirn age (Cooper *et al.*, 1995). They are predominantly composed of finely laminated siltstone with subordinate sandstone and mudstone. The bedding strikes around E–W, with low dips to the south; to the north of the GCR site the strike swings nearer to NE–SW. The slump folds and soft-sediment deformational structures characteristic of this formation elsewhere are not significantly developed in this area though small slump folds are cut by a granite vein at one locality (1116 1539). Tectonic structures are also sparse and the regional cleavage is generally absent or only weakly developed; where present it strikes broadly parallel to bedding but with steeper dips. Within the GCR site the rocks are all thermally metamorphosed by the intrusion, developing a hard splintery texture. The hornfels has a greenish-grey colour but as the main contact is approached alteration on joints marked by pale-pink or red staining may pervade the whole rock giving it a pale bleached look. Hughes and Fettes (1994) recorded the presence of biotite and incipient spots of cordierite and/or andalusite close to the contact. Quartz veins are widely developed within these rocks, both as thin laminae parallel to the bedding and as larger cross-cutting structures. These veins are themselves cut by the granitic veins.

Marginal granitic veining within the Skiddaw Group is generally sparse though where present it may be relatively abundant, for example on the crags above the Bowness Knott car park (109 155). Most of the veins persist for only a few tens of metres away from the main contact. The veins are irregular and branching and range from a few centimetres to two or three metres in width. They may be markedly cross-cutting in respect of the sedimentary bedding and have sharp margins and no sign of chilling. Locally, (for example at 1118 1540), the marginal veins may become so numerous near the main contact that they isolate large blocks of the country rock. However, such effects are uncommon, as are true xenoliths.

The main mass of the Ennerdale intrusion is composed of a relatively uniform pinkish medium- to fine-grained granite, commonly with chloritic clots and white feldspar phenocrysts. Locally, particularly towards the margins, the granite may become more felsitic. Patches of light-coloured microgranite occur within the mass and locally these have transitional contacts with the main granite, though elsewhere they appear to be later; they probably relate to a series of late-stage minor acid intrusions within the mass including microgranites, fine-grained granophyric microgranites and aplitic microgranites (Eastwood *et al.*, 1931; Clark, 1963). The mass is well jointed with two or three near-vertical sets and one sub-horizontal set. The rock consists of quartz, plagioclase, potash feldspar, biotite and chlorite; accessories include epidote, iron oxides, titanite, apatite and zircon. Rastall (1906) showed that granophyric textures are generally absent from the margins of the body and increase towards the centre where, the '... intergrowth becomes continuously finer in texture, and of an increasingly perfect micropegmatitic structure'. Chemical analyses of the granite (Clark, 1963; O'Brien *et al.* 1985; Millward *et al.*, in press) show the body to be chemically coherent but with anomalously high soda and correspondingly low potash values, suggesting some form of metasomatic exchange. The chemical characteristics are consistent with an I-type granite generated within a volcanic-arc environment.

Basic rocks occur in a zone near the margin of the main mass on the eastern shoulder of Bowness Knott. The zone covers an area of *c.* 500 × 200 m, though the transitional nature of its margins make exact definitions difficult. Within the zone there is a complex inter-relationship of rock types. Three main varieties may be recognized. The first and most basic variety is a dark compact doleritic rock that contains some interstitial potash feldspar (Clark, 1963); the second is a dark-grey dioritic rock which, in part, grades into the third variety comprising the common granite of the mass. On crags at 114 155 veins of granite cut the more basic varieties and blebs of granitic material lie within more basic varieties. The more basic varieties are most numerous near the main contact and to the east the amount of ferromagnesian minerals in the intermediate types falls eventually to give way to the uniform granite of the mass. Clark (1963) described dioritic rocks cut by a vein of granite that is itself cut by a vein of finer-grained granite. Rastall (1906) described a peculiar form of intermediate rock, which he termed 'needle rock', characterized by long acicular crystals of uralitized augite.

Minor intrusions are found throughout the GCR site. Clark (1963) described a series of microdiorite dykes on and around Bowness Knott. They vary from 0.2–4 m in width and have SE and SW trends. They are composed of plagioclase and secondary actinolitic amphibole, possibly after pyroxene. Acid dykes also occur, many having a splintery felsitic appearance

(Eastwood *et al.*, 1931). A notable example is provided by a 3 m-thick spherulitic felsite which trends ENE and crosses Rake Beck (1136 1603). The spherulites, which are up to 15 mm across, are regular and arranged in bands parallel to the margins. Other examples of major acid veins may be examined at 110 156 where a 2 m vein cuts obliquely across the bedding lamination and at 1143 1602 where a 2 m vein trending at 135° runs along a major joint and is itself finely jointed at its margins.

Interpretation

Rastall (1906) regarded the Ennerdale intrusion as a laccolith or series of laccoliths that pre-dated the regional cleavage-forming event, a view supported by Green (1917). Eastwood *et al.* (1931) and subsequently Clark (1963) argued against these views. They noted the near vertical attitude of the contact of the granite mass across Ennerdale and the fact that it flattens out to the NE across Starling Dodd and suggested that this indicates a stock-like geometry. They further argued that the mass was affected by regional-scale thrusting and therefore must pre-date that event. They noted that the granophyre cuts folds in the metasedimentary rocks and tentatively suggested that the veins must post-date the cleavage, assuming that the latter is genetically related to the folds. However, if the folds are accepted as slump structures the basis of the argument fails. The early radiometric dates on the granite seemed to support the late Caledonian age; Brown *et al.* (1964) derived a whole-rock K-Ar age of 370 ± 20 Ma for the main granite, and Rundle (1979) a whole-rock Rb-Sr age of 420 ± 4 Ma. However, Hughes and Fettes (1994) concluded from thin-section studies and variations in the nature of the cleavage across the aureole that the cleavage has been imposed on the hornfels and that in consequence the intrusion pre-dates the regional deformation. This view was supported by Hughes *et al.* (1996) who presented a U-Pb zircon age of 452 ± 4 Ma, indicating a late Caradoc age of intrusion.

Lee (1989) interpreted the Ennerdale mass as a shallow laccolith c. 1–2 km thick overlying a denser granitic mass. Evans *et al.* (1994) refined this model and suggested that the mass consists of a 1100 m-thick laccolith underlain by further laccolith-style members of the Lake District batholith.

Much discussion has taken place on the basic and acid complexes (Rastall, 1906; Eastwood *et al.*, 1931; Clark, 1963). It is generally accepted, on the basis of the complex age relationships, the transitional rock types and the confinement of the basic rocks to the margins of the mass, that there has been some form of hybridization between an early basic magmatic phase and the later granitic magma, probably by some form of metasomatic exchange. Both Clark (1963) and Millward *et al.* (in press) argued that the early basic phase was dioritic and that the doleritic rocks represent some form of cumulate or early differentiate.

The Ennerdale intrusion is most probably a subvolcanic intrusion emplaced in a supra-subduction zone setting as a series of two or three magmatic pulses. Locally, the host rocks were metamorphosed and hardened, and this carapace largely resisted the subsequent regional cleavage-forming events.

Conclusions

The Bowness Knott GCR site provides excellent sections through the contact of the Ennerdale intrusion and the host Skiddaw Group rocks and allows a study of the nature of the intrusion and, in particular, its age relative to the regional events.

The Ennerdale intrusion, one of the surface expressions of the Lake District batholith, is a relatively uniform, pink granite, characterized for the greater part by granophyric intergrowths and feldspar phenocrysts. Diorite phases occur within the main mass and as minor intrusions around Bowness Knott; they have locally hybridized with the slightly later granite. The hybrid rocks contain a range of rock types including the famous 'needle rock' well seen on the eastern shoulder of Bowness Knott.

The regional cleavage is only incipiently developed in the aureole of the intrusion and overprints the aureole minerals indicating that its development post-dates the intrusion. Radiometric dating suggests a late Caradoc age for the intrusion linking it with the formation of

the Borrowdale Volcanic Group. Chemical characteristics of the mass are consistent with a subvolcanic setting for its intrusion.

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