Hill of Johnston

[NJ 575 250]

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Introduction

One of the most distinctive features of the 'Younger Basics' is the development of a pronounced fractionation trend towards iron-rich, felsic residual material, which appears to be represented by the final stages of the Insch cumulate succession from Lower Zone (12), Middle Zone (MZ) and eventually through to Upper Zone (UZ) stages. Read *et al.* (1961) were the first to describe these late-stage differentiates, which they recognized as forming a series of small hills (referred to as the 'Red Rock Hills', because of the reddish 'syenitic' rocks found at their summits), trending from SW to NE, to the west of Insch town (Figure 3.11). Clarke and Wadsworth (1970) formally grouped all the olivine-bearing rocks (and closely related felsic material) lying to the west and NW of the predominantly olivine-free MZ gabbros (hypers-thene-gabbros of Read *et al.,* 1965) as comprising the Insch UZ, which they subdivided into three sub-zones (UZa, b and c) according to their detailed mineralogy. This classification was further refined by Wadsworth (1986). The UZa rocks are widespread throughout this part of the Insch intrusion, and are ferrogabbros (Fe-rich olivine-plagioclase-pyroxene cumulates). The ferrogabbros are overlain locally (in the 'Red Rock Hills') by UZb, which consists of ferromonzodiorites (monzonites locally) (similar to UZa, but with cumulus alkali feldspar), and then by UZc, which is always heavily altered but is approximately quartz-syenitic in composition.

This type of sequence is represented to varying degrees on all the 'Red Rock Hills', but exposures are generally very poor (Figure 3.12). The most complete sequence (both in terms of exposure and variety of rock types) is found at Hill of Johnston, the most south-westerly of the 'Red Rock Hills', where UZb has been quarried for roadstone and where UZc is at least seen *in situ,* although by no means well exposed.

Description

Although UZa rocks are not exposed in the immediate vicinity of Hill of Johnston, excellent examples of very fresh material from this sub-zone occur elsewhere in the north-western part of the Insch intrusion, e.g. at Brankston [NJ 589 308], and clearly represent the immediate precursors to the more extreme differentiates at this locality. They are essentially gabbroic cumulates, comprising Fe-rich olivine, two pyroxenes (Fe-rich orthopyroxene and ferroaugite) and plagioclase (approximately An_{50}).

The 'stratigraphically' lowest rocks of the sequence at Hill of Johnston are exposed in the roadside quarry at the SW foot of the hill, and in another small quarry at Mill of Johnston, 200 m to the SE.

The rocks from the lower part of the main quarry (no longer worked) are cumulates, although there is no small-scale layering visible at this locality. They are mineralogically complex, consisting mainly of cumulus plagioclase (An_{45}), alkali feldspar, olivine (Fo_9) and ferroaugite ($Ca_{42}Mg_{21}Fe_{37}$), with relatively abundant apatite and zircon, both of which may be cumulus phases, and intercumulus hornblende and biotite. Orthopyroxene (En_{24}) occurs in some rocks and interstitial quartz is generally present. The cumulus alkali feldspar, which is microperthitic orthoclase, is notable for its high Ba content ($Ab_{19}Or_{71}Cn_{10}$). These rocks were termed syenogabbros by Read *et al.* (1961) but are probably more accurately described as olivine ferromonzodiorites (or ferromonzonites) and have been interpreted as representing UZb (Wadsworth, 1986). They are well jointed, and tend to weather spheroidally.

At higher levels in the quarry the rocks are slightly less mafic, and also contain more alkali feldspar ($Ab_{19}Or_{76}Cn_5$) relative to plagioclase (An_{37}). The ferromagnesian minerals tend to be more altered, with olivine (Fo_6) almost completely serpentinized, and ferroaugite ($Ca_{42}Mg_{14}Fe_{44}$) occurring as relict cores in amphibole. Zircon and apatite are still abundant, and are accompanied by interstitial biotite and quartz. These relatively felsic rocks also occur as near-vertical

veins, up to 5 cm across, cutting the more mafic UZ material.

Above the quarry, there are numerous small natural outcrops on the SW slopes of Hill of Johnston. The rocks are distinctly reddish in colour, hence the term 'Red Rock Hills', and they are generally rather altered. Some examples are fresh enough to indicate that they are very rich in alkali feldspar, and approach syenitic compositions as described by Read *et* al. (1961). There is no clear textural evidence that they are cumulates, but they have been referred to UZc by Wadsworth (1986). The alkali feldspar is not Ba-rich (approximately $Ab_{18}Or_{81}Cn_1$) at this level in the intrusion, and it is always heavily sericitized. The mafic minerals, mainly amphibole and biotite have been largely replaced by chlorite. Apatite, zircon and interstitial quartz are also present. Some of these rocks appear to have been silicified.

Despite the absence of overt layering in these UZ rocks, the general occurrence of the more differentiated UZc material towards the summit of Hill of Johnston suggests that the cumulate succession is approximately horizontal in this area of the Insch intrusion. Elsewhere in the 'Red Rock Hills' sub-horizontal layering occurs at Hill of Dunideer and Hill of Christ's Kirk, but dips of 50° to the NNW have been recorded at Hill of Newleslie (Gould, 1997).

Interpretation

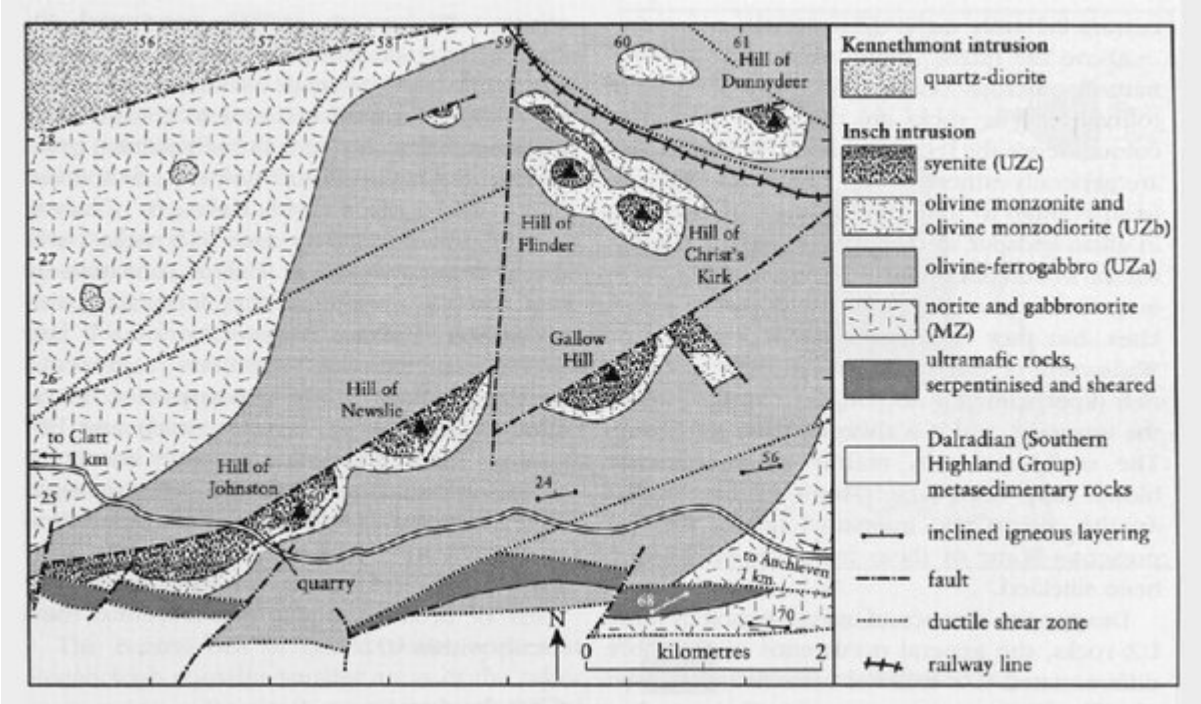
The Hill of Johnston outcrops provide the clearest evidence available that the parental magma of the 'Younger Basics' was capable of evolving towards extremely felsic and iron-rich compositions, as represented by the rocks of UZb and UZc. Read *et al.* (1961) demonstrated the essential coherence of the Insch olivine-gabbros and associated 'syenogabbros' and 'syenites' of the 'Red Rock Hills' on the basis of geological, petrological and chemical characteristics. They also hinted at a broader association between these rocks (now referred to the Insch UZ) and the peridotites and troctolites at the eastern end of the Insch intrusion (now referred to the LZ).

Clarke and Wadsworth (1970) developed this theme, and extended it to include the hypers-thene-gabbros, as representing the intermediate stage (MZ) of the complete fractionation sequence. They identified the bulk of the rocks in the intrusion as cumulates, on textural grounds, and confirmed the general progression of mineral compositions expected in such a situ ation. Wadsworth (1986) continued this approach for the Insch UZ, and was able to construct a detailed cumulate succession, emphasizing the trend towards extreme iron enrichment, and comparing this with broadly similar trends in the Bushveld (South Africa), Skaergaard (Greenland) and Fongen–Hyllingen (Norway) layered intrusions. The Insch UZb rocks, particularly well displayed at Hill of Johnston, are probably the uppermost true cumulates in the succession, and are noteworthy for the large number of cumulus minerals represented (olivine, orthopyroxene, clinopyroxene, plagioclase, alkali feldspar, apatite, zircon and Fe-Ti oxide). The UZc rocks are generally interpreted as having crystallized from the residual magma after significant crystal settling had ceased (Read *et al.,* 1961; Clarke and Wadsworth, 1970; Wadsworth, 1986). This is also indicated by the veins of broadly similar quartz-syenite found locally within UZb.

Conclusions

The Hill of Johnston GCR site is particularly important in providing information about the later stages (UZ) of crystallization in the 'Younger Basics' in general, and the Insch intrusion in particular. In this way, it is complementary to the 12 (Hill of Barra and Bin Quarry) and MZ (Pitscurry and Legatesden) GCR sites. The most significant geochemical aspects of the Hill of Johnston rocks are their pronounced iron, barium and zirconium enrichment, as indicated by the olivine and pyroxenes (UZb and c), alkali feldspar (UZb) and cumulus zircon (UZb), respectively. Similar features are known to result from extreme fractionation of tholeiitic basic magma in other layered intrusions worldwide, e.g. Bushveld, Skaergaard and Fongen–Hyllingen, but the Hill of Johnston is the only example in Britain.

References



(Figure 3.11) Map showing the location of the principal 'Red Rock Hills' (UZb and UZc of the Insch intrusion), west of Insch, from BGS 1:50 000 Sheet 76W (1993).

(Figure 3.12) The 'Red Rock Hills': Hill of Christ's Kirk (left distance) and Hill of Dunnideer (centre distance, with ruined castle) from near Auchleven. The hills are composed of syenite and olivine monzonite and the foreground is underlain by olivine-ferrogabbros, all of the Upper Zone, Insch intrusion. (Photo: BGS no. D4542.)