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Open University Geological Society
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Bennachie geology

An excursion guide

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GEOLOGY OF THE BENNACHIE AREA

An excursion guide

Introduction

Welcome to the land of the Doric and the buttery, or to lapse into the vernacular "fit like?" Bennachie is situated 30 km north-west of Aberdeen in the heart of Gordon country (Figure 1). Rising to a height of 528 m above the surrounding lowlands of Aberdeenshire it is one of the most prominent landmarks in north-east Scotland. The hill is steeped in local folklore stretching back to Pictish times when a fort was established on the Mither Tap. It is also immortalised in the song 'Gin I whaur the Gadie rins at the back of Bennachie' although, as will become evident during the weekend the Gadie is a very insignificant stream.

The three day excursion will encompass a wide range of rock types (Figure 2), from Dalradian schists to Devonian sedimentary rocks long famed for their fossil plants and now also renowned as a source of epithermal gold. However, the emphasis will be on the Ordovician and Silurian intrusive rocks contained in the Insch Basic Intrusion and the granites of Bennachie, Kemnay and Crathes. The following brief description of the geology is based largely on Gould (1997) and Leslie (1987a ands 1987b)

Geological overview

Geology and topography

The gently rolling land surface that characterises this part of north-east Scotland is largely the result of two processes which occurred late in its geological history - Tertiary tropical deep weathering and a relatively static ice-cap during the subsequent Pleistocene glaciation. That said, in the Bennachie area, there is ample evidence that bedrock still exerts a strong control on the topography. In particular, with the exception of the syenitic and monzonitic components, which give rise to a series of small rounded topographic highs, known as the 'Red Hills', the Insch Intrusion largely occupies low ground. In contrast, thermally altered Dalradian rocks on the northern edge of the Insch Intrusion and the Bennachie Granite to the south characteristically underlie high ground.

Dalradian metasedimentary rocks

These are late Precambrian marine sedimentary rocks that were folded and metamorphosed during the early Palaeozoic Caledonian orogeny. They consist mainly of psammites, semipelites and pelites belonging to the Southern Highland Group, except in the south-east where the succession forms part of the Aberdeen Group. Interest in the Dalradian will be confined to an examination of the superimposed thermal metamorphism in psammites and pelites of the Macduff Formation within the aureole of the Insch Intrusion.

Insch Intrusion

The Insch Intrusion (Figure 3) is roughly rectangular in surface form, extending 30 km in an east-west direction and 7 km from north to south. Its is the largest of late-tectonic basic masses in the north-east Grampian Highlands which were intruded into hot continental crust close to the peak of metamorphism during early Ordovician times(c 470 ma). Moreover, it contains the widest range of compositions of all these intrusions, extending from dunite to syenite. It contains many of the characteristic features of large basic bodies including cumulate textures, rhythmic-, phase- and cryptic layering and igneous lamination.

The intrusion is divisible into Lower, Middle and Upper zones, the higher rocks in general , but not universally, being encountered as the intrusion is traversed in a west-north-westerly direction. Lower Zone rocks are confined to the margins of the intrusion the largest mass being in the south-east close to Oldmeldrum. The Lower Zone is the only one containing ultrabasic rocks; it comprises variably serpentinised dunite, peridotite, troctolite and olivine norite.

The base of the Middle Zone is defined by the disappearance of olivine as a cumulus phase. Rocks of this zone occupy most of the southern part of the Insch Intrusion, but are of different character on either side of the belt of Upper Zone rocks. To the east, as will seen in Pitscurrie Quarry the rocks are norites of three intimately associated types: two pyroxene-plagioclase-ilmenite-magnetite cumulates; fine grained granular gabbros; and porphyritc granular gabbros.

The boundary between the Middle and Upper zones, which is apparently concordant, is marked by the incoming of iron-rich olivine. Rocks of the Upper Zone can be divided into three: the base of UZa is characterised by the reappearance of (much more iron-rich) olivine, the dominant lithology being olivine-ferrogabbro: the base of Uzb is defined by the incoming of cumulus K-feldspar, the subzone comprising olivine- monzonite and olivine-monzodiorite: the base of Uzc is marked by the final disappearance of olivine and orthopyroxene the sub-zone consisting entirely of syenite.

The relationship between the intrusion and the Dalradian country rocks is often difficult to interpret, not least because of the general low level of exposure, but there is evidence much of the contact is tectonic in nature. There is extensive shearing along the southern margin (Figure 3), and it has been demonstrated that the ultramafic rocks which constitute the Lower Zone occur in a narrow belt, up to 1.5 km wide, bounded to the north and south by east- to ENE-trending shear zones.

The northern contact is affected by a c1 km wide zone of shear deformation thought to be of the same age as that affecting the southern margin. Despite this, there is a broad ($\leq$ 2 km) aureole of thermally metamorphosed Dalradian rocks along much of the northern margin of the intrusion. A good section through the aureole is provided by a series of small quarries between Hill of Tillymorgan and Cairnhill (Figure 4). Most of these are in slate, which was worked for local roofing material until the end of the 19th century, but Cairhill was worked (probably for roadmetal) as recently as the 1980s. The Dalradian rocks are blue, grey or green, well-cleaved, highly fissile pelitic schists of the Macduff Formation (Southern Highland Group). They are typically finely laminated with thin beds of fine grained psammitic material, interpreted as turbidity

current deposits. The textures and mineralogical zonation of pelitic lithologies, which can be recognised on traversing the aureole, are shown in Table 1.

Granites of Crathes, Kemnay and Bennachie

Granite has traditionally had an important role in the economic and social history of north-east Scotland to the extent that Aberdeen is often referred to as the Granite- or Silver City. The industry in Aberdeenshire dates back to the 18th century, although granite was used long before this in the medieval castles of the area. Prior to the Union of Parliaments in 1707, most houses were constructed of wood or freestone, although there were probably a few granite buildings in Aberdeen. The widespread use of granite in house building did not happen until after a disastrous fire had laid waste to much of the city in 1741. The need for granite was further fuelled in subsequent years by the industrial revolution and the requirement for better public health. To meet the demand quarries were opened in and around the city, and into the hinterland as far away as Braemar. Probably the best known and most productive of these was Rubislaw, opened in 1741 and 485 feet deep when it closed in 1970. Kemnay Quarry was worked almost continuously from 1858 until 1999, and is best known as the provider of stone for Marischal College in Aberdeen, reputedly the world's second largest granite edifice. At present there are 3 working granite quarries in Aberdeen including Craigenlow and Tom's Forest, which will be visited on the field trip. Current production consists almost entirely of crushed rock aggregate, suitable for roadmaking and concreting, although in the late 1980s Kemnay produced over1500 tonnes of blockstone for the new Bon Accord shopping centre in Aberdeen.

The Aberdeenshire granite industry is based on a number of plutons which were emplaced in the latter stages of the Caledonian Orogeny and include examples of both late- and post tectonic bodies. The late tectonic episode of emplacement, which includes the Aberdeen, Kemnay and Correnie granites and the Tillyfourie Tonalite, occurred during the Ordovician, and marked the first period of uplift of the Caledonian Orogeny. They are generally well foliated and, except where faulted the margins are marked by extensive vein complexes. The Kemnay pluton, which will be viewed in Tom's Forest Quarry, comprises a white leucocratic biotite-muscovite granite with a weak north-east trending foliation defined by parallel orientation of biotite and, to a lesser extent, feldspar. The post-tectonic granitic intrusions have been divided into two suites. The Crathes Suite ranges from diorite through tonalite and granodiorite to granite and probably predates the last major uplift of the district. A K-Ar date of 420±2 Ma for the Crathes Granodiorite is interpreted as a cooling age but, nevertheless suggests that the Crathes Suite is probably slightly older that the Cairngorm Suite. In Craigenlow Quarry the Crathes Granodiorite consists of at least two phases, differing slightly in colour, grain size and proportion of megacrysts, with sharp mutual contacts, and containing subangular xenoliths of fine-grained mafic diorite. The later Cairngorm suite, consisting entirely of biotite granites is the surface expression of the East Grampians Batholith. It was emplaced during and following the major end-Caledonian uplift. These granites have low initial $^{87}Sr/^{86}Sr$ ratios, close to 0.706, indicating evolution by differentiation from a largely mantle or lower crustal source, with little or no metasedimentary input. The Cairngorm Suite includes the Bennachie pluton, most of which consists of a pale pink coarse-grained sparsely to abundantly porphyritic biotite-granite, characterised by smoky quartz and orthoclase

perthitic macrocrysts. The eastern contact of the Bennachie Granite, visible at Maiden Castle, is marked by a 150 m wide breccia zone comprising clasts of silicified aplite set in a matrix of cherty silica containing much haematite after sulphides.

Devonian rocks

Constituents of the Quarryhill Sandstone Formation and the Rhynie Chert Member represent the youngest rocks which will be examined on this excursion. They belong to a sequence of Devonian sedimentary rocks of continental Old Red Sandstone facies and minor volcanic rocks known as the Rhynie Outlier, which extends from Kildruummy to Gartly. In the area between Rhynie and Quarry Hill the outlier has the form of a gentle syncline with a partially faulted western margin and a number of NW-SE cross-faults.

A discontinuous series of disused sandstone quarries on Quarry Hill provides the best exposures of the Quarry Hill Sandstone Formation. It consists of massive, hard, pale pink sandstone with significant interbedded siltstone and abundant mudflake conglomerate, occurring as large channel infills, and rootlets. Ripples, load casts, cross-bedding and graded bedding are all well developed.

The Rhynie Chert Member is the most celebrated unit of the Rhynie Outlier, principally because of its fossil plant remains. The chert, now thought to have formed in a hot spring environment, is blue-black in colour and occurs as beds up to 0.65 m thick in a sequence dominated by grey cherty and carbonaceous and micaceous sandstone. It shows laminated, brecciated, vuggy and geopetal textures typical of siliceous sinters. Most of the cherts are fossiliferous containing the genera *Rhynia* and *Aglaophyton* as well as rarer forms. The plants are generally preserved in the position of growth. Modern studies have also established that the chert is enriched in gold and silver. Surprisingly, there are no natural exposures of the chert. However, it can be found in the Windyfield area as boulder and float in fields and in dry stone walls. Specimens can also be seen in the museum at Rhynie School.

Maps

Topographic Sheets 29 (Banff), 37 (Strathdon) and 38 (Aberdeen).
Geological Sheets 76W (Alford), 76E Inverurie and 86E (Turriff)

References

Gould, D 1997 Geology of the country around Inverurie and Alford. *Memoir of the British Geological Survey,* Sheets 76E and 76W (Scotland).

Leslie, A G. 1987a. Glens of Foudland: thermal metamorphic aureole of the Insch mass. 173-178 in *Excursion guide to the geology of the Aberdeen area.* Trewin, N H, Kneller, B C and Gillen C (Editors). (Edinburgh: Scottish Academic Press).

Leslie, A G. 1987b. Southern contact of the Insch mass and the Bennachie Granite. 179-184 in *Excursion guide to the geology of the Aberdeen area.* Trewin, N H, Kneller, B C and Gillen C (Editors). (Edinburgh: Scottish Academic Press).

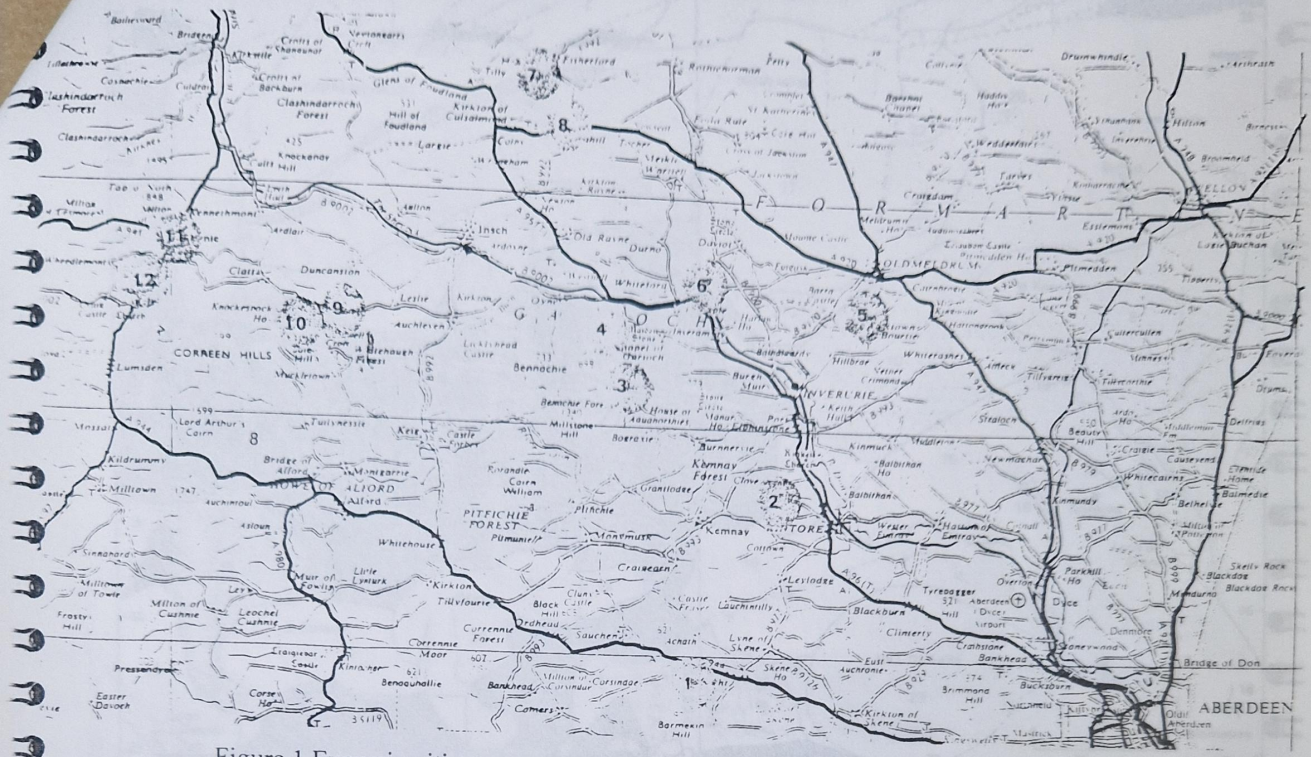


Figure 1 Excursion itinerary

Saturday

1. Craigenlow Quarry [NJ 732 093] Two phases of granodiorite, cut by microdiorite and microgranite. Visits by courtesy of Thistle Aggregates.

2. Tom's Forest Quarry [NJ 761 169] Foliated and xenolithic late-tectonic granite, locally sheared and hydrothermally altered. Visit by courtesy of Bardon Aggregates.

3. Bennachie Visitors Centre [NJ 698 217] Eastern end of Bennachie Granite. Post-tectonic pink granite and brecciated silicified microgranite.

4. Rownatree Car Park [NJ 693 245] Tertiary deep weathering in Bennachie Granite and view point.

Sunday

5. Hill of Barra [NJ 802 257] and Lowhillside [NJ 806 238] Lower zone of Insch intrusion. Dunite, troctolite, sheared gabbro and Dalradian country rocks.

6. Pitscurry Quarry [NJ729 267]. Middle zone of Insch intrusion. Coarse grained and granular norite and gabbro and igneous layering. Ordovician tourmaline granite.

7. Hill of Tillymorgan [NJ 65 34 and 65 33] Slate quarries. Progressive thermal metamorphism in the contact aureole of the Insch intrusion.

8. Cairnhill Quarry [NJ 6690 3265] High grade hornfelses in the inner zone of the Insch contact aureole.

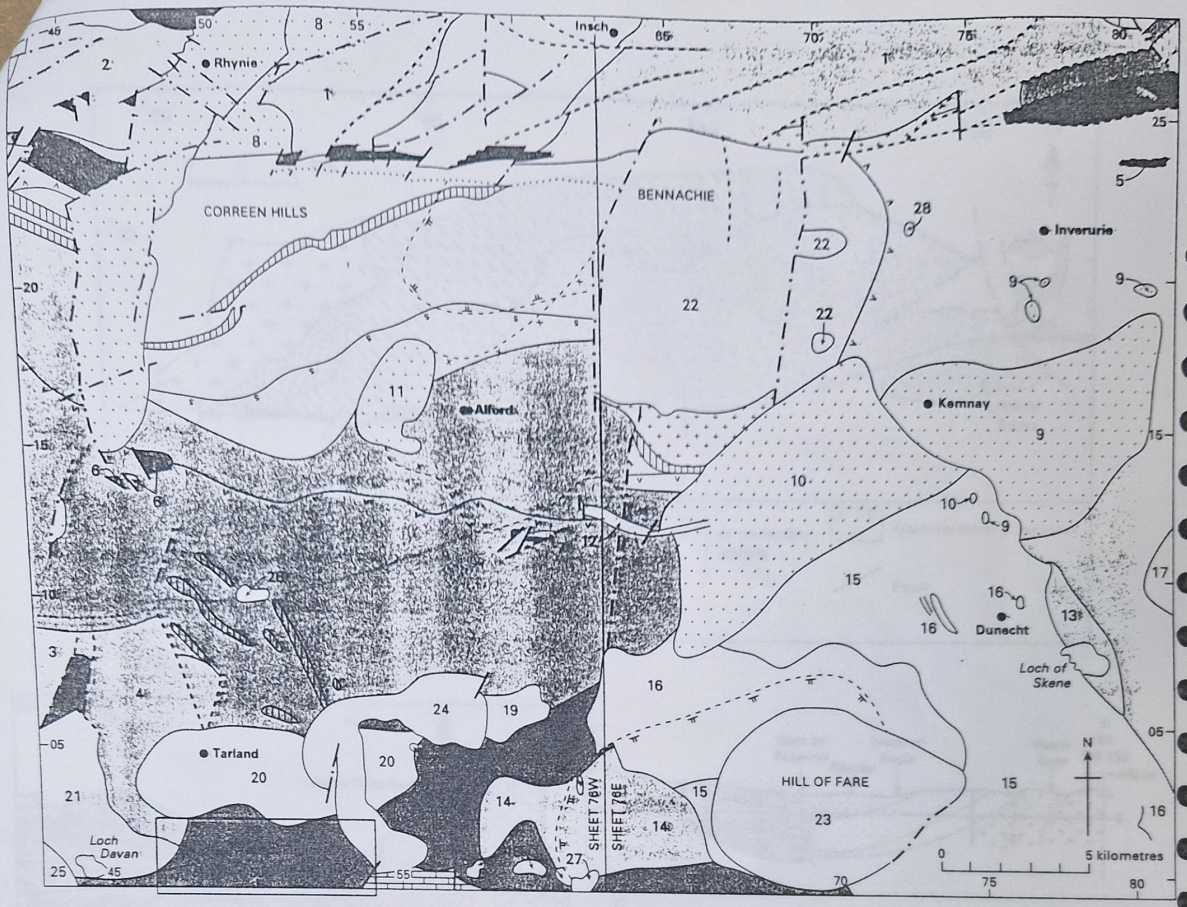
Monday

9. Hill of Johnston [NJ 571 247]. Upper zone of the Insch intrusion. Syenite, olivine monzonite and ferrogabbro.

10. Suiefoot Quarry [NJ 552 244] Sheared contact between syenite and serpentinite on the southern margin of the Insch intrusion.

11. Rhynie Museum[NJ 498 272] Display of plant bearing Devonian chert.

12. Quarryhill [NJ 485 274] Sedimentary structures, including ripples, load casts, cross bedding and graded bedding in Devonian sandstone.



DEVONIAN–OLD RED SANDSTONE

Conglomerate, sandstone, siltstone with minor andesitic lava

POST–TECTONIC INTRUSIONS

Granite–Cairngorm Suite

Granodiorite } Crathes Suite

Tonalite and diorite } Crathes Suite

LATE–TECTONIC INTRUSIONS

Granite

Granite, granodiorite, diorite

Basic and ultramafic rocks:

Upper Zone–olivine-ferrogabbro, olivine-monzonite, syenite

Middle Zone–norite, granular gabbro, quartz-biotite-norite

Lower Zone–dunite, harzburgite, wehrlite, troctolite, olivine-norite

Basic rocks, undifferentiated

PRECAMBRIAN–DALRADIAN SUPERGROUP

Suie Hill Formation } Southern Highland Group

Clashindarroch Formation } Southern Highland Group

Craigievar Formation

Aberdeen Formation

Deeside Limestone Formation } Argyll Group

Queen's Hill Formation } Argyll Group

Magnetic horizon defined by aeromagnetic survey

Hornfelsed and partially melted rocks

Sheared rocks (igneous and metasedimentary)

Minor intrusions omitted for clarity

Geological boundary

Fault

Ductile shear zone or thrust

Limit of sheared/hornfelsed rocks

Limit of fibrolitic sillimanite

Limit of migmatisation

Limit of granodiorite/tonalite vein complex

Limit of aplite/pegmatite vein complex

Figure 2 Generalised Solid geology of the Inverurie–Alford district.

List of intrusions

Late-tectonic basic–ultramafic intrusions

1. Insch
2. Boganclogh
3. Morven-Cabrach
4. Tarland
5. Lawel Hill
6. Kildrummy
7. Lynturk

Late-tectonic granitic intrusions

8. Kennethmont
9. Kemnay
10. Tillyfourie
11. Syllavethy
12. Corrennie

Post-tectonic granitic intrusions

(a) Crathes Suite

13. Gask
14. Torphins
15. Crathes
16. Balblair
17. Clinterty
18. Kincardine O'Neil
19. Lumphanan
20. Tomnaverie
21. Logie Coldstone

(b) Cairngorm Suite

22. Bennachie
23. Hill of Fare
24. Cromar
25. Ballater
26. Cushnie
27. Ord Fundlie
28. Middleton

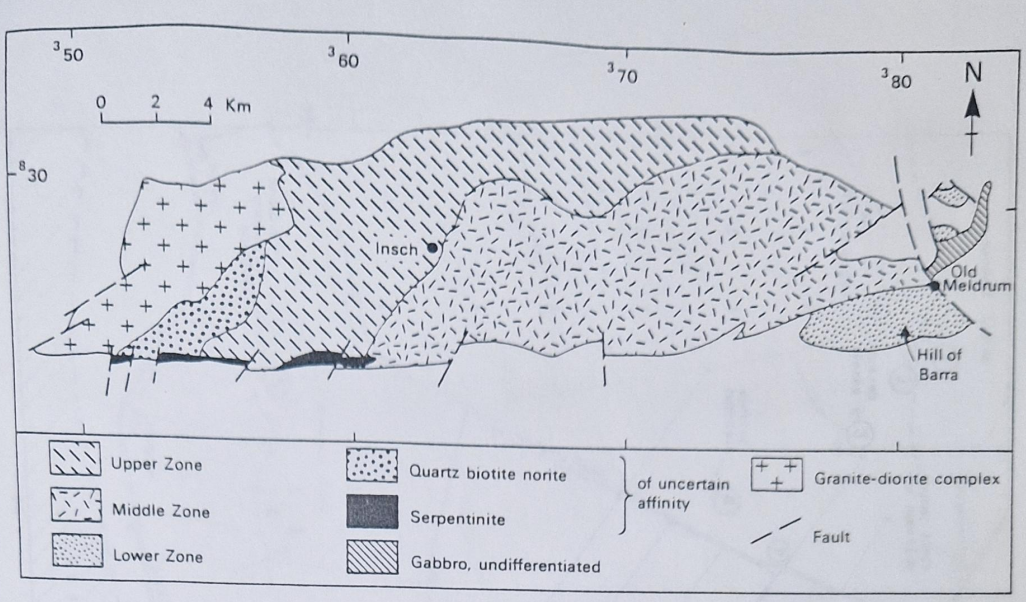


Figure 3 Geology of the Insch Intrusion

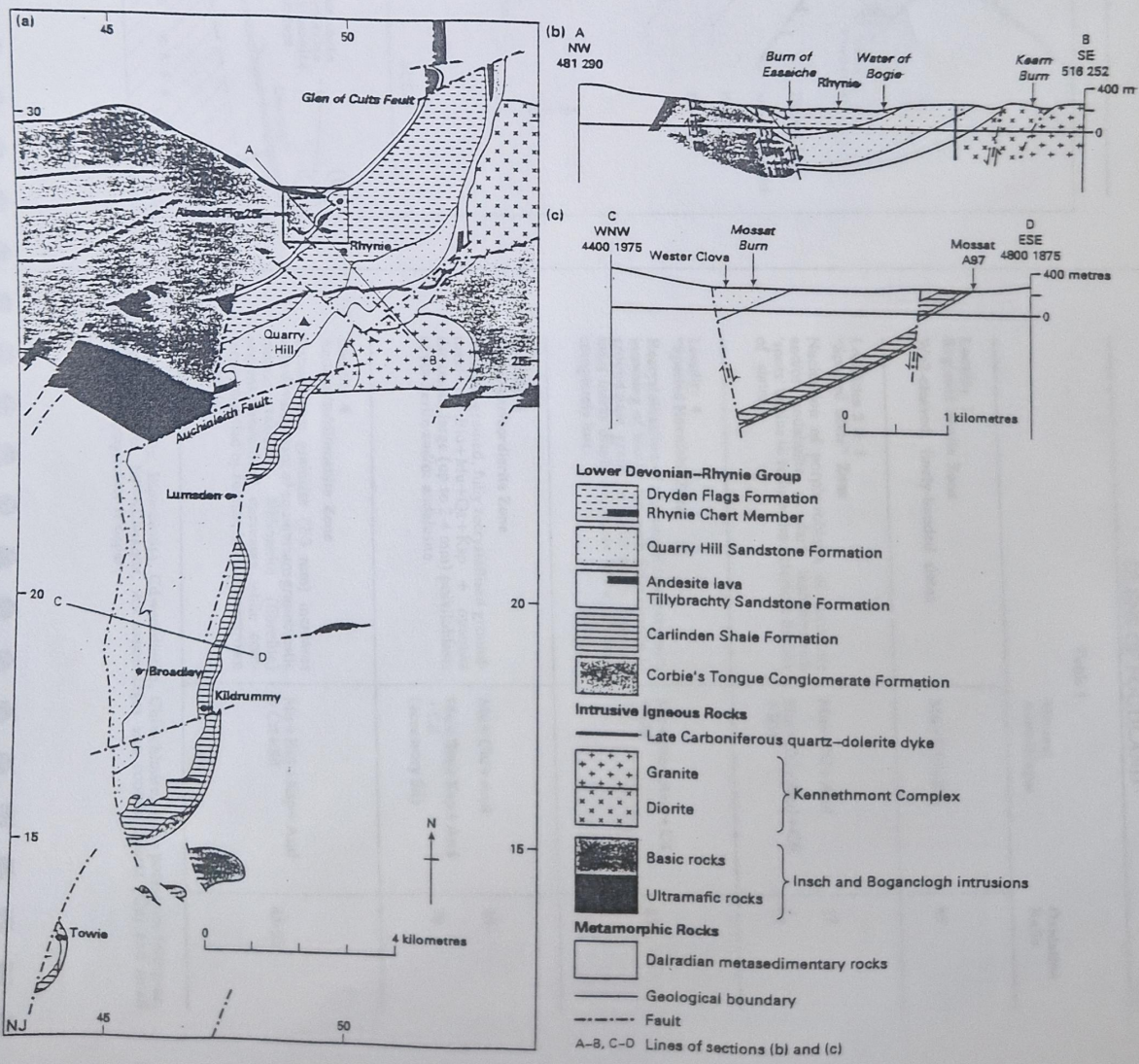


Figure 5 Geology of the Rhynie Outlier

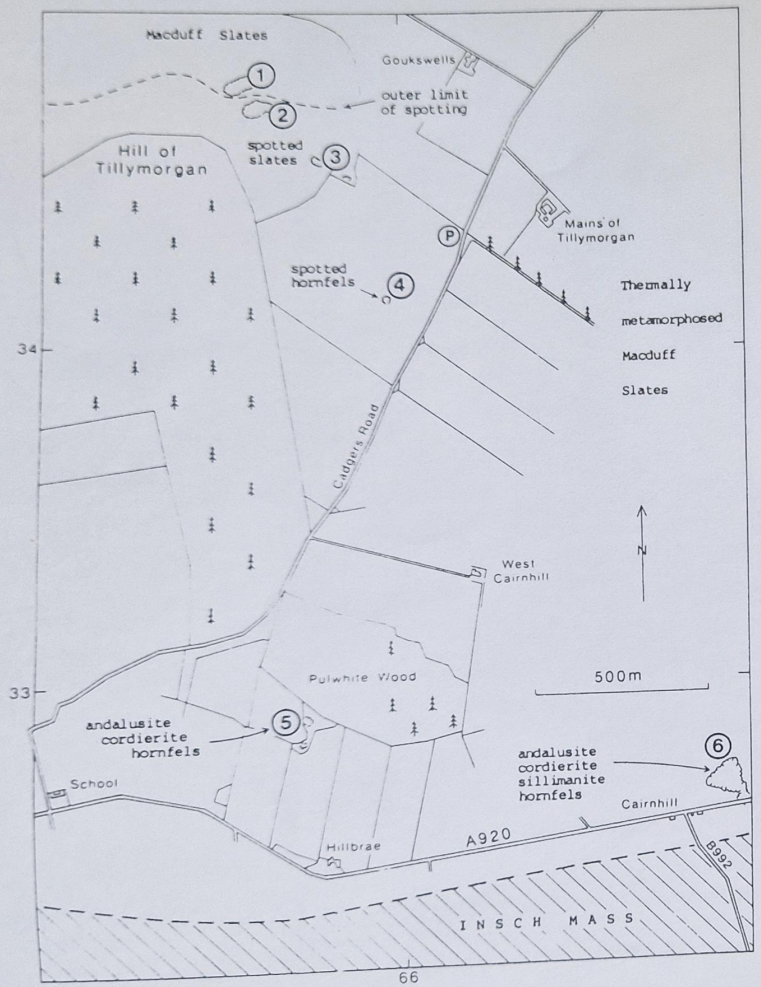


Figure 4 Location map of the Tillymorgan area

Table 1

	Mineral Assemblages	Oxidation Ratio
Locality 1 **Regional biotite Zone** Well-cleaved, finely-banded slates	Mu+Chl+Bio	85
Localities 2 & 3 **"Spotted Slate" Zone** Nucleation of porphyroblasts of cordierite and/or andalusite as dark inclusion-rich 'spots' begins to reduce characteristic fissility of slates	Mu+Chl+And Mu+Chl+And+Cd +Bio	17 94
Locality 4 **"Spotted Hornfels" Zone** Recrystallisation of the matrix advances with incoming of biotite but with little change in groundmass grainsize (0.05 mm). Groundmass micas disply decussate fabric. Fissility completely lost.	Mu+Bio+And+Cd +Chl	85
Locality 5 **Andalusite/cordierite Zone** Medium-grained, fully recrystallised groundmass of Bio+Mu+Qz+Ksp + opaques surrounds large (up to 2-4 mm) poikiloblasts of cordierite and/or andalusite.	Mu+Chl+And Mu+Bio+Ksp+And +Cd (accessory Sil)	18 78
Locality 6 **Andalusite/sillimanite Zone** Groundmass grainsize (2-3 mm) increases with development of equilibrium granoblastic mosaic textures. Sillimanite (fibrolite) present, andalusite decreases while commonly mantled by biotite, heavily overgrown by fibrolite.	Mu+Bio+Ksp+And +Cd+Sil	45-55

And=andalusite, Bio=biotite, Cd=cordierite, Chl=chlorite, Ksp=potassium feldsp-ar, Mu=muscovite, Sil=sillimanite. All assemblages also contain quartz (Qz) and small amounts of plagioclase feldspar.