OR/15/026 Introduction

From Earthwise

Jump to navigation Jump to search

Gunn, A G, Mendum, J R and Thomas, C W. 2015. Geology of the Huntly and Turriff Districts. Sheet description for the 1:50 000 geological sheets 86W (Huntly) and 86E (Turriff) (Scotland). *British Geological Survey Internal Report*, OR/15/026.

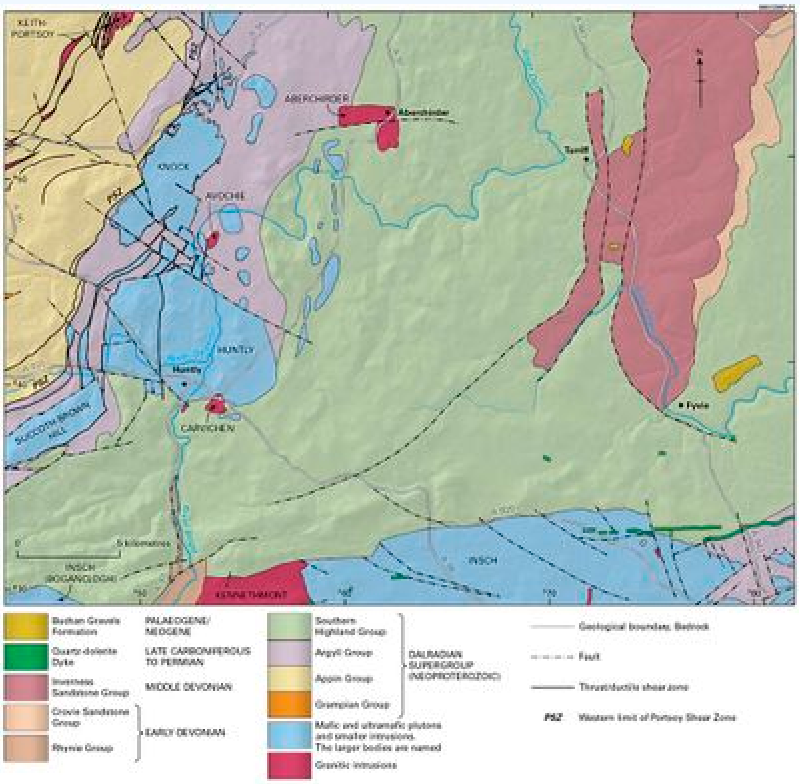

Figure 1 Simplified bedrock geology map of the Huntly and Turriff districts.

The Huntly and Turriff districts lie in the central and western parts of Buchan in north-east Scotland. The economy of the region is based largely on agriculture and forestry, with tourism and whisky production also important. The scenery is typically gently rolling, with the Turriff district forming part of the Buchan plateau, lying between 100 m and 200 m above OD. The districts are drained by the River Deveron and its tributaries, notably the rivers Bogie and Isla, except for their south-eastern part, which is drained by the River Ythan. The drainage pattern in part reflects the routes followed by glacial meltwaters across the districts as they moved generally from west to east. Higher hill ground occurs mainly within the Huntly district, particularly in the west and south, culminating in the Tap o'Noth (563 m), a prominent sentinel overlooking Strathbogie. These higher areas are given over largely to forestry and hill farming.

This account summarises current knowledge of the geology of the districts. Although bedrock exposure is distinctly limited across most of the area, recent BGS mapping has clarified and refined the Dalradian Supergroup stratigraphy in an area that was previously poorly understood. The presence of precious metals, notably nickel, copper, platinum group elements (PGE) and gold, within and associated with the major mafic-ultramafic intrusions, is of potential economic importance. Hence, the recent research into the mafic-ultramafic rocks and results from the prospecting and exploration are highlighted and discussed.

The geology of the Huntly and Turriff districts is dominated by metasedimentary rocks of the mainly

Neoproterozoic Dalradian Supergroup and the Ordovician gabbro-peridotite plutons of Huntly, Knock and Insch (Table 1, Figure 1). Note that the western part of the Insch Pluton is here termed the Boganclogh sector. The presence of representative units of much of the Dalradian succession, the mafic-ultramafic intrusions, and the regionally significant Portsoy Shear Zone (PSZ), are all important with regard to the Late Proterozoic to Early Palaeozoic evolution of Scotland leading up to and immediately following the Early to Middle Ordovician Grampian Orogeny. The districts lie partly within the type area for low pressure, high temperature 'Buchan' series metamorphism but the Dalradian rocks to the west of the PSZ were also subjected to moderate pressure, medium to high temperature Barrovian metamorphism.

Lower Devonian sandstones, siltstones, mudstones and andesitic lavas occur in the Bogie Outlier, the northern extension of the larger Rhynie Outlier, which crops out in Strathbogie in the southern part of the Huntly district. The larger but poorly exposed Turriff Outlier, which consists of Lower Devonian conglomerates, sandstones and siltstones, overlain by Middle Devonian conglomerates, underlies an area extending north from Fyvie to Turriff and Cuminestown. Post-Devonian rocks are absent. Superficial deposits include the possible Pliocene age deposits of the Buchan Gravels Formation near Turriff and Fyvie, the abundant Pleistocene glacial and postglacial deposits, and more recently formed peat and alluvium.

Table 1 Geological succession of the Huntly and Turriff districts.

SUPERFICIAL DEPOSITS (DRIFT)					
Quaternary	Flandrian				Peat, alluvium, river terrace deposits
	Late Devensian				Glaciolacustrine deposits, glaciofluvial sand and gravel, diamicton: till, moranic deposits and glacially deformed weathered rock
Palaeogene/Neogene				Buchan Gravels Formation, undivided: gravel with white clayey matrix	Windy Hills Gravels Member: gravel, sand and micaceous clay
BEDROCK					
Sedimentary and volcanic rocks					
Age	**Supergroup**	**Group**	**Subgroup**	**Formation**	**Member/lithology**
Devonian	Orcadian Old Red S'stone Supergroup				
Mid Devonian		Inverness Sandstone Group		Gardenstown Conglomerate Formation	Conglomerate and breccia with subordinate sandstone and minor shale
Early Devonian		Crovie Sandstone Group undivided			Sandstone and shale with minor conglomerate
		Rhynie Group		Dryden Flags Formation	Mudstone and siltstone
				Tillibrachty Sandstone Formation	Sandstone and conglomerate
		Lavas			Andesite, basaltic, commonly vesicular
Metasedimentary and metavolcanic rocks					

Neoproterozoic to early Cambrian	Dalradian Supergroup	Southern Highland Group		Macduff Formation	Psammite, semipelite and minor pelite, with rare calc-silicate laminae
					Hill of Foudland Pelite Member: pelite and semipelite, commonly slaty
				Whitehills Grit Formation	Quartzite, schistose pelite and rare, thin impure metalimestone
				Clashindarroch Formation	Semipelite and pelite, with minor coarse psammite and quartzite
					Garnel Burn Pelite Member: pelite, schistose
		Argyll Group	Units unassigned to subgroups	Unnamed units within or adjacent to Portsoy–Duchray Hill Shear Zone	Semipelite and pelite with minor psammite and metalimestone, and inclusions of mafic igneous rocks
					Pelite and semipelite with minor psammite, metalimestone and quartzite
				Aberdeen Formation	Psammite and semipelite. migmatitic
				Strichen Formation	Pelite and psammite, calc-silicate ribs, largely migmatitic
				Blackwater Formation	Grumack Hill Quartzite Member: quartzite
					Corinacy Pelite Member: Pelite, schistose to phyllitic, with psammite
				Beldorney Pelite Formation, undivided	Pelite, semipelite and psammite
			Crinan Subgroup	Cowhythe Psammite Formation	Psammite and semipelite, migmatitic and gneissose, with some quartzite units
			Easdale Subgroup	Unit unassigned to a formation	Semipelite and metalimestone with calcsilicate rocks
				Castle Point Pelite Formation	Pelite and semipelite with thin calc-silicate and metalimestone lenses
			Islay Subgroup	Durn Hill Quartzite Formation	Quartzite with tillite lenses developed locally near base
		Appin Group	Units within Keith Shear Zone unassigned to Subgroups	Keith Limestone Formation (poss part of Blair Atholl Subgroup	Semipelite, schistose
					Semipelite, schistose to gneissose, with limestone
					Cuthill Limestone Member: metalimestone
			Blair Atholl Subgroup	Unit unassigned to a formation	Semipelite with some metalimestone and quartzite beds
				Fordyce Limestone Formation	Pelite and semipelite, schistose, with thin limestone and calc-silicate rock
					Limehillock Limestone Member: metalimestone with thin semipelite and pelite beds

	Ballachulish Subgroup	Tarnash Phyllite and Limestone Formation	Semipelite with metalimestone and calcsilicate rock; prominent white limestone unit common near base
		Corryhabbie Quartzite Formation	Orthoquartzite
		Mortlach Graphitic Schist Formation	Pelite and semipelite Dufftown Limestone Member: metalimestone with thin pelite beds
	Lochaber Subgroup	Pitlurg Calcareous Flag Formation	Calcareous psammite and semipelite with with thin tremolite laminae; rare quartzite beds Drummuir Calcareous Member: Semipelite, flaggy, with thin calc-silicate rock and metalimestone beds
		Findlater Flags Formation	Semipelite, schistose, commonly flaggy in upper part; psammite and semipelite with local thin quartzite beds dominant in lower part
Grampian Group		Cullen Quartzite Formation	Bellyhack Quartzite Member : quartzite, massive

Geography and physiography

The principal settlements are the market towns of Huntly and Turriff, although there are numerous outlying villages and hamlets. Although generally the area is one of low to moderate and rolling relief, elevations locally exceed 300 m. The lowest point of the districts lies in the lower part of the Deveron valley at around 15 m above OD. The highest point is Tap o' Noth (564 m) in the south-west part of the Huntly district, which overlooks the Clashindarroch Forest where the Kirkney Water and its tributaries effectively dissect a 'plateau' topography that attains 380 to 430 m above OD. Brown Hill (483 m), Clashmach Hill (375 m), The Balloch (366 m) and Knock Hill (430 m) form prominent rounded hills in the higher western part of the Huntly district. Further east and north, the gently undulating Buchan plateau at 130 to 160 m above OD, is incised by the major river valleys of the Deveron and Ythan and their tributaries. In the southern parts of the districts lie the 'Slate Hills' that stretch westwards from Core Hill (245 m) to the Hill of Rothaise (261 m), the Hill of Tillymorgan (381 m), the Hill of Foudland (467 m) and Knockandy Hill (434 m).

The River Deveron and its principal tributaries, the Bogie and the Isla, form the main river system, draining the northern and western part of the districts. The Deveron follows a meandering, typically deeply incised course between Milltown of Rothiemay [NJ 548 481] and Turriff, from where it turns sharply north to reach the sea at Banff Bay. The River Ythan drains the central and south-east part of the Turriff district. It follows a similarly meandering course eastwards passing through the narrow Fyvie Gorge. Many of the broad tributary valleys contain only small burns, e.g. the Idoch Water between Turriff and Cuminestown, reflecting their origins as glacial meltwater channels.

Geological history

Dalradian

Dalradian metasedimentary rocks ranging from the Grampian Group through to the Southern Highland Group are represented within the district. The stratigraphical successions of the uppermost Grampian Group, Appin and Argyll Groups record deposition of sandstones and siltstones, mudstones and limestones under mainly shallow water marine conditions on slowly rifting and subsiding continental crust, probably between about 750 and 510 million years ago (Ma)

(Neoproterozoic to Cambrian). Diamictites, interpreted as glaciogenic ('tillites') in origin, occur at the base of the Durn Hill Quartzite Formation and mark the start of the Argyll Group sequence. Ahough undated, they are considered to have been formed during the global Marinoan glaciation which took place about 630 Ma. They are correlated with similar glaciogenic deposits elsewhere in the Scottish Highlands, and in Greenland, Norway and Spitsbergen. Shallow marine shelf sediments pass up into deeper water sandstones, siltstones and mudstones in the middle part of the Argyll Group and this facies is dominant in the overlying Southern Highland Group. These younger arenites, semipelites and pelites were largely deposited from turbidity currents in continental edge fan systems which developed as the crust thinned and fractured as a result of the lithospheric extension of the Rodinian supercontinent. The continental crust eventually ruptured between about 600 and 550 Ma ago, to produce the continents of Laurentia and Gondwana with the consequent formation of the Iapetus Ocean.

Subsequent tectonic activity focussed at the continental margins, notably in Ordivician times, prior to closure of the Iapetus Ocean in the early Silurian. This activity, which included collision between the Laurentian continental margin and microcontinents, island arcs, spreading ridges, etc resulted in the Grampian Orogeny in Scotland and Ireland between about 500 and 450 Ma. During this event, Dalradian sediments were pervasively deformed and metamorphosed, and intruded by igneous bodies that ranged from ultrabasic to granitoid in composition.

Pretectonic granites

Pretectonic granite bodies occur in the north-western part of the Huntly district, linked to the Keith–Portsoy Shear Zone. They form lenticular bodies and sheets and are mostly foliated, coarse-grained biotite-muscovite granites with potash feldspar augen. The main intrusions stretch from Keith north-eastwards to Lurg Hill {504 575) with outlying bodies farther north-east by Boggierow [575 652] in the Portsoy district (Sheet 96W) and farther south-west on Hill of Mulderie [383 517] and on the Hill of Bellyhack [389 424] in the Glenfiddich district (Sheet 85E). The emplacement of these granites has been dated at 600 Ma (Barriero, 1998)[1].

Caledonian igneous intrusions

Synorogenic intrusions

The mafic and ultramafic intrusions (Table 2) of the North-east Grampians Basic Subsuite (part of the Scottish Highlands Ordovician Suite) underlie extensive areas of the Huntly district and are a key feature of the geology of the Huntly and Turriff districts. Read (1919)[2] divided these mafic-ultramafic intrusions into an 'Older' group that he interpreted as predating the regional metamorphism, and a 'Younger' group, emplaced approximately synchronous with the climax of regional metamorphism at about 475 to 470 Ma (Carty, 2001[3]; Dempster et al., 2002[4]; Condon and Martin, cited in Oliver et al., 2008[5] as a personal communication). Both groups are currently regarded as of Ordovician age but the 'Older' group intrusions are undated and some at least may be of Cambrian or Neoproterozoic age. In the Huntly district small intrusive basic and ultrabasic bodies of the 'Older' group are widespread along the PSZ. They have undergone multiple phases of recrystallisation, deformation and alteration during metamorphism and shearing.

Intrusions of the 'Younger' suite crop out more extensively. The Huntly and Knock gabbro-perdotite plutons underlie a total area of approximately 65 km^2. Only the northern part of the larger Insch Gabbro-peridotite Pluton crops out along the southern edge of the districts but this underlies some 75 km^2. A small part of the Boganclogh sector of the Insch Pluton outcrops in the south-west corner of the map, but covers an area of less than 5 km^2. These intrusions range in composition from peridotite through gabbro and norite to quartz syenite. In contrast to the ‘Older’ Basics, they preserve various magmatic features with deformation generally restricted to discrete shear zones or marginal areas.

The distinction between the ‘Older’ and ‘Younger’ Basic intrusions can be unclear in the proximity of the regional shear zones. Detailed studies of some of the larger ‘Older’ intrusions, such as the Succoth–Brown Hill Ultramafic Intrusion, have shown that they differ petrologically and geochemically from the ‘Younger’ Huntly and Knock plutons and show evidence of a more complex geological history (Gunn et al., 1996)[6].

Late-orogenic intrusions

Late- to post-orogenic granitic intrusions include those at Aberchirder, Avochie, Carvichen and Kennethmont, the latter being the largest of these (Stephenson and Gould, 1995)[7]. Most are biotite granites, although Kennethmont also includes a quartz-diorite and granodiorite phase.

Old Red Sandstone Supergroup

Erosion accompanied and followed uplift of the Grampian terrane in Late Ordovician and early Silurian times. Subsequently, sedimentary rocks belonging to the late Silurian to Middle Devonian Old Red Sandstone Supergroup were deposited in fault-bounded, continental basins under tropical semi-desert conditions.

Within the Huntly and Turriff districts, these rocks are represented by two separate successions. Conglomerates, breccias, sandstones and siltstones belonging to the Crovie and Inverness Sandstone Groups crop out in the Turriff Outlier which extends north from Fyvie to the Banffshire coast. Conglomerates, sandstones and mudstones, belonging to the Rhynie Group, crop out in Strathbogie, these rocks forming the northward continuation of the Rhynie Outlier, well known for its Early Devonian plant and fish remains and preserved hot spring system. The late Silurian to Early Devonian was a period of considerable volcanic activity in Scotland. Within the Huntly district volcanic rocks are represented by andesitic lavas interbedded with the sedimentary rocks in the northern part of Strathbogie.

Cenozoic superficial deposits

Although sedimentary rocks of Late Palaeozoic and Mesozoic age may have been deposited within the Huntly and Turriff districts after the Devonian, none are preserved, reflecting the fact that the area has undergone net erosion for nearly 400 Ma. The only preglacial, post-Devonian sediments present within the district are unconsolidated, white to cream clayey and pebbly quartz gravels of the probable Pliocene age known as the Buchan Gravels Formation. This formation crops out in a few small outliers north-east and south-south-east of Turriff and in a rather larger outlier east of Fyvie at Windy Hills. The deposits are probably remnants of more widespread fluvial deposits of Palaeogene age which have subsequently been removed by erosion during the Palaeogene/Neogene uplift which affected Scotland. The Palaeogene/Neogene was also a time of intense weathering during a warm climatic period.

Towards the end of the Neogene at about 2 Ma, the climate deteriorated leading to episodic glaciation of Britain during the Pleistocene. Pleistocene superficial deposits within the Huntly and Turriff districts result mostly from the last major Late Devensian glaciation, which comprised the Dimlington Stadial that occurred between approximately 26 000 and 13 000 years ago, and the subsequent Windermere Interstadial between 13 000 and 11 500 years ago.

Table 2 Timing and relationships of the major deformation and metamorphic events, and the emplacement of igneous intrusions

Age (Ma)	Deformation and metamorphic events	Igneous intrusions
295	East and east-north-east-trending faulting	Quartz-dolerite dykes
400	North-west-trending faulting	
	Dextral strike-slip movement on Portsoy Shear Zone	
	D3 deformation	
450		Kennethmont Granite
	Localised shearing	Aberchirder, Avochie, Carvichen and other small foliated granites
	Extensional shearing focussed on the PSZ	Huntly, Knock and Insch plutons and related smaller intrusions
470	Metamorphism (M2)	Metadolerite sheets
	D2 deformation: folding, thrusting and shearing	
	D1 deformation and Metamorphism (M1)	
500		Succoth–Brown Hill and related intrusions
600	Faulting, minor shear zones, coincident with rifting of Rodinian Continent prior to break-up and formation of Iapetus Ocean	Keith–Portsoy Granite

The superficial deposits are dominated by widespread but commonly thin and even patchy tills and locally developed spreads of glaciofluvial sand and gravel. Glacial meltwater channels were developed extensively and have strongly modified the former river pattern. There is only sparse evidence of features and deposits that resulted from the pre-Late Devensian ice sheets. Early in the Dimlington Stadial, the Moray Firth ice sheet transported dark grey, clay-rich till containing rafts of Jurassic mudstones and Quaternary marine sediments onshore to the south and south-east as far as Turriff. This ice stream also diverted the inland ice sourced in the Grampian Highlands eastwards and southwards, as shown by recorded striations and distribution of both local and far-travelled erratics. A later phase of north to north-eastward movement by this East Grampians ice sheet is indicated by north-trending striae and the distribution of troctolite and gabbro erratics from the Huntly intrusion (Read, 1923[8]; Merritt et al., 2003[9]). Till resulting from the East Grampians ice sheet occurs mainly to the north in the Portsoy and Banff districts (Sheets 96W and 96E respectively). The presence of ice in the Moray Firth during deglaciation resulted in the formation of marginal lakes and as a result the bulk of meltwater was diverted eastwards via a series of glacial meltwater channels. Classic examples include the Fyvie Gorge, occupied now by the River Ythan, and the valley of the Idoch Water. The courses of the Deveron and Ythan rivers and their tributaries were also considerably modified by the glacial meltwaters. Recent superficial deposits comprise river alluvium in the valleys of the rivers and larger streams, and patches of peat locally developed to the north and west of the River Deveron and to the east of Fyvie and Cuminestown.

Structure and metamorphism

The regional scale tectonic pattern in the north-east Grampian Highlands is dominated by a suite of major shear zones. The largest structure is the steep north-north-east-trending Portsoy Lineament which runs southwards from Portsoy and traverses the Huntly district in its western part (Figure 1). This structure initially acted as a major control on Dalradian sedimentation patterns, but during the Grampian Orogeny it acted as a regional shear zone. This Portsoy Shear Zone (PSZ) also limits the distribution of ‘Older’ and ‘Younger’ mafic and ultramafic intrusions (Ashcroft et al., 1984[10]; Fettes et al., 1986[11], 1991[12]). The shear zone was the locus of considerable deformation during and after emplacement of the ‘Younger’ basic intrusions, such as the Huntly and Knock plutons (Table 2). The lineament forms the western boundary of the Buchan block, a tectonic unit with distinctive geophysical and structural features compared to the other parts of the Grampian Highlands. Shear zones are also developed along the margins of, and more rarely transect, many of the ‘Younger Basic’ plutons–notably Huntly, Insch, and farther south-east Belhelvie.

East of the PSZ early upright to west verging folding and a single cleavage are present in the Southern Highland Group arenites and slates. Secondary folding occurs in areas of higher metamorphic grade, for example in the Fyvie Gorge, and in the ‘Slate Hills’, north of the Insch intrusion, where it postdates the main metamorphism.

Metamorphic grades range from greenschist facies in the structurally and stratigraphically higher part of the succession in the Turriff Syncline, to middle and upper amphibolite (sillimanite-potash feldspar) grade adjacent to the Portsoy Lineament and ‘Younger Basic’ intrusions. Mineral assemblages in pelitic rocks include cordierite and andalusite, minerals characteristic of low pressure, high temperature ‘Buchan’ type regional metamorphism. This phase of metamorphism was augmented by emplacement of the mafic-ultramafic intrusions at about 470 Ma.

To the west of the PSZ the Dalradian rocks show evidence of two phases of deformation and amphibolite facies metamorphism, resulting overall in north-west verging asymmetrical folds and accompanying shear zones. The earlier deformation phase was characterised by low to medium pressure amphibolite facies metamorphism and the later phase by a marked pressure increase, manifest locally by kyanite pseudomorphs after andalusite in the pelitic lithologies. The trace of the anastomosing north-north-east-trending Keith–Portsoy Shear Zone cuts across the north-west corner of the Huntly district (Figure 1). This zone was a locus for intrusion of granite sheets at about 600 Ma and was subsequently reactivated during the Grampian Orogeny as a site of significant north-west-directed shearing movements. The PSZ itself is a complex sheared and faulted zone that ranges in width from a few hundred metres to about 1.5 km on the coast at Portsoy. Its present steep nature reflects its later history where it appears to have acted as a zone of differential uplift.

History of geological research

The sheet was originally surveyed for the Geological Survey by J Horne, J S Grant Wilson and L W Hinxman between 1880 and 1894. H H Read subsequently revised the mapping in considerable detail between 1917 and 1919 and the resultant 1:63 360 scale survey map of the Huntly district (Sheet 86) was published in 1923, along with the memoir for Sheets 86 and 96 (Read, 1923[8]). Read published extensively on the geology of north-east Scotland and maintained an interest in the area throughout his working life. Revision and remapping have been carried out by the survey in the 1980s and 1990s as part of the East Grampian Project, whose aims were to produce a coherent bedrock geological map of north-east Scotland at a 1:50 000 scale. This work has made use of academic and economic studies and used geophysical and geochemical techniques where applicable.

The Huntly, Knock and Insch plutons have been the subject of many detailed studies despite their poor surface exposure. Read acknowledged the early work of Watt (1914)[13] who described the petrography of the main constituent lithologies and contaminated marginal rocks of the Huntly Pluton. Shackleton (1948)[14] postulated that Huntly Pluton was overturned based on the steeply dipping rhythmic cumulate banding of the mafic-ultramafic rocks in the Bin Quarry. He subsequently suggested (in discussion of Read and Farquhar, 1956[15]) that the pluton was part of a single folded and boudinaged mafic-ultramafic sheet that underlay much of north-east Scotland. Stewart and

Johnson (1960)[16] and Stewart (1970)[17] reviewed the evidence for a single sheet-like intrusion and concluded that whilst feasible, folding and deformation had occurred closely following emplacement while the sheet was still ductile. Weedon (1970)[18] used the major and limited trace element chemistry and plagioclase feldspar compositions from the cumulate succession in the south-western part of the Huntly Pluton to conclude that there were significant breaks in the igneous sequence. This was confirmed by a drilling and trenching programme carried out by Munro (1970)[19], which concentrated initially on defining the boundaries and general distribution of lithologies in the Huntly and Knock plutons and in the Portsoy Gabbro-serpentinite Intrusion-swarm. Subsequently Munro (1984)[20] and Munro and Gallagher (1984)[21] documented the distribution of cumulates and other elements of these intrusions in detail based on a comprehensive outcrop sampling, drilling and trenching programme carried out over many years. They concluded that the intrusions represented a much disrupted and variably deformed complex of partially layered mafic and ultramafic intrusions, but the evidence did not support their emplacement as a single body.

In the Insch Pluton, Sadashivaiah (1954)[22] studied the dunite-troctolite cumulates from the eastern part of the intrusion. Read et al. (1961)[23] described the differentiated sequence from the north-western part of the pluton that ranges from gabbro to syenite. Clarke and Wadsworth (1970)[24] divided the Insch Pluton into Lower, Middle and Upper zones based largely on petrographical data backed up by some chemical analyses. Wadsworth (1986[25], 1988[26]) later described the mineralogy of the Upper Zone and Middle Zone rocks in more detail. More recently, detailed major, trace element and isotopic studies by Hay (2002)[27] have clarified the nature and origin of the basic magmas that gave rise to the Huntly, Insch and Belhelvie plutons.

The relationships between the intrusions of the North-east Grampians Basic Subsuite and the adjacent Dalradian metasedimentary rocks have also been the subject of considerable work. Fettes (1968[28], 1970[29]) showed that in Southern Highland Group arenites and pelites lying north of the Insch Pluton the hornfels mineralogy and texture overprinted an early penetrative fabric, but were in turn overprinted by a secondary deformation and metamorphism. Droop and Charnley (1985)[30] estimated pressure (P) and temperature (T) conditions from metamorphic assemblages in pelitic rocks in the inner hornfels of the Morven–Cabrach, Huntly, Knock and Belhelvie plutons. Using several geobarometers they obtained pressures of 4 to 5 kb and temperatures of 700°C to 850°C, implying that the plutons were all intruded at about the same crustal level (15 to 18.5 km). Later work by Droop et al. (2003)[31] used more modern thermodynamic datasets to assess P-T conditions of the partially melted migmatitic rocks associated with the Huntly Pluton and the surrounding pelitic rocks. Their results corroborated the earlier work giving P values of 5 kb but higher T values for the migmatites of about 900°C.

The conditions prevailing during regional metamorphism in the wider Buchan region have been the subject of a number of studies since the 1960s. Hudson (1980[32], 1985[33]) used a range of geobarometers and geothermometers to demonstrate an increase in pressure and temperature westwards from the central part of the Turriff Syncline to Portsoy. Subsequent work has further constrained general pressure conditions throughout the region (Baker, 1985[34]; Beddoe-Stephens, 1990[35]). Chinner (1966)[36] interpreted sillimanite to result from a thermal overprint on the regional metamorphic pattern that related to depth of burial. Subsequently, Fettes (1970)[29], Pankhurst (1970)[37], and Ashworth (1975)[38] suggested that the high temperature metamorphic effects, manifest as sillimanite, resulted from the high heat flow associated with intrusion of the mafic-ultramafic plutons. They postulated that their emplacement was approximately coeval with the peak of regional metamorphism. Hudson (1980[32], 1985[33]) delineated two stages of sillimanite growth, one related to the regional metamorphism and the other associated with the basic masses. However, they believed that development of the 'regional' and 'contact' sillimanite occurred at approximately the same time.

The pseudomorphing of andalusite by kyanite west of the PSZ was first noted by Elles (1931)[39] and subsequently studied by Chinner (1980)[40], Chinner and Heseltine (1979)[41] and Beddoe-Stephens (1990)[35]. Beddoe-Stephens used several geothermometers to elucidate the pressure and temperature conditions under which the inversion from andalusite to kyanite occurred. He showed that there was an increase in pressure of about 2 kb across the PSZ and interpreted this in terms of westerly directed thrusting across this structure as postulated by Baker (1987)[42]. In contrast, Dempster et al. (1995)[43] suggested that the superimcumbent load imposed by the emplacement of the mafic-ultramafic intrusions may have been responsible for this pressure increase.

The role of the Portsoy Lineament and Shear Zone was not recognised during the original surveys. Read (1923)[8] placed the main dislocation, the Boyne Line, farther east and interpolated its extension southwards into the Huntly district where it was position was defined by sparse exposures of gneissose and schistose lithologies. Elles (1931)[39] first recognised a major dislocation in the Dalradian succession farther west at the junction of the Portsoy Limestone Formation and Cowhythe Psammite Formation in Links Bay by Portsoy. She termed this structure the Portsoy Thrust. Subsequent work has shown that there is a major shear zone, the Portsoy Shear Zone (PSZ), some 1.5 km wide, exposed on the Banffshire coast at Portsoy. Its role in the geological history of north-east Scotland has been variously interpreted but most authors agree that it is a regionally significant structure with a long history of movement (Fettes et al., 1986[11], 1991[12]; Goodman, 1994[44]; Stephenson and Gould, 1995[7]; Carty, 2001[3]; Viete et al., 2010[45]). Ashcroft et al. (1984)[10] showed that the PSZ was part of a network of steeply inclined shear zones that bounded and transected the Buchan area of north-east Scotland, approximately coeval with emplacement of the North-east Grampian Basic Subsuite. Although the PSZ now dips steeply eastwards authors differ as to whether formerly it dipped more gently and was the site of regional westward thrusting (Baker, 1987[42]; Beddoe-Stephens, 1990[35]; Viete et al., 2010[45]).

There have been widely differing interpretations of the nature of the protoliths and geological history of the Cowhythe Psammite Formation (‘Cowhythe Gneiss’). Read (1923[8], 1955[46]) interpreted this unit as part of his Keith Division — older gneissose metasedimentary rocks with a more complex structural and metamorphic history that formed the autochthonous basement to the Banff Nappe. Ramsay and Sturt (1979)[47] emphasised this structural and metamorphic complexity, and in combination with Rb-Sr isotopic data from the Inzie Head and Ellon gneisses that gave Neoproterozoic ages (Sturt et al., 1977[48]), they suggested that this unit represented allochthonous pre-Caledonian basement, thrust westwards along the Portsoy Thrust. Oliver (in Viete et al., 2010 [45]) obtained a U-Pb SHRIMP age of 1012 ± 10 Ma from zircon overgrowths in a migmatitic leucosome from the western part of the Cowhythe Psammite Formation, suggesting that Grenvillean basement is present. Viete et al. (2014)[49] obtained more detailed U-Pb SHRIMP ages from 55 small euhedral zircons, typically with prominent oscillatory zoning, sampled from both the leucosome and mesosome of the migmatitic pelite. The zircons gave concordant ages between 1025 and 975 Ma, with a mean 206Pb/238U age of 1003± 6 Ma age, interpreted as dating the migmatisation. Inherited ages ranged from 3000 Ma to 1000 Ma.

A more conventional model views the unit as an integral part of the Dalradian succession (Crinan Subgroup) that has undergone Caledonian deformation and high grade metamorphism largely as a result of its structural position in the immediate hangingwall of the PSZ (e.g. Stephenson and Gould, 1995[7]). The British Geological Survey published the regional Bouguer gravity and aeromagnetic survey maps in 1978 (Institute of Geological Sciences, 1978a[50], b[51] respectively). The results of a regional stream-sediment survey are summarised in the East Grampians geochemical atlas (British Geological Survey, 1991[52]). The patterns of major and trace element abundances derived from the stream-sediment samples in the Huntly and Turriff districts generally reflect the underlying rock units, despite the extensive cover of superficial glacial deposits (mainly till). Hence Ca, Mg, Fe, V, Cr, Ni and Co concentrations are enhanced over the mafic-ultramafic plutons, and K and Ga depleted. In contrast, the Southern Highland Group rocks show enhanced B, Li, Ti and Ga concentrations but low Zr and Ca values. Granitic rocks show enhanced concentrations of K, Rb, Be and Li. The correspondence of stream-sediment and hence till geochemistry with the underlying bedrock suggests that the subglacial till was formed largely in situ.

Both geophysical and geochemical data have been employed to facilitate the delineation of geological boundaries and the nature and extent of units in the poorly exposed Huntly and Turriff districts. Bouguer gravity modelling was used to provide some estimates of the thickness of both the Devonian sequence in the Turriff Outlier (Ashcroft and Wilson, 1976[53]). Leslie (1984)[54] used ground magnetic surveys and pitting to model the north-eastern contact of the Insch Pluton and its aureole. Similarly Fettes et al. (1991)[12] combined geological and geophysical methods (mainly detailed ground magnetic surveys) to delineate the nature of the PSZ and the Dalradian stratigraphy to the south-west of Huntly. Gunn et al. (1996)[6] combined detailed ground magnetic surveys, and limited new gravity data with borehole information to elucidate the nature of the Succoth–Brown Hill Ultramafic intrusion. This last work linked to an assessment of the amount and nature of platinum group elements associated with the ultramafic and mafic intrusions. The potential for economic quantities of platinum group and other elements has attracted several mineral companies to north-east Scotland, commencing in the 1970s. The companies undertook extensive geophysical surveys, notably of magnetic susceptibility, and drilled considerable numbers of boreholes in the Huntly and Knock Plutons and adjacent migmatitic rocks. Fletcher used material from prospective boreholes to study the mineralogy of the Huntly and Knock plutons and associated mineralisation (Fletcher, 1989[55]; Fletcher and Rice, 1989[56]). However, to date, no economic deposits have been found.

The Quaternary deposits and features of north-east Scotland have been studied for over 150 years, commencing with the pioneering work of Thomas Jamieson who reconstructed the glacial history of the region based mainly on the stratigraphical record (e.g. Jamieson, 1858[57], 1906[58]). Jamieson’s mantle was taken over by Alexander Bremner who published numerous papers in the early 1900s focussed particularly on the glacial meltwater channels formed during ice retreat (e.g. Bremner, 1934[59], 1942[60]). The significant early work by Jamieson and Bremner, their models of Late Devensian glaciation, and the work of later workers on the Quaternary geology of north-east Scotland were summarised in Merritt et al. (2003)[9], who provided a comprehensive account of the Cenozoic geology and landscape evolution of north-east Scotland.

References

1. ↑ BARREIRO, B A. 1998. U-Pb systematics on zircon from the Keith and Portsoy granites, Grampian Highlands, Scotland. *NERC Isotope Geosciences Laboratory, Report Series,* No. 132.
2. ↑ READ, H H. 1919. The two magmas of Strathbogie and Lower Banffshire. *Geological Magazine*, Vol. 56, 364–371.
3. ↑ 3.0 3.1 CARTY, J. 2001. Deformation, magmatism and metamorphism in the Portsoy Shear Zone, North East Scotland. Unpublished PhD thesis, University of Derby.
4. ↑ DEMPSTER, T J, ROGERS, G, TANNER, P W G, BLUCK, B J, MUIR, R J, REDWOOD, S D, IRELAND, T R, and PATERSON, B A. 2002. Timing of deposition, orogenesis and glaciation within the Dalradian rocks of Scotland: constraints from U-Pb zircon ages. *Journal of the Geological Society of London*, Vol. 159, 83–94.
5. ↑ OLIVER, G J H, WILDE, S A, and WAN, Y. 2008. Geochronology and geodynamics of Scottish granitoids from the late Neo- proterozoic break-up of Rodinia to Palaeozoic collision. *Journal of the Geological Society of London*, Vol. 165, 661–674.

6. ↑ 6.0 6.1 GUNN, A G, STYLES, M T, ROLLIN, K E, and STEPHENSON, D. 1996. The geology of the Succoth–Brown Hill mafic- ultramafic intrusive complex, near Huntly, Aberdeenshire. *Scottish Journal of Geology,* Vol. 32, 33–49.
7. ↑ 7.0 7.1 7.2 STEPHENSON, D and GOULD, D. 1995. The Grampian Highlands: British Regional Geology. (Keyworth, Nottingham: British Geological Survey.) ISBN 0 11 884521 7
8. ↑ 8.0 8.1 8.2 8.3 READ, H H. 1923. The geology of the country around Banff, Huntly and Turriff (Lower Banffshire and North-west Aberdeenshire) Explanation of Sheets 86 and 96. Memoir of the Geological Survey, Scotland. (Edinburgh: HMSO).
9. ↑ 9.0 9.1 MERRITT, J W, AUTON, C A, CONNELL, E R., HALL, A M, and PEACOCK, J D. 2003. Cenozoic geology and landscape evolution of north-east Scotland. Memoir of the British Geological Survey, Sheets 66E, 67, 76E, 86E, 87W, 87E, 95, 96W, 96E and 97 (Scotland).
10. ↑ 10.0 10.1 ASHCROFT, W A, KNELLER, B C, LESLIE, A G, and MUNRO, M. 1984. Major shear zones and autochthonous Dalradian in the north-east Scottish Caledonides. Nature, Vol. 310, 760–762.
11. ↑ 11.0 11.1 FETTES, D J, GRAHAM, C M, HARTE, B, and PLANT, J A. 1986. Lineaments and basement domains: an alternative view of Dalradian evolution. Journal of the Geological Society of London, Vol.143, 453–464.
12. ↑ 12.0 12.1 12.2 FETTES, D J, LESLIE, A G, STEPHENSON, D, and KIMBELL, S F. 1991. Disruption of Dalradian stratigraphy along the Portsoy Lineament from new geological and magnetic surveys. Scottish Journal of Geology, Vol. 27, 57–73.
13. ↑ WATT, W R. 1914. Geology of the country around Huntly (Aberdeenshire). Quarterly Journal of the Geological Society of Lon- don, Vol.70, 266–293.
14. ↑ SHACKLETON, R M. 1948. Overturned rhythmic banding in the Huntly gabbro of Aberdeenshire. Geological Magazine, Vol. 85, 358–360.
15. ↑ READ, H H, and FARQUHAR, O C. 1956. The Buchan anticline of the Banff nappe of Dalradian rocks in north-east Scotland. Quarterly Journal of the Geological Society of London, Vol. 112, 131–154.
16. ↑ STEWART, F H, and JOHNSON, M R W. 1960. The structural problem of the younger gabbros of north-east Scotland. Transactions of the Edinburgh Geological Society, Vol. 18, 104–112.
17. ↑ STEWART, F H. 1970. The 'younger' basic igneous complexes of north-east Scotland, and their metamorphic envelope: Introduction. Scottish Journal of Geology, Vol. 6, 3–6.
18. ↑ WEEDON, D S. 1970. The ultrabasic/basic rocks of the Huntly region. Scottish Journal of Geology, Vol. 6, 26–40.
19. ↑ MUNRO, M. 1970. A reassessment of the 'younger' basic igneous rocks between Huntly and Portsoy based on new borehole evidence. *Scottish Journal of Geology*, Vol. 6, 41–52.
20. ↑ MUNRO, M. 1984. Cumulate relations in the 'Younger Basic' masses of the Huntly–Portsoy area, Grampian Region. *Scottish Journal of Geology*, Vol. 20, 343–359.
21. ↑ MUNRO, M, and GALLAGHER, J W. 1984. Disruption of the 'Younger Basic' masses in the Huntly–Portsoy area, Grampian Region. Scottish Journal of Geology, Vol. 20, 361–382.
22. ↑ SADASHIVAIAH, M S. 1954. The form of the eastern end of the Insch mass, Aberdeenshire. Geological Magazine, Vol. 91, 137–143.
23. ↑ READ, H H, SADASHIVAIAH, M S, and HAQ, B T. 1961. Differentiation in the olivine-gabbro of the Insch mass, Aberdeenshire. Proceedings of the Geologists' Association, Vol. 72, 391–413.
24. ↑ CLARKE, P D, and WADSWORTH, W J. 1970. The Insch layered intrusion. *Scottish Journal of Geology*, Vol. 6, 7–25.
25. ↑ WADSWORTH, W J. 1986. Silicate mineralogy of the later fractionation stages of the Insch Intrusion, NE Scotland. *Mineralog- ical Magazine*, Vol. 50, 538–595.
26. ↑ WADSWORTH, W J. 1988. Silicate mineralogy of the Middle Zone cumulates and associated gabbroic rocks from the Insch Intrusion, NE Scotland. Mineralogical Magazine, Vol. 52,

309–322.
27. ↑ HAY, S V. 2002. Some geochemical and isotopic studies of the Insch, Huntly and Belhelvie Intrusions, NE Scotland. Un- published PhD thesis, Royal Holloway, University of London.
28. ↑ FETTES, D J. 1968. Metamorphic structures of Dalradian rocks in north-east Scotland. Unpublished PhD thesis, University of Edinburgh.
29. ↑ 29.0 29.1 FETTES, D J. 1970. The structural and metamorphic state of the Dalradian rocks and their bearing on the age of emplacement of the basic sheet. Scottish Journal of Geology, Vol. 6, 108–118.
30. ↑ DROOP, G T R, and CHARNLEY, N. 1985. Comparative geobarometry of pelitic hornfelses associated with the newer gabbros: a preliminary study. Journal of the Geological Society of London, Vol. 142, 53–62.
31. ↑ DROOP, G T R, CLEMENS, J D, and DALRYMPLE, D J. 2003. Processes and conditions during contact anatexis, melt escape and restite formation: the Huntly Gabbro Complex, NE Scotland. Journal of Petrology, Vol. 44, 995–1029.
32. ↑ 32.0 32.1 HUDSON, N F C. 1980. Regional metamorphism of some Dalradian pelites in the Buchan area, NE Scotland. Contributions to Mineralogy and Petrology, Vol. 73, 39–51.
33. ↑ 33.0 33.1 HUDSON, N F C. 1985. Conditions of Dalradian metamorphism in the Buchan area, NE Scotland. Journal of the Geological Society of London, Vol. 142, 63–76.
34. ↑ HUDSON, N F C. 1985. Conditions of Dalradian metamorphism in the Buchan area, NE Scotland. Journal of the Geological Society of London, Vol. 142, 63–76.
35. ↑ 35.0 35.1 35.2 BEDDOE-STEPHENS, B. 1990. Pressures and temperatures of Dalradian metamorphism and the andalusite-kyanite transfor- mation in the north-east Grampians. Scottish Journal of Geology, Vol. 26, 3–14.
36. ↑ CHINNER, G A. 1966. The distribution of pressure and temperature during Dalradian metamorphism. Quarterly Journal of the Geological Society of London, Vol. 122, 159–186.
37. ↑ PANKHURST, R J. 1970. The geochronology of the basic igneous complexes. Scottish Journal of Geology, Vol. 6, 83–107.
38. ↑ ASHWORTH, J R. 1975. The sillimanite zones of the Huntly–Portsoy area in the north-east Dalradian, Scotland. Geological Magazine, Vol. 112, 113–136.
39. ↑ 39.0 39.1 ELLES, G L. 1931. Notes on the Portsoy coastal district. Geological Magazine, Vol. 68, 24–34.
40. ↑ CHINNER, G A. 1980. Kyanite isograds of Grampian metamorphism. Journal of the Geological Society of London, Vol. 137, 35–39.
41. ↑ CHINNER, G A, and HESELTINE, F J. 1979. The Grampide andalusite/kyanite isograd. Scottish Journal of Geology, Vol. 15, 117–127.
42. ↑ 42.0 42.1 BAKER, A J. 1987. Models for the tectonothermal evolution of the eastern Dalradian of Scotland. Journal of Metamorphic Ge- ology, Vol. 5, 101–118.
43. ↑ DEMPSTER, T J, HUDSON, N F, and ROGERS, G. 1995. Metamorphism and cooling of the NE Dalradian. Journal of the Geological Society of London, Vol. 152, 383–390.
44. ↑ GOODMAN, S. 1994. The Portsoy–Duchray Hill Lineament: a review of the evidence. Geological Magazine, Vol. 131, 407– 415.
45. ↑ 45.0 45.1 45.2 VIETE, D R, RICHARDS, S W, LISTER, G S, OLIVER, G J H, and BANKS, G J. 2010. Lithospheric-scale extension during Grampian orogenesis in Scotland. 121–160 in Continental tectonics and mountain building: the legacy of Peach and Horne. LAW, R D, HOLDSWORTH, R E, KRABBENDAM, M, and STRACHAN, R A (editors). Special Publication of the Geological Society of London, No. 335. ISBN 978-1-86239-300-4
46. ↑ READ, H H. 1955. The Banff Nappe: an interpretation of the structure of the Dalradian rocks of north-east Scotland. Proceedings of the Geologists' Association, Vol. 66, 1–29.
47. ↑ RAMSAY, D M, and STURT, B A. 1979. The status of the Banff Nappe. 145–151 in The Caledonides of the British Isles– reviewed. HARRIS, A L, HOLLAND, C H, and LEAKE, B E (editors). Special Publication of the Geological Society of London, No. 8.

48. ↑ STURT, B A, RAMSAY, D M, PRINGLE, I R, and TEGGIN, D E. 1977. Precambrian gneisses in the Dalradian sequence of north-east Scotland. Journal of the Geological Society of London, Vol. 134, 41–44.
49. ↑ VIETE, D R, OLIVER, G J H, and WILDE, S A. 2014. Discussion of ‘Metamorphic P-T and retrograde path of high-pressure Barrovian metamorphic zones near Cairn Leuchan, Caledonian orogeny, Scotland’. *Geological Magazine*, Vol. 151, 755–763.
50. ↑ INSTITUTE OF GEOLOGICAL SCIENCES. 1978a. Moray–Buchan sheet 57°N-04°W 1:250 000 series, Bouguer gravity anomaly map.
51. ↑ INSTITUTE OF GEOLOGICAL SCIENCES. 1978b. Moray–Buchan sheet 57°N-04°W 1:250 000 series, Aeromagnetic anomaly map.
52. ↑ BRITISH GEOLOGICAL SURVEY. 1991. Regional geochemistry of the East Grampian area. (Keyworth, Nottingham: British Geological Survey.) ISBN 0 85272 198 6
53. ↑ ASHCROFT, W A, and WILSON, C D V. 1976. A geophysical survey of the Turriff basin of Old Red Sandstone, Aberdeen- shire. *Journal of the Geological Society of London*, Vol. 132, 27–43.
54. ↑ LESLIE, A G. 1984. Field relations in the north-eastern part of the Insch igneous mass, Aberdeenshire. Scottish Journal of Geology, Vol. 20, 215–235.
55. ↑ FLETCHER, T A. 1989. The geology, mineralisation (Ni-Cu-PGE) and stable isotope systematics of Caledonian mafic intrusions near Huntly, NE Scotland. Unpublished Ph D thesis, University of Aberdeen.
56. ↑ FLETCHER, T A, and RICE, C M. 1989. Geology, mineralisation (Ni-Cu) and precious - metal geochemistry of Caledonian mafic and ultramafic intrusions near Huntly, north-east Scotland. Transactions of the Institution of Mining and Metallurgy (Sec- tion. B: Applied Earth Science), Vol. 98, B185–200.
57. ↑ JAMIESON, T F. 1858. On the Pleistocene deposits of Aberdeenshire. Quarterly Journal of the Geological Society of London, Vol.14, 509–532.
58. ↑ JAMIESON, T F. 1906. The glacial period in Aberdeenshire and the southern border of the Moray Firth. Quarterly Journal of the Geological Society of London, Vol. 62, p. 13–39.
59. ↑ BREMNER, A. 1934. The glaciation of Moray and ice movements in the north of Scotland. Transactions of the Geological Soci- ety of Edinburgh, Vol. 13, 17–56.
60. ↑ BREMNER, A. 1942. The origins of the Scottish river system. Scottish Geographical Magazine, Vol. 58, 15–20, 54–59, 99–103.

Category:

- OR/15/026 Geology of the Huntly and Turriff districts

Navigation menu

Personal tools

- Not logged in
- Talk
- Contributions
- Log in
- Request account