OR/15/026 Summary

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.

This report describes the geology of the Huntly and Turriff districts that were mapped as part of the East Grampian Project, a major regional study carried out by the British Geological Survey in the 1980s and 1990s. This East Grampian area, totalling some 8500 km^2, had been mapped originally by the Geological Survey between 1885 and 1920, but coverage was very variable, based in part on one-inch-scale field slips. The academic community had largely neglected the area due to its generally poor inland exposure and complex geology. In consequence, the Dalradian stratigraphy and structure, the role of the mafic-ultramafic plutons, and the nature and timing of the Grampian orogenic event, were unclear.

The introductory chapter sets the scene both topographically and geologically. It briefly describes the main geological units represented in the districts and relates them to the geological history, with particular emphasis on the Grampian event of the Caledonian Orogeny. A section on the history of research describes the efforts of the early surveyors, notably H H Read, in delineating the nature and extent of both the bedrock and Quaternary units. Studies in the latter part of the 20th century have focussed on the mafic-ultramafic plutons, the nature of the Buchan metamorphism, and the search for economic minerals, in part linked to geophysical surveys. More recently, tectonic models that attempt to explain the geometry and timing of the Grampian event in north-east Scotland have been promulgated.

Dalradian Supergroup section describes the Dalradian stratigraphical succession but firstly explains the terminology used. Not all lithological units have been assigned to formations; some have only been assigned to subgroups or to groups. This partly due to the poor exposure, but also reflects the locally varied stratigraphy and the considerable structural complications. Grampian and Appin Group rocks are restricted to the north-western part of the Huntly district where they lie in the footwall of the Portsoy Shear Zone. Semipelite is the dominant lithology but the sequence contains significant quartzite, pelite (in part graphitic), metalimestone and calcareous units. This shallow marine shelf sequence has a generally coherent stratigraphy, except around Keith where metalimestone and semipelite units cannot be simply correlated. Appin Group rocks are overlain by quartzite of the Islay Subgroup (Argyll Group) and subsidiary pelitic units of the Easdale Subgroup, but in several places the stratigraphical sequence is truncated by the westernmost thrusts of the Portsoy Shear Zone. Within and adjacent to the shear zone are pelitic units attributed to the Argyll Group, which show affinities with Easdale Subgroup units elsewhere. Here they are host to several mafic-ultramafic intrusions. They are succeeded eastwards by migmatitic psammite and semipelite (Crinan Subgroup), in turn overlain by a mixed quartzite, psammite and pelite unit with thin metalimestones. This last unit, the Whitehills Grit Formation, and its semipelite-dominated lateral equivalent, the Clashindarroch Formation, belong to the Southern Highland Group, and appear to truncate the underlying Argyll Group succession progressively to the south-west. The more typical turbiditic Southern Highland Group rocks, mainly arenite (psammite) and pelite, are represented by the Macduff Formation, which underlies the south-east part of the Huntly district and most of the Turriff district.

Old Red Sandstone Supergroup section describes the Devonian Old Red Sandstone outliers, now

preserved in the fault-bounded Turriff and Rhynie basins. These northerly trending basins were infilled by fluvial and lacustrine sediments derived from erosion of the uplifted Caledonian Orogen. The sequence consists of conglomerates, sandstones and minor siltstones.

Cenozoic superficial deposits section describes the nature of the weathering profiles and products that developed under sub-tropical conditions in the Palaeogene and Neogene, and the isolated exposures of distinctive quartz gravels that occur in Buchan. These deposits are preserved due to the limited erosion beneath the ice sheets that spread across the districts during the Quaternary. Blue-grey clayey till, derived from offshore in the Moray Firth, has been transported east-south-east into the northern part of the Turriff district. Elsewhere fawn, pale grey, or orange-brown till that reflects the underlying bedrock was deposited from a generally cold-based Grampian ice sheet that advanced slowly from the south-west. Glacial meltwater channels are a distinctive geomorphological feature, particularly in the Turriff district, now commonly occupied by misfit streams.

Intrusive igneous rocks section describes the igneous rocks, a major feature of the Huntly and Turriff districts. They range from Neoproterozoic foliated granite, found in the Keith area, to the Early to Mid Ordovician age mafic-ultramafic plutons and related intrusions that dominate around Huntly and Knock and form the southern boundary to the districts (Insch Pluton). The later Ordovician granitic intrusions and sparse late Carboniferous quartz dolerite dykes are also described. The oldest mafic-ultramafic rocks, the Succoth-Brown Hill type, are dominated by clinopyroxene and are mineralogically and chemically distinct from the gabbros, norites, peridotites, etc of the Huntly, Knock and Insch plutons. They are now altered, deformed and metamorphosed; their age of emplacement is not known but they predate the main Grampian deformation event. The Ordovician mafic-ultramafic plutons exhibit cumulate compositional layering that ranges from dunite, peridotite, troctolite and olivine-gabbro (Lower Zone) to norite and gabbro (Middle Zone) and olivine ferrogabbro, monzonite and syenite (Upper Zone). The full sequence is best represented in the Insch Pluton. In contrast, in the Huntly and Knock plutons Lower Zone cumulate rocks exhibit steeply dipping layering and occur in separate disconnected bodies. The cumulate rocks show evidence of contamination and minor modification. Middle Zone lithologies are mainly represented by granular gabbros and norites that have been pervasively recrystallised and are commonly foliated. Contaminated and xenolithic gabbros and norites are abundant both within and marginal to the Huntly and Knock plutons. Pressure and temperature estimates of 4.5 kb and up to 900°C have been obtained from the contaminated and hornfelsed rocks showing that localised partial melting occurred. The generally poor exposure, combined with the variable and inter-leaved nature of the igneous and metasedimentary rock types, and the structural complexity, have necessitated the use of borehole data and geophysical surveys to decipher their geology. Other sheeted mafic bodies occur farther east around Marnoch, and also west of the Portsoy Shear Zone. The relationships of these amphibolitic gabbros and metadolerites to the main plutons are unclear, but their lithologies and field relationships suggest that they were emplaced roughly coeval with the main bodies. Small granitic pods and dykes occur within and adjacent to the mafic-ultramafic plutons, and larger diorite and granite bodies are also present. Isotopic age determinations suggest that they were emplaced only a short time after the main mafic-ultramafic plutons.

Concealed geology section highlights the main anomalies and features shown by the regional gravity and magnetic data. The data is used to erect 2D and 3D models that attempt to reconcile gravity and magnetic profiles with the main features of the geology and thus to extend the geological interpretation to deeper crustal levels. The geophysical modelling suggests that the Insch Pluton extends to about 2.5 km, but the Huntly Pluton is limited to relatively shallow depths (< 1 km). Gravity data is used to model the thickness of the Old Red Sandstone sequence in the Turriff Basin, suggesting that it ranges from 800 m in the north to 1400 m farther south.

Structure section describes the regional and detailed structure of the Huntly and Turriff districts,

which is dominated by the Portsoy Shear Zone. This steeply east-south-east-dipping structure shows evidence of a long history and marks the western extent of the Ordovician mafic-ultramafic plutons. Its trace corresponds to a lineament across which the Dalradian sequence shows distinct facies and lithological variations. Subsequently, it appears to have acted as a major thrust zone that transported the upper parts of the Dalradian succession to the west-north-west. There is evidence for later lateral transcurrent movements and faulting. Exposures of shear zone/fault rocks are sparse, but ductile shear zones occur both within the mafic-ultramafic plutons and in places farther west. A further shear zone, the Keith Shear Zone, tracks across the north-west part of the Huntly district. The textures, fabrics and lineations in the granites within this moderately south-east-dipping shear zone show clear evidence of thrust movement to the west-north-west. Shear zones are also present at or adjacent to the northern margin of the Insch Pluton. The structures and fabrics in the Dalradian rocks were formed during two main deformation and related metamorphic events; one predates emplacement of the Ordovician mafic-ultramafic plutons, the other postdates emplacement. The early deformation is linked to few if any large-scale folds, but has resulted in a pervasive cleavage and metre- to kilometre-scale folding. The secondary deformation is linked to large-scale folding that controls the distribution of stratigraphical units but is only seen in the higher grade rocks below the andalusite isograd. Related cleavage development ranges from penetrative, to locally developed, to absent. Within the Portsoy Shear Zone several deformation phases can be identified locally, but their interrelationships and correlation to the regional pattern is unclear. Two boreholes, drilled by Drumnagorrach Farm illustrate the variable pattern of deformation and its relationships to the mafic-ultramafic intrusive rocks. The regional structure of the Turriff district is largely governed by the late-stage open Turriff Syncline, which has a broad hinge zone and folds the metamorphic isograds. Models for the structural evolution of north-east Scotland and the role of the Portsoy Shear Zone during the Grampian event are discussed. The role and pattern of faulting is also described. North-west-trending faults offset elements of the Portsoy Shear Zone and parts of the Huntly and Knock plutons and north-trending faults have controlled the development of the Devonian half-graben basins. East-north-east-trending faults are generally interpreted as late Carboniferous in age.

Metamorphism section describes the pattern of metamorphism that developed in the Dalradian rocks during the Grampian orogenic event. The mineral assemblages range from chlorite and biotite grade (greenschist facies) at shallow exposed levels in the Turriff district up to sillimanite + K feldspar (upper amphibolite facies) at deeper crustal levels adjacent to the Ordovician mafic-ultramafic plutons. In the marginal and contaminated zones of the Huntly and Knock plutons granulite facies conditions were attained and partial melting occurred locally. Here igneous intrusion overlapped with peak metamorphic conditions. The metamorphic mineral assemblages have been divided into two facies series, namely the lower pressure Buchan series, and the medium pressure Barrovian series. Buchan assemblages occur east of the Portsoy Shear Zone and Barrovian assemblages to the west. However, there is evidence of Barrovian overprinting of Buchan assemblages (kyanite after andalusite) in the footwall of the Portsoy Shear Zone, implying a marked pressure increase attributed to west-north-west-directed thrusting across the shear zone. The Insch Pluton show good evidence of a metamorphic aureole on its northern side, manifest as biotite, cordierite and andalusite development in the slate hills. The earliest formed metamorphic assemblages ranged from Buchan to Barrovian from east to west, and developed shortly after the first main deformation. Subsequent thrusting and development of the second major structures were accompanied by a Barrovian overprint, but this is absent from rocks at shallow crustal levels. Many of the assemblages have been partially or even wholly retrogressed.

Applied geology section describes the Applied Geology of the districts. It summarises the geological resources, namely hard rock (aggregate), building stone, limestone and dolomite, slate, sand and gravel, brick clay, peat and metalliferous minerals. Although there has been extraction of many of

these materials in the past, most are not currently exploited. The search for metalliferous minerals has not resulted in any identifiable economic deposits and exploration has now ceased, although concentrations of Ni and Cu were found. The hydrogeology of the Huntly and Turriff districts is also described. Groundwater flow in the bedrock is invariably fracture and fissure controlled. Superficial deposits, particularly sands and gravels, do form more permeable local aquifers. Springs are numerous and have been used for water supply for generations. Since the introduction of the Deveron Water Scheme and provision of a mains supply the use of local groundwater sources has declined markedly.

Sources of Information section lists the multiple sources of information on the geology of the districts held by the British Geological Survey. The sources are listed under numerous subject headings and subheadings to assist with searches. Note that much of the data and map information is now available in digital formats

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