Rocks of Devonian age that form a small part of the Old Red Sandstone Supergroup crop out in the Turriff Outlier and in the Rhynie and Bogie outliers in Strathbogie, south of Huntly (Figure 1). The Turriff Outlier occupies an approximately 4 to 8 km-wide half-graben which extends for a further 10 km north-eastwards to the coast at Gardenstown and Gamrie in the Banff district (Sheet 96E). It contains units of the Upper Devonian Crovie Sandstone Group and the Middle Devonian Inverness Sandstone Group, separated by an unconformity that is well seen on the Banffshire coast (Read, 1923[1], Archer, 1978[2]; Trewin et al., 1987[3]). The western boundary of the outlier is defined by the Afforsk Fault (Read, 1923[1]), a major structure that dips steeply to moderately eastwards. Two subsidiary parallel, approximately north–south trending faults define a horst and a further fault-
bounded outcrop immediately to the west of the main basin. This last outcrop extends through the eastern part of Turriff itself. The succession through the Old Red Sandstone rocks of the Turriff Outlier is shown schematically in Figure 2. Note that the Gardens-town Conglomerate Formation (Inverness Sandstone Group) is locally directly unconformable on the Macduff Formation in the southern part of the outlier. The overall thickness of the succession has been estimated from gravity modelling as between 800 m in the north and 1400 m in the south (see Concealed geology section).

The Bogie Outlier forms a narrow northern extension of the larger Rhynie Outlier, which outcrops mainly in the adjoining Alford district (Sheet 76W) to the south (Gould, 1997[4]). In Strathbogie the outlier is fault bounded on its western side between Newnoth [NJ 518 302] and Mains of Collithie [NJ 515 352].

The northern tip of the main Rhynie Outlier is terminated by a fault which extends from just west of Newnoth, east-north-eastwards up the Glen of Cults between Knockandy Hill [NJ 550 314] and Hill of Corskie [NJ 540 324]. To the north of this Glen of Cults Fault, erosion has removed the upper part of the succession, including any overstep of the Tillbrachty Sandstone Formation to the west across the north-south trending Strathbogie Fault. The Strathbogie section of the Rhynie Outlier was originally thought to be bound to the west by a significant fault giving rise to a half-graben structure similar to that of the Turriff Outlier. There is little doubt that the western margin of the outlier is faulted, but the significance of this fault in relation to the structure of the outlier has been called into question by Trewin and Rice (1992)[5]. Their borehole investigations of the outlier around Rhynie suggest that rocks of the Tillybrachty Sandstone Formation lie unconformably on the Macduff Formation on the western side of the outlier. This is the interpretation shown on the 1:50 000 map of the Alford district (Sheet 76W), which has been continued northwards. If correct, it implies that the Rhynie Outlier has a synclinal structure modified by coeval faulting (Gould 1997[4]; fig. 24b). The age of the sequence in the Rhynie inlier, notably that of the Rhynie Chert, has been estimated from detailed assessment of the spore assemblage as early

Praghain to early Emsian (Wellman, 2006[6]). Recent isotopic ages give contrasting results. Mark et al. (2011)[7] obtained an \(\text{Ar}^{40}/\text{Ar}^{39}\) age of 403.9 ± 2.1 Ma from orthoclase feldspar in a hydrothermal vein from the Rhynie Chert. However, Parry et al. (2011)[8] have reported an ID-TIMS U-Pb zircon age of 411.5±1.3 Ma from the nearby andesitic lavas that relate to the fossilised sinter (hot spring) deposits preserved at Rhynie.

The lithostratigraphical descriptions that follow are mostly based on those of Read (1923)[1].

**Turriff outlier**

**Crovie Sandstone Group**

Rocks considered to be of Early Devonian age (Praghian to Emsian; Westoll, 1977[9]) in north-east Scotland are assigned to the Crovie Sandstone Group. They outcrop in a narrow strip up to 1.7 km wide along the eastern margin of the Turriff Outlier between Meikle Gourdas [NJ 775 415] in the south and east of Byth House [NJ 818 564] in the north-east corner of the Turriff district. There is no continuous section through the sequence, merely isolated exposures in burns, small quarries and pits.

The basal unconformity is only exposed on the roadside a little north-west of Keithen [NJ 795 452] (Read, 1923). Here a thin basal breccia, composed mainly of angular to subangular clasts of gritty arenite and semipelite, patently derived from the underlying Macduff Formation, is overlain by red sandstones and conglomerates that in turn pass up into red sandstones. The rocks all dip to the west
at between 20° and 40°. A thicker development of the basal breccia and conglomerate unit has been interpreted to occur between Cuminestown [NJ 804 503] and New Byth [NJ 822 540] but outcrop is poor and the unit may well be lenticular. The basal breccia and conglomerate is succeeded by dull red to reddish grey sandstones with thin shale partings that form the bulk of the sequence. Pebby lenses and clay galls occur locally. An example is recorded some 900 m south-west of Byth House at [NJ 8115 5572] where in a small quarry red clay galls are concentrated along bedding planes in coarse-grained micaceous sandstones. Dips in the sandstones are generally lower than in the underlying conglomerates, varying between about 10° and 25°. Given an overall dip of 20° the overall sequence can be estimated at about 500 m thick around Byth House.

**Inverness Sandstone Group**

**Gardenstown Conglomerate Formation**

The Crovie Sandstone Group succession is unconformably overlain by conglomerates and breccias of the Gardenstown Conglomerate Formation of the Inverness Sandstone Group. These rocks dominate in the Turriff Outlier, overstepping the Crovie Group in the southernmost part of the outlier to lie directly on the Macduff Formation. In general, bedding dips gentle westwards, normally between 10° and 30°, but steeper dips do occur in parts, notably adjacent to the west- bounding faults where bedding dips locally exceed 60°. The unit becomes more sandstone rich in the ground around Wood of Delgaty [NJ 760 500], where Read (1923) recorded about 35 m of dull red sandstone intercalated with breccia and conglomerate. The sandstone thins to the south towards Hatton Castle [NJ 758 469]. Exposures recorded by Read in several former quarries around the Water of Idoch show sandstones in beds 0.3 to 1 m in thickness with thin beds of conglomerate and scattered pebbles. The sandstones are locally interbedded with thin beds of purple shales. The sandstones indicate a general fining upwards sequence in the Gardenstown Conglomerate Formation; any pre-existing fine-grained lithologies have subsequently been removed by erosion.

**Bogie outlier**

**Rhynie Group**

**Tillybrachty Sandstone Formation**

Much of the following text is based on observations made by Read (1923), and others therein, based partly on exposures which are no longer visible. The base of the Lower Devonian Tillybrachty Sandstone Formation occurs in the Glen of Cults [NJ 535 315] where it is marked by a thin (0.7 m) conglomerate unit resting unconformably on rocks of the Macduff Formation. The conglomerate includes abundant local clasts and is overlain by green and dark grey calcareous shales with nodules and thin beds of limestone probably resulting from caliche development in a semi-arid environment. These shales contain fragmentary fossil plant remains, identified by Kidston as resembling *Pachytheca* (Read, 1923, p.180). The plant remains occur at a similar stratigraphical horizon to that of the Rhynie Chert Member (Dryden Flags Formation) that occurs 5 km to the south-west and whose flora was described in detail initially by Kidston and Lang (1917, 1920a, b, 1921a, b). The green and grey shales are overlain by red laminated sandy shales and friable red sandstones.

Included within the Tillybrachty Sandstone Formation are andesitic lavas. Although only locally developed south of the Glen of Cults fault, they form the bulk of the succession to the north of the fault. They extend up the valley of the Bogie to near Mains of Collithie [NJ 516 352] fringed on their eastern side by a very thin strip of sandstone and shale. In 1990 the A97 was realigned on its west...
side immediately north of Kirkney Bridge [NJ 518 336] by Culdrain, exposing deeply weathered andesitic lavas lying beneath purple and green volcanielastic and tuffaceous sandstones. This indicates that the lavas are interbedded with locally derived sandstones. The lavas were known locally as ‘cork rock’ because of their vesicular character and light weight. The extent of the lavas can be discerned from the distribution of fragments in the fields between Newnoth [517 302] and Mains of Collithie. The lavas are typically highly altered by weathering or hydrothermal activity. Rice et al. (1995) obtained a fresher sample of andesitic lava from a small quarry by the A97 near Whitelums at [NJ 521 324]. They also recorded the presence of associated volcanielastic rocks that show features typical of hyaloclastites. The lava consists of sparse microphenocrysts of both plagioclase feldspar (An 48–An 53) and chloritic pseudomorphs after olivine in an ophitic matrix composed of calcic augite, abundant ilmenite laths and largely devitrified interstitial glass. Geochemical analysis showed it to be a basaltic andesite belonging to the high K calc-alkaline series. The lava also shows high LILE/HFSE ratios (e.g. Ba/Nb – 32, Rb/Nb – 3, Th/Nb – 0.56, La/Mb – 2.63) and a high Zr/Nb ratio. These features are typical of subduction-related magmas and the andesite is geochemically similar to calc-alkaline lavas near Montrose (Rice et al., 1995).

Read (1923) noted that andesitic lavas appear to predominate, but he also described a dark green olivine basalt from the Whitelums area [NJ 520 322]. In thin section the rock consists of sparse large plagioclase phenocrysts (labradorite) in an ophitic matrix of augite, plagioclase and highly altered olivine. Iron oxide is not common. Read considered the rock to represent a mafic sill intruded into the lavas, but noted that its field relationships could not be seen.

South of the outcrop of lavas, conglomerate is exposed in the River Bogie some 200 m south-west of Candy [NJ 530 303]. The conglomerate is composed of pebbles of locally derived arenite, slaty pelite and red sandstone and was interpreted by Read (1923) to overlie the lava sequence.

Dryden Flags Formation

The Tillybrachty Sandstone Formation is overlain by very poorly exposed sandstones and shales of the Dryden Flags Formation. These are better known from their type area in the Rhynie district to the south, where they host the famous Rhynie Chert deposits (Archer, 1978; Rice and Trewin, 1988). Here they contain dessication cracks, mudflake breccias and caliches indicative of semi-arid lacustrine environments on an alluvial plain. Read (1923) documented grey to reddish grey, flaggy micaceous sandstone and shales that were exposed by the River Bogie, adjacent to Haremire farmhouse [NJ 525 300], and just east of the bridge on the minor road opposite Smithston at [NJ 521 215].

Environmental setting

During Early and Mid Devonian times Scotland lay some 30° to 25°S of the equator and formed part of a large continental mass termed Laurussia that incorporated much of North America, Greenland and northern Europe. Climatic conditions were subtropical and sedimentation was typically terrestrial to lacustrine, occurring in fault-controlled sedimentary basins, formed during the major uplift that marked the last phase of the Caledonian Orogeny. The resulting Old Red Sandstone Supergroup rocks in north-east Scotland formed in small restricted basins whose sedimentary fill was mainly conglomerates, sandstones and siltstones. The common occurrence of caliche limestones testifies to the presence of palaeosols and there is other evidence of the periodic emergence of the succession, e.g. dessication cracks, plant remains, rip-up mud clasts.

The Turriff Outlier contains basal lithologies that reflect their local derivation and deposition in alluvial fans. The sandstones were deposited by a northward flowing river system that prograded...
farther north into an impermanent lake. The overlying conglomerates and sandstones of the Middle Devonian Gardenstown Conglomerate Formation were probably deposited in alluvial fans from high energy rivers, again probably flowing northwards. The presence of an Achanarras fish fauna near Gamrie on the coast shows that the Orcadian Lake did cover parts of the area at the time of maximum transgression but at other times alluvial conditions prevailed (Trewin and Thirlwall, 2002).

The Lower Devonian sandstones and shales of the Rhynie/Bogie outlier were also deposited in a fault-controlled basin dominated by alluvial fan systems that here gradually gave way to a dominantly lacustrine environment. Again palaeocurrents appear to have flowed northwards. The Tillybrachty Sandstone Formation contains conglomeratic lenses and is an immature, poorly sorted unit probably indicative of deposition from flash floods on outwash fans. The overlying Dryden Flag Formation represents a dominantly lacustrine and alluvial plain environment. Thin andesitic lava flows were extruded locally in the basin during deposition of this unit and the fossil sinter deposit that is the Rhynie Chert Member represents extensive localised hot spring activity. Despite the semi-arid conditions and tropical latitudes the environment was locally biologically very active, as shown by the plant flora and mainly arthropod fauna preserved at Rhynie and the abundant bioturbation of the sands, silts and muds by burrowing organisms.

References


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