Excursion 5 Bridge of Allan and Dumyat

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Purpose: To examine lavas and volcaniclastic rocks of the Ochil Volcanic Formation (Arbuthnott–Garvock Group) and related small sills; to view fluvially deposited sandstones of the Scone Sandstone Formation, which are well displayed in a former building-stone quarry.

Logistics: The itinerary is a long single day, but could be shortened. Localities 5.1–5.5, in and around Bridge of Allan, make a convenient half day on foot. Localities 5.1–5.4 could be added to the footpath between the Sheriffmuir road and Dumyat, linking Localities 5.7–5.9 to make a whole day, returning via the same footpath to transport parked at Bridge of Allan or along the Sheriffmuir road near Locality 5.7 (***this road is not suitable for coaches***). Because of the precipitous nature of some of the crags and the height of summertime bracken, the mineralisation at Blairlogie (Localities 5.9 and 5.10) might best be viewed as a separate visit (half day), upstream via the track behind the car park on the A91 to the east of the village. Any of the whole-day itineraries will involve at least 8 km of walking, though it is not particularly steep except on the Ochil Fault Scarp itself.

Maps: OS 1:50,000 sheets 57 Stirling and 58 Perth & Kinross; OS 1:25,000 Sheet 366 Stirling & Ochil Hills West; BGS 1:50,000 sheets 39W Stirling and 39E Alloa; locality map (Figure 5.1).

This excursion deals with the youngest lavas in the Ochil Volcanic Formation. Some of the flows, which dip NW at 15° and are mainly andesite and basalt, contain patches of quartzose sandstone and siltstone. These are examples of peperite, which indicates interaction between wet sediment and hot magma. The interbedded volcaniclastic rocks are coarsest and thickest along this southern margin of the Ochil Hills. Minor intrusions include a microgranitic sill that makes an escarpment with prominent talus (scree).

The overlying fluvial sandstones of the Scone Sandstone Formation are also seen (Locality 5.1), where the youngest lava flow forms the top of the exposed sequence. Copper mineralisation is seen at some of the old mine workings, as veins in the volcanic rocks. Distant landscape views are a striking feature of this walk.

Locality 5.1 [NS 7895 9808] Wolf's Hole Quarry: Scone Sandstone Formation

Park at [NS 7893 9801] outside the quarry entrance at the west end of Sunnylaw Road, Bridge of Allan. This quarry, last worked in 1899, provided much building stone for the expansion, during the nineteenth century, of Bridge of Allan as a notable spa town. Massive, cross-bedded brown sandstones are overlain by one of the youngest lava flows of the district (Plate 5.1). The sandstones, which belong to the basal Scone Sandstone Formation of the Arbuthnott–Garvock Group (Armstrong & Paterson, 1970; Browne *et al*., 2002), have yielded ostracoderm fishes, including *Pteraspis mitchelli, Cephalaspis scotica* White, *Securiaspis caledonica* White and *S*. *waterstoni* White (Dineley & Metcalf, 1999). The sandstones, which were deposited in braided river channels, display cross-sets about 1 m thick. Both on erosional surfaces and within massive units, thin strings of pebbles and coarse-grained sandstone are picked out. Thin pale-grey siltstone beds, interpreted as overbank deposits, may also be observed between the sandstone units. The overlying vesicular olivine basalt lava flow is best seen at the quarry entrance [NS 7915 9793].

Feldspar phenocrysts up to 5 mm long are picked out in a weathered matrix. Onion-skin weathering is prominent. **Be aware of possible rock falls from the lava, even though the quarry is used for climbing**. There is an interpretation board at the entrance, and a published trail leaflet is available from Stirling and Clackmannan RIGS Group.

Locality 5.2 [NS 7915 9793] Mine Wood: Ochil Volcanic Formation conglomerates; mineralisation

East of Wolf's Hole Quarry, conglomerate, comprising subangular to subrounded water-worn pebbles of lava in a sand-grade volcaniclastic matrix, are seen near the Coppermine Path in Mine Wood, or preferably along the road. It is probable that the conglomerates have been eroded and transported by sporadic flash floods and laid down as flood (or wadi) fan deposits. Good exposure of a boulder conglomerate is seen at the adit to Airthrey Hill Mine [NS 7955 9786]. The mine was driven along two veins of pink baryte, and although the adit is boarded up, mineralisation may still be seen in the roof entrance. The veins cut a boulder conglomerate. Copper minerals were worked intermittently between 1661 and 1815. Even earlier working may have taken place in the sixteenth century when, according to tradition, copper from Bridge of Allan was used in the first coinage of bawbees, struck in the mint at Stirling for the coronation of Queen Mary in 1543. The copper ores include chalcopyrite and grey copper ore (chalcocite and tetrahedrite). Pyrite and mispickel are also present. During the mid-eighteenth century two shafts were sunk into the mineral veins and a day level constructed to drain spring waters from the workings. This operation proved to be of great benefit to the town since it provided easy access to the waters which, being mineralised, became popular with townsfolk and visitors alike. Soon large numbers of visitors were arriving to 'take the waters' at Airthrey Well. Following the abandonment of the copper workings, in the early years of the nineteenth century, the exploitation of the waters continued apace. Samples collected by Sir Ralph Abercrombie in 1820 were analysed and found to be rich in dissolved minerals (Dickie & Forster, 1974, pp. 15–19). The waters, though salty, became famed for their medicinal qualities and led to the development of Bridge of Allan as a notable nineteenth-century spa.

In 1821 a well house was built by Sir Ralph over the top of the lowermost shaft (35 m deep) on the main workings. The first bath house was completed in 1829 and over the next few decades several hotels and residences were built to accommodate the increasing number of visitors. The Bridge of Allan Hotel in Sunnylaw Road, built in 1864, the nearby Pump House in Mine Road, the Royal Hotel in Henderson Street, and many fine mansions in the area constructed of the local sandstone testify to the prosperity and success of the Spa in Victorian times. The location of Airthrey Silver Mine, which yielded about 12 tonnes of ore between 1760 and 1764, was originally considered to be in the vicinity of Airthrey Hill Copper Mine. It is now thought to be sited about 18 m north of a hairpin bend on the Blairlogie–Sheriffmuir road [NS 8152 9720], above old Logie Church (Francis *et al*., 1970, p. 294). Here, an adit on the east side of a small stream is cut into a 15–25cm-thick mineralised breccia containing calcite, chalcopyrite, iron minerals and galena.

Locality 5.3 [NS 8015 9770] Pendreich Road: viewpoint geology

Walk up the Coppermine Path, to reach Pendreich Road. Walking SE along this lane, past Drumbrae Farm, a fine view of both local and distant geology and scenery is seen. Ben Lomond, Ben Venue, Ben Ledi and other mountains of Dalradian rocks of the Grampian Highlands can be seen, north of the Highland Boundary Fault. In the middle distance, the low ground of the Carse of Stirling is composed of Holocene mudflat intertidal deposits, underlain by Late Devensian marine silts, clays and sands deposited after the last ice sheet abandoned this area 14,000 years ago. Formerly, the carse was blanketed by peat but much was removed 200 years ago to provide farming land. The stepped or terrace-like features of the Touch and Gargunnock hills, comprising a succession of Lower Carboniferous basaltic lava flows (Clyde Plateau Volcanic Formation), form the abrupt southern margin of the valley of the Forth. Prominent hills above the valley floor, including Stirling Castle rock and Abbey Craig (110 m above OD) which at times formed islands in the post-glaciation seas, represent remnant outcrops, offset by faulting, of the Midland Valley Sill-complex. The dolerite was harder and more resistant to glacial scouring than the Carboniferous sedimentary rocks into which it was intruded.

Locality 5.4 [NS 8050 9718] Hermitage Wood: Ochil Volcanic Formation conglomerates

Reaching Sheriffmuir Road, the entrance into Hermitage Wood is gained through a door in the wall. The path through the wood should be followed high above the campus of Stirling University, descending eventually to Airthrey Castle [NS 8120 9670]. Fine examples of water-laid, bedded, volcaniclastic pebble conglomerate and medium- to coarse-grained sandstone may be seen in various sections. The sedimentary rocks dip gently to the NW. The conglomerates consist of commonly well-rounded, water-worn pebbles and boulders of lava. Locally, imbrication is evident. These Lower Devonian sedimentary rocks, as elsewhere in the Midland Valley, probably accumulated under semi-arid conditions. It seems likely that most of the conglomeratic deposits were derived from pre-existing volcanic debris and lavas, transported and laid down in a series of coalescing fans that developed from time to time.

Locality 5.5 [NS 8116 9677] Stirling University campus: geomorphology and Quaternary history

Just north of Airthrey Castle (built in 1791 by Robert Haldane to a design by Robert Adam) a superb example of a wave-notched cliff and platform (about 30 m above OD), cut into coarse-grained volcaniclastic rocks, may be seen (Plate 5.2). The crudely bedded, locally imbricated conglomerates, which consist of ill-sorted fragments and boulders of igneous rock, commonly subangular, set in a fine-grained matrix, probably represent a debris flow. The cliff, which may have been etched prior to the last glaciation, is considered to have defined a shoreline of the sea during the Late Devensian, about 14,000 years ago, shortly after ice vacated the area. The notch in the cliff can be seen 100 m NNE of the castle, at [NS 8116 9677], just before the rhododendron wood.

The university campus is sited on superficial deposits, which are shown on BGS maps as 'late-Glacial raised beach deposits' (Figure 5.2). Sissons & Smith (1965) however, on the basis of detailed levelling, regarded all the deposits except those underlying the low ground of the playing fields as kame terraces, formed at a time when the ice margin of the Forth glacier stood near Stirling (Figure 5.2). The two interpretations appear incompatible. It is possible that both ice-contact and marine depositional processes played a part in the formation of the deposits. Sissons & Smith (1965) considered that the ice front of the Forth glacier was positioned close to the kame terraces, which they surveyed between Bridge of Allan and Airthrey Castle (Figure 5.2). While it is recorded that Airthrey Loch was artificially excavated as part of improvements to the Airthrey Estate in the nineteenth century by Sir Robert Abercrombie, the depression may be partly natural, which is compatible with the view that it represents a kettlehole. The presence of kettleholes lends credence to an ice-contact origin but, as has been demonstrated in east Fife (Chisholm, 1966), kettleholes can form in beach deposits.

The possibility of marine planation and partial reworking of rock, till and kame deposits at a later stage in deglaciation cannot be excluded. The area on (Figure 5.2) shown as 'Late Devensian raised beach deposits' demonstrates the extent over which such planation may have taken place. The ice-contact depositional mode of origin preferred by Sissons & Smith (1965) seems a more feasible explanation for the sand and gravel deposits. However, if sea level was high (at *c*. 30 m above OD) while the glacier margin stood at Stirling, the meltwater deposits formed at this time (14,000 years ago) most likely represent some form of ice-contact delta moraine which has suffered partial reworking by marine processes.

The MacRobert Centre is named after Lady MacRobert, Rachel Workman, who did pioneering geological work in the Eildon Hills near Melrose. The estate was acquired by the university in 1966. All the modern university buildings are faced with chips of marble from Torrin in Skye, together with subordinate basalt chips.

Locality 5.6 [NS 8133 9800] Sheriffmuir Road: glassy hypersthene andesite sill

On the Sheriffmuir road, approximately 1 km NNW of Logie Church, examples of hypersthene andesite can be seen in the stone walls. The rock crops out along both sides of the track leading eastwards from the road towards Dumyat, and where fresh, has been described as a very striking and beautiful rock, pitch black, with a velvety lustre and veins of brilliant red. Even where it is devitrified and brownish in colour, it contrasts with the weathered and dull-coloured porphyritic lavas of the neighbourhood. The rock contains no vesicles, but has a well-marked fluxion structure in which phenocrysts of feldspar and green hypersthene are embedded in a mainly glassy groundmass. The rock was mentioned by Geikie (1897, p. 276) under the heading of 'Bedded Lavas', but was mapped by Peach as an intrusive sheet – an interpretation reinforced at the western extremity of outcrop by discordance across the bedding planes of the volcaniclastic rocks above and below. Indeed, it can be seen from careful examination that the discordance between andesite and baked sedimentary rock, particularly the fine-grained green siltstone, is so highly complex as to resemble the peperites described by Kokelaar (1982) from the Lower Devonian volcanic rocks of Ayrshire, where high-level sills were emplaced into wet unlithified sediments and caused fluidisation.

Locality 5.7 [NS 8320 9780] West of Dumyat summit: microgranodiorite sill

Eastwards towards Dumyat, the track crosses basalts, andesites and volcaniclastic rocks. They are displaced by a series of NNW-trending faults, which have given rise to prominent erosion gullies. Good exposures of green sedimentary rock may be seen 30 m from the start of the upper path [NS 8158 9787]. At [NS 8167 9783] on smooth rounded exposures, there is a good example on the path of flow texture (fluxion), and an excellent view of Ben Lomond, Ben Ledi, Stob Binnein, Stuc a' Chroin, Ben More and Ben Vorlich. Continue uphill, where eventually, north of the track, a thick microgranodiorite (formerly called 'acid porphyrite') forms pink-weathering crags and screes (>100 m long, (Plate 5.3)). Before reaching the microgranodiorite, a volcaniclastic conglomerate crops out on the path after a sharp bend where it climbs markedly higher, with a tongue or wedge of sandstone at [NS 8257 9773]. Green lichen covers the scree and pink rock at [NS 8273 9781]. In hand specimen, the sill is made of a blotchy pink and purple rock containing scattered microphenocrysts of plagioclase feldspar in a fine-grained groundmass. It is mapped as a sill (striking 110° and dipping 26°N) partly because it thins out abruptly along strike and also because a very similar body farther south shows signs of minor transgression (i.e. discordance across interbedded lavas and volcaniclastic rocks).

Localities 5.8 [NS 8357 9768] to 5.9 [NS 845 985] Dumyat summit to Menstrie Glen: Ochil Volcanic Formation

Walk eastwards from the summit of Dumyat towards Menstrie Glen for about 550 m and find the footpath downhill towards Menstrie Glen (the glen itself is deep and partly inaccessible); a volcanic sequence 600 m thick is traversed (Francis *et al*., 1970, pp. 31–32). It includes more than 20 lava flows ranging in thickness from 3–30 m with eight volcaniclastic intercalations, some of them breccias up to 45 m thick. The uppermost flows, near Dumyat summit, are basaltic, with a thick feldspar-phyric variety capping three flows which are partly flow-banded. Most of the lavas below these lack any distinctive macroscopic features; they are aphyric or microporphyritic, in hues of grey, blue or purple. Downhill from the summit are minor solifluction terracettes on the lee slope. From [NS 8411 9765], follow the path downhill towards the glen. In the first prominent crags on the left hand side, just above the path, there are exposures of imbricated conglomerate, intercalated with lavas. The conglomerate has subrounded to subangular clasts and is matrix supported. Lenses of green sedimentary material occur within the lava by the footpath below the crags at [NS 8416 9768]. Microporphyritic, pink and greenish grey, devitrified glassy lava occurs at [NS 8438 9750]. A prominent cave in volcaniclastic conglomerate can be investigated at [NS 8442 9746] (Plate S.2). Two flows near the base can be readily distinguished. The higher, just above Lipney Cottage [NS 8465 9725], is a block-jointed pyroxene andesite with plagioclase phenocrysts set in a brown fine-grained base and with vaguely defined ropy layers. The lower, just below the cottage, on the north side of track [NS 8427 9710], is a flow-banded trachyandesite with red mottling and distinctive platy weathering.

Pass the fenced-in water supply installation on the right hand side of the path, then take the grassy path that meets a rough unmetalled road. By the gate just above the farm buildings of Dumyat Farm, on the roadside, are exposures of lava then conglomerate. If parked at Sheriffmuir Road, return to vehicles and end excursion here. If on foot, continue to Locality 5.10.

Locality 5.10 [NS 829 973] Blairlogie: Ochil Volcanic Formation

The steep slopes above Blairlogie are formed mainly of thick sequences of unsorted volcaniclastic breccias interrupted by only a few thin flows of basalt lava with trap featuring (Plate 5.4), which tail out to the west, and by a few porphyritic microdiorite and highly altered microdioritic dykes and small plugs. The sequence is traversed by a set of NNE- and NNW-trending faults, weathered out in gullies. The faults above the village are mineralised and have been explored at several points by trial adits (horizontal entrances), most of which are driven for only a very short distance into the hill. They can be seen from [NS 8365 9696], where the path leaves the road to cross a burn by a notice board. The principal copper ores recorded from these veins are chalcocite (Cu_2S) and tetrahedrite (Cu, Fe, Ag, Zn)$12Sb_4S_{13}$ with some malachite $Cu_2(CO_3)(OH)_2$ and chrysocolla $Cu_{2-x}Al_x(H_{2-x}\ Si_2O_5)(OH)_4{\cdot}nH_2O$ (x<1); there are also traces of lead and silver. The ores are contained in a gangue of mainly pink baryte with impurities in the form of quartz stringers. In places the veins comprise fracture zones containing blocks of lava and volcaniclastic rocks strung through with baryte veining. The greatest measured width is 4.5 m, exposed about 100 m north of Blairlogie [NS 8270 9722] in a small burn which, on

its way down the slope to the village, follows the line of the biggest of the group of faults.

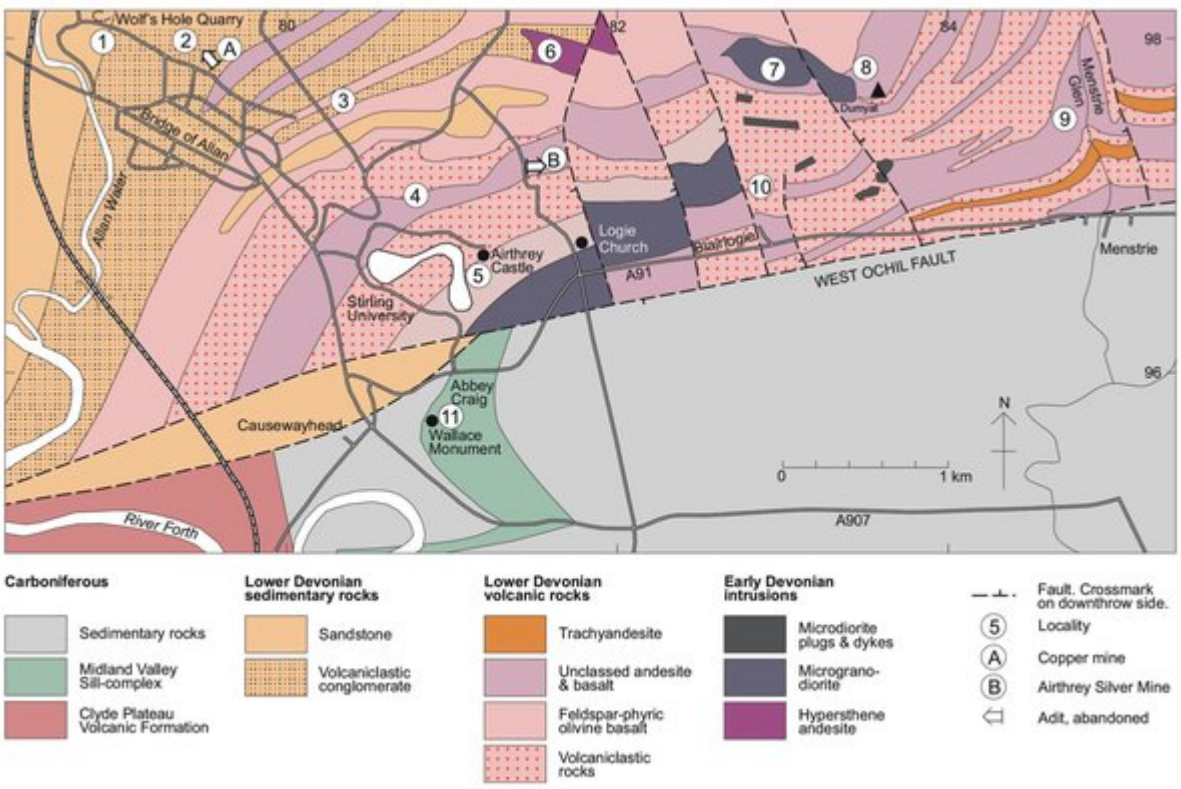
Locality 5.11 [NS 8092 9566] Wallace Monument: viewpoint, rockfall protection

From Locality 5.10, follow the A91 towards Bridge of Allan, taking a right turn onto the B998 leading to the car park at the Wallace Monument. The 67 m-high monument was completed in 1869. It is constructed of coarse-grained, cross-bedded, fluvial sandstone, which was quarried locally from Lower Limestone Formation strata below the outcrop of the Abbey Craig Sill. Within the tower, the Hall of Heroes contains a bust of Hugh Miller (1802–56), the Cromarty stonemason and geologist.

From the top of the monument, in the foreground looking south, are the meanders of the River Forth, which loop across the low ground of Cambuskenneth. These extend downstream across the Carse as far as Alloa. Bonded warehouses are prominent on the north bank of the river, and to the east is the Kincardine Bridge; on the far horizon, the outline of the Pentland Hills (Lower Devonian lavas) is seen. Carse deposits are also present under the flat land along the foot of the Ochils, past Menstrie and Alloa and as far as Tillicoultry. It was in a field of the Airthrey Estate (7 m above OD), just NE of Abbey Craig, that during drainage operations in 1819 the entire 21 m skeleton of a whale was found in the Carse deposits (Cadell, 1913). To the SW lies Stirling, dominated by Stirling Castle rock composed, like Abbey Craig, of quartz-dolerite. From here the tail of the 'crag and tail' at the castle is best seen. In addition, the Touch Hills (Clyde Plateau Volcanic Formation) and Gillies Hill (Midland Valley Sill-complex) are visible.

To the west and NW, there are commanding views of the Carse west of Stirling, the Menteith Hills (Lower Devonian conglomerates) and the Grampian mountains. Immediately to the north is the campus of Stirling University and Airthrey Loch. To the NE, the scarp of the West Ochil Fault, one of the most spectacular in the Midland Valley, is well seen. The fault, which may have a normal displacement of up to 3000 m, throws down Carboniferous and Upper Devonian sedimentary rocks (which underlie much of the Carse) in the footwall against Lower Devonian (Ochil Volcanic Formation) in the hanging wall. Evidence indicates that the fault dips to the south. Davison (1924) listed over 200 earthquakes between 1736 and 1916, with epicentres concentrated in a zone parallel to and north of the fault plane, suggesting that at depth the fault might be reversed. Haldane (1927) suggested that the movement of another fault or a series of NNW-trending faults, which meet the plane of the West Ochil Fault, may have been responsible for the many tremors.

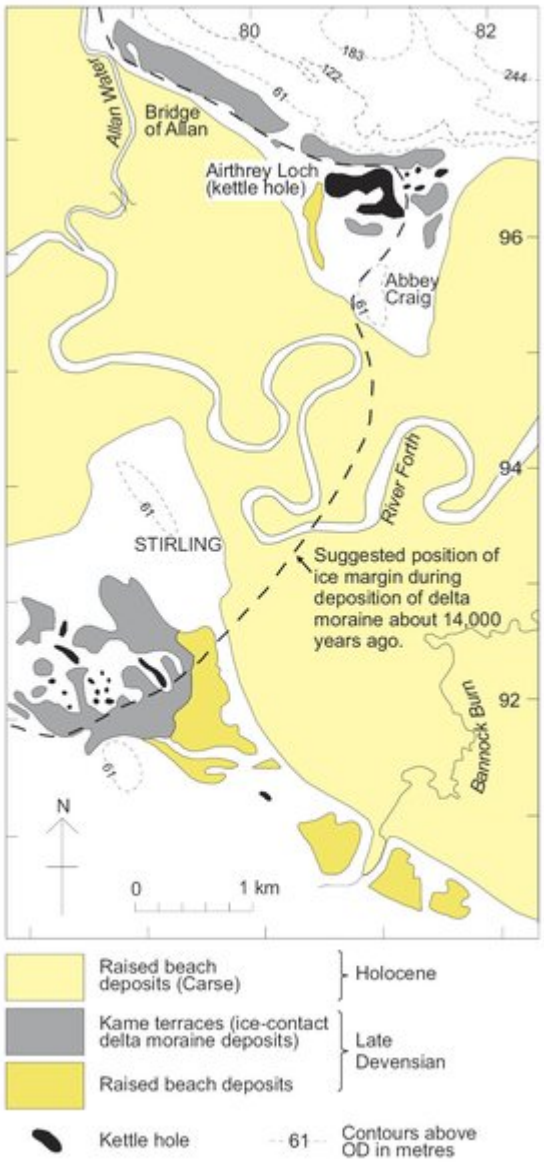
References



(Figure 5.1) Geological bedrock map of the Bridge of Allan–Menstrie area, showing localities for Excursion 5.

(Plate 5.1) Locality 5.1. Wolf's Hole Quarry, in Scone Sandstone Formation overlain by youngest known lava flow (feldspar-phyric basalt) of the Ochil Volcanic Formation.

(Plate 5.2) Locality 5.5. Stirling University campus; volcaniclastic conglomerate of Ochil Volcanic Formation; notice notch in cliff, of possible beach origin.



(Figure 5.2) Quaternary geological map of the Bridge of Allan– Stirling area.

(Plate 5.3) Locality 5.7. Talus (scree) of microgranodiorite sill intruded into the Ochil Volcanic Formation.

(Plate S.2) Lower Devonian volcaniclastic conglomerate at cave east of Dumyat summit. See Excursion 5.

(Plate 5.4) Locality 5.10. Ochil Volcanic Formation lavas and conglomerates showing trap-like step featuring, from Logiealmond.