Geological hazards, Southern Uplands

From Earthwise

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Introduction

Ioseismal map of the 26 December 1979, Carlisle earthquake, showing the extent of the felt area. P912379.

Regional geochemical images showing the distribution of (a) strontium (Sr) and (b) chromium (Cr). P912328.

Remains of smelter flues at Wanlockhead (P266683). P266683.

The region’s geology exerts a major influence on a wide range of land use and environmental issues, and in some circumstances may introduce natural hazards that constrain or limit development. Some potential hazards are discussed briefly below.

**Seismicity**

The south of Scotland is an area of very low seismicity, but the region is not entirely seismically quiescent. Historical records describe minor events in the Galashiels area of the Scottish borders in 1650, 1728 and 1844, whilst a series of minor earthquakes have been recorded around Lockerbie and Dumfries from the late 19th century onwards.

From the records of the Galashiels events, the largest seems to have occurred on 1st March 1728,
with an epicentre between Galashiels and Selkirk. This earthquake was felt from Cumbria in the south, to Fife in the north, but apparently caused no damage. The magnitude is estimated to have been 4.3 ML and the focus was most probably deep. A series of small events felt in the Leadhills–Wanlockhead area between 1748 and 1828 were most probably initiated by the local mining activity.

Small earthquakes in the Lockerbie–Dumfries district are likely to be related to the regional seismicity of the north of England, which is characterised by a band of relatively intense activity up the spine of the Pennines, with some activity to the west of this but with practically nothing to the east (P912378). This pattern terminates in the vicinity of the Anglo–Scottish border, north of which there is only a little activity, for example an earthquake near Dumfries on 26 December 2006 that had an instrumental magnitude of 3.7 ML. In the same general area, the 26 December 1979 Carlisle earthquake, with instrumental magnitude of 4.7 ML, was one of the larger British earthquakes of the 20th century. It was felt over most of southern Scotland, Cumbria and north-east England (P912379) and was generated at a depth of about 5 km. There was a marked directionality to energy release, resulting in the earthquake being much more perceptible to the north than to the south. The strongest effects were felt around Carlisle, Longtown (close to the epicentre and about 5 km south of the border) and Canonbie (about 2 km north of the border), with damage caused to roofs and chimney stacks, debris falling and cracks appearing in walls. A series of significant aftershocks continued until 1981. The fault plane solution of the aftershock sequence, and the lineation of aftershock epicentres, shows lateral movement on a near-vertical plane with a strike of 123°.

It seems likely that the pattern of seismicity is related to the geometrical reaction of structural components, most likely the major geological blocks, to the overall pattern of crustal stress. There is currently a maximum compressive stress from the north-west or north-north-west arising from the widening of the Atlantic Ocean. Such a regime could induce generally rotational movements of the Pennine and Lake District blocks, with shearing movements on their flanks and between them and the adjacent Southern Uplands block.

**Factors affecting ground stability**

Across the south of Scotland, bedrock or glacial till usually provides adequate foundation conditions for conventional structures, though bedrock may be significantly weakened locally by weathering, faulting or mineralisation. Stability problems are most likely to occur either on steep slopes, or within areas covered by alluvium or peat where soft or unpredictable ground conditions may be associated with a high groundwater table. Particular problems of subsidence arise in the coalfields and metal-mining areas, and where limestone has been extracted from underground workings. This issue is also taken up in the section below on ‘mining legacy’.

Ancient, inactive landslide deposits are fairly widespread across the region and are generally under-represented on existing geological maps. They were mostly initiated during the late glacial period, when the melting ice-sheets left glacially oversteepened slopes unsupported and unstable. Thawing of permafrost led to water oversaturation and high pore-water pressures that reduced rock shear strength and facilitated failures. The ancient landslides range from deep-seated rotational slides to relatively shallow translational slides and include progressive, multiple slope failures. These landslides may be stable under present-day conditions, though human intervention by excavation or loading, or any alteration of the local groundwater regime, could cause renewed instability.

Today, infrastructure following steep-sided valleys through the Southern Uplands is particularly vulnerable to disruption by landslips. These are usually initiated by periods of unusually heavy rain, and may range from debris flows and surface outwash, commonly coupled with gulley erosion by
swollen streams, to larger-scale mass movement. The following two examples of the latter are illustrative.

In December 2006, following a period of prolonged, heavy rainfall, the B7068 road linking Langholm and Lockerbie was undermined by a landslide at Scroggs Cleuch (NY 1621 8135). The relatively small, rotational failure of unconsolidated, superficial deposits was instigated by a combination of factors: elevated pore water pressure through the substrate, a raised water table, and erosional undercutting of the bank beneath the road by the swollen burn. Part of the road was carried away and the rest affected by tensional fissuring. Despite the small absolute size of the slip, its location was damaging and disruptive. Such local events are not unusual.

In July 2008, again following a period of torrential rainfall, the main A7 road through Langholm was blocked by large landslides both to the north and to the south of the town. In each case the landslide originated on the slopes above the road in water-saturated, superficial deposits. It is perhaps a telling feature of the southern landslip, at Auchenrivock (NY 373 805), that it was initiated in an area that had been recently disturbed by engineering works for a new road, though destabilisation of the slope by human intervention was not unequivocally established. The Langholm landslips resulted in the closure of the main road through the Borders for several weeks, with a significant impact on the local economy.

The coastal routes along both the eastern and western sides of the region pass through cliffs and cuttings in places and have a history of disruption by rockfall. In the east, the main East Coast railway linking Scotland and England passes through steep sided cuttings in bedrock, close to the edge of sea cliffs, to the north of Berwick. The difficulties are obvious to any rail passenger. On the west coast, the main A77 road hugs the coastline between Girvan and Ballantrae, utilising the raised beach. In several stretches, the road skirts the relic sea cliffs, which have required much stabilisation over the years and have in places encouraged the re-routing of the road inland.

With all of the issues described above in mind, appropriate engineering solutions were required for the region’s largest civil engineering project in recent years, the construction of the M74 motorway linking Glasgow to north-west England across the Southern Uplands via Abington and Beattock. Large-scale, gently inclined cutting faces, and extensive drainage works are much in evidence.

**Flooding**

Quite apart from its influence on ground stability, periods of unusually heavy rainfall lead to flooding. There is a growing consensus that climate change is likely to cause an increase in the frequency of these extreme events and so flood prevention and mitigation is likely to become a more pressing issue. Alluvial flood plains are, by definition and of necessity, prone to flood ([P711492](#)). Nonessential development of these areas should be resisted and suitable precautions taken to protect vulnerable infrastructure where it has to cross them. Dumfries has a particular and long-standing problem of flooding in parts of the town centre, especially when high discharge levels in the River Nith coincide with high spring tides in the Solway Firth and an onshore wind. Elsewhere, in the Scottish Borders, some towns and villages are at risk of flash flooding after periods of heavy rain, surrounded as they are by high ground. Selkirk, for example, has suffered regularly, with a road bridge being swept away in 1977, and a major flood defence scheme has been initiated there.

**Radon**

Most people receive almost 90 per cent of their average annual radiation dose from natural sources. Of those sources linked to geology, the most important are terrestrial gamma radiation from the
ground and buildings, and the short-lived decay products of radon gas released from rock and soil.

About 15 per cent of the average annual radiation dose is due to terrestrial gamma-rays which originate chiefly from the radioactive decay of natural potassium, uranium and thorium, all of which are widely distributed in rocks, soils and excavated building materials. Relatively high levels of background gamma radiation are associated with the granite outcrops in Galloway and the Cheviot Hills, and particularly with the uranium mineralisation associated with the Criffel pluton. However, even there, the overall hazard to human health from background gamma radiation is considered to be negligible in comparison to the risk that may be posed, in some circumstances, by radon gas. Radon is a radioactive gas derived from the decay of the naturally occurring uranium that is found in small quantities in all rocks and soils. It may be responsible for as much as 50 per cent of the average annual radiation dose. The rate of release of radon is largely controlled by the uranium concentration in the source material and the type of minerals in which it resides. Once radon is released it is quickly diluted in the atmosphere and does not normally present a hazard. However, radon that enters poorly ventilated or enclosed spaces can reach high concentrations. The health risk arises from decay of the gas to form solid radioactive particles that may be inhaled, in which case they may lodge in and irradiate the lung.

Regional variations in radon levels are related principally to geology. Across the outcrop of the Lower Palaeozoic turbidite successions the highest radon potential, though not at a level sufficient to cause concern, arises from the Ordovician, Leadhills Supergroup. Curiously, it appears to decrease progressively from north-east to south-west, perhaps reflecting some cryptic change in the bulk composition of the rocks. The Silurian Gala, Ettrick and Hawick groups display low radon potential, but the Riccarton Group outcrop shows higher values similar to those associated with the Ordovician turbidites. Some granites release radon and the Criffel and Cheviot plutons present a limited hazard. The highest levels would be expected inside granite-built properties sited on granite bedrock, such as might be encountered in the Dalbeattie area of the Criffel pluton. However, of likely greater importance is the well-established link between limestone and high levels of radon emission, with the Carboniferous limestones presenting the greatest hazard in parts of southern Scotland. Here, a moderate risk has been identified in some parts of the Berwickshire Merse, the western Borders between Langholm and Annan, and the southern margin of the Thornhill outlier. Radon monitoring is only considered advisable in these limestone areas.

The nature of the superficial sediment cover on bedrock can influence radon potential. Apart from the obvious compositional influences, the permeability of the unconsolidated deposits is important. Impermeable till and clay will restrict radon flow, whereas permeable sand and gravel will facilitate its release. In general, a good proxy for radon potential is provided by stream sediment geochemistry (e.g. P912328). As might be expected, the strongest correlation is with uranium, followed by rubidium, potassium, yttrium, lanthanum and zirconium.

**Mining legacy**

In common with all coalfield areas with a long history of underground working, parts of the Sanquhar and Canonbie coalfields are at risk of surface subsidence and instability.

Subsidence due to modern mining is usually predictable and manageable but may become less so if the modern, deep workings underlie older, shallow ones. Whilst reliable plans exist for most modern workings, the extent and detail of the earliest mining activity, which was generally by the pillar and stall method, is commonly known only in general terms, and may be completely unrecorded. Voids created during the early work may remain open long after abandonment, with collapse taking place unpredictably over many years. Should such old workings be present above modern longwall
Groundwater levels typically rise following the reduction or cessation of pumping after mine abandonment. In addition to the risk of surface discharge of contaminated water, such groundwater rebound may affect ground stability, causing renewed subsidence in long-abandoned workings. In north-east England, groundwater rebound has been linked to fault reactivation with associated surface instability, and this may prove to be a wider problem. Any mine waters discharged are likely to be acidic and enriched in iron and manganese, plus a range of potentially toxic chemical elements such as lead, arsenic and cadmium. Apart from surface discharge, there is also the possibility that contaminated mine water could access permeable rock formations and so degrade the quality of aquifers. Most coals and coal-bearing successions generate methane, the cause of many catastrophic underground explosions. Methane continues to be released into old mine workings whence it may reach the surface via abandoned shafts and adits, or via faults or permeable rock formations, driven in part by rising groundwater. Low barometric pressure may also lead to a short-term increase in methane release. Bings of colliery waste have in the past presented problems of stability and spontaneous combustion. Weathering of colliery waste may also produce high sulphate and acid ground water. However, as this material is progressively removed, and the areas it once occupied are landscaped, these problems are much reduced. Some of the subsidence and mine water hazards described above from the coalfields also have limited application in other areas with a history of metal mining. Those mining sites, mostly in the Leadhills-Wanlockhead area and in parts of Galloway, are much more restricted in extent than the coal workings, tend to be relatively shallow, and are in parts of the region where there is only a sparse local population. Apart from the obvious danger of open shafts and accessible adits, the principal hazard probably results from the waste tips and smelting facilities with their elevated levels of toxic base metals. The paucity of vegetation at these sites is testament to the contamination. The underground limestone workings around Harelawhill and Closeburn may also be a potential cause of localised subsidence.

**Bibliography**


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