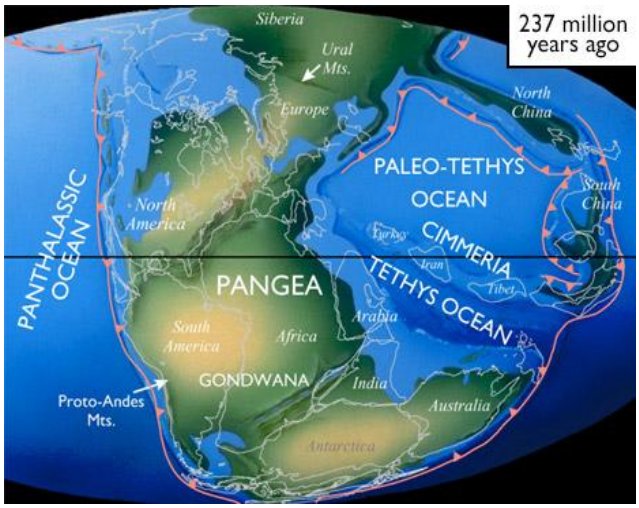
Sessions 10/11 - The Volcanic History of Scotland

An overview

61-58 Ma BP:	The Palaeogene – Hebrides
360-290 Ma BP:	Permian & Carboniferous – Midland Valley, S Kintyre, W Highlands, Orkney, Barra, S Uplands, Borders, etc
420-360 Ma BP:	Old Red Sandstone – Lorn, Ochils, Glen Coe, Ben Nevis
500- 420 Ma BP:	Lower Palaeozoic – Southern Uplands, Ballantrae, Highland Border
600-595 Ma BP:	Dalradian – Tayvallich, Loch Avich
2500-600 Ma BP:	Earlier Pre-Cambrian – Loch Maree, Scourie, Colonsay, Islay, etc



Palaeozoic – Permian and Carboniferous

- Scotland buried in the middle of a continental tectonic plate
- Dating from 360 Ma BP to 290 Ma BP, the remains of hundreds of volcanoes litter the landscape of Scotland – from Orkney to Kelso, from St Andrews to Barra!
- So where did all this activity come from?

Mainly intra-plate vulcanism!

The Early Carboniferous *Beware: plate collision imminent!*

- Pangaea not yet formed, but Gondwana and Laurasia are about to collide – hold tight!
- Complex collision, lots of bumping, grinding and rotating!
- New mountains chains formed in the crumple zone – the Variscan Orogeny, affecting England, Wales and Ireland.
- But under Scotland, the plate was stretched and thinned instead, allowing magma to escape!
- From 350Ma BP, volcanoes get going in the south of Scotland.

Volcanoes of the Early Carboniferous...

...tend to be small, with localised eruptions and limited quantities of lava produced.

...are located to each side of the Solway-Tweed line, the buried site of the post-Iapetus suture between England and Scotland.

...are probably related to the faults associated with this suture line, with magma rising through fault lines that are under tension.

Bathgate: 600m thick
Clyde plateau: 1000m thick
Macrihanish: 400 m thick
Heads of Ayr: Cliff section through vent
Edinburgh: The classic volcano!
North Berwick: 500+m thick
Eildon Hills: Trachyte/ rhyolite sills

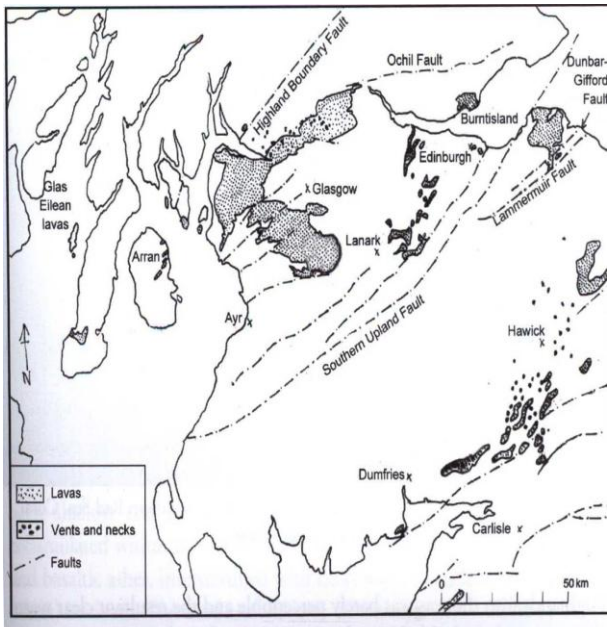


Fig. 8.1 Map of South and Central Scotland showing distribution of early Carboniferous volcanic rocks. *(After W. A. Read et al., 2002)*

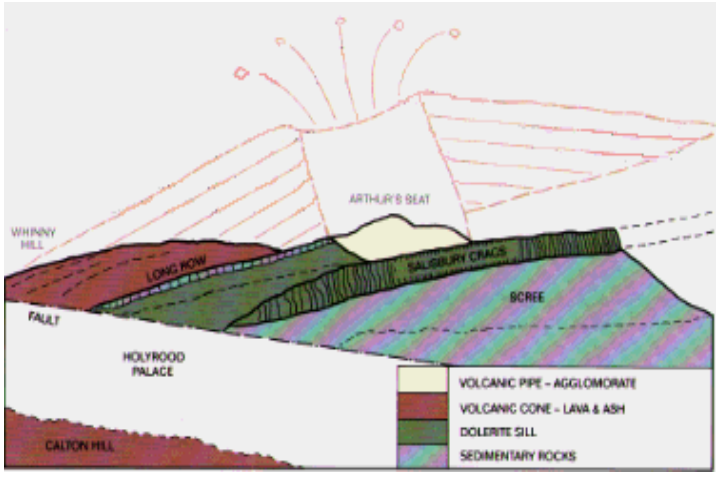
Mid-Carboniferous Volcanoes ...

...were active 355 Ma – 320 Ma.

...are much larger in scale than those of the early Carboniferous, with great thicknesses of basalt lavas erupted over wide areas.

...are mainly related to the Southern Upland Fault, and parallel faults in the Midland Valley.

...have left remains that form major landscape features at the present time.



Edinburgh – Arthur's Seat

Evolution of the Clyde Plateau

- Probable major fault line Stirling-Dumbarton buried below later sediments provided the conduit for rising magma.
- Low-lying area in mid-Carboniferous, with surface water and waterlogged sediments.
- Rising magma encounters wet sediments – 'boiler explosions'!
- Basaltic ash propelled up and out by the superheated steam.
- Cone of basaltic ash builds up around the vent.
- Gradually the water-table recedes, and quieter eruptions of extensive basalt lava flows occur.
- Successive lava flows (mainly *aa* type – slightly more viscous, slaggy top) build up the plateau.
- Weathering and erosion of weaker flow-tops produces stepped profile of the escarpment.

.....

Upper Carboniferous and Permian Volcanoes...

...were active 320 Ma – 290 Ma BP

...were generally smaller but much more numerous than earlier in the Carboniferous

...are associated with emplacement of extensive dyke swarms and thick sills

...so in total accounted for the largest volume of basaltic magma generated before the Palaeogene event in Scotland.

...mainly occurred on the south-eastern side of the Midland Valley, but were scattered all over Scotland from Shetland to Stranraer.

Upper Carboniferous and Permian Volcanics of the Midland Valley

...were all situated *intra-plate* in Pangaea.

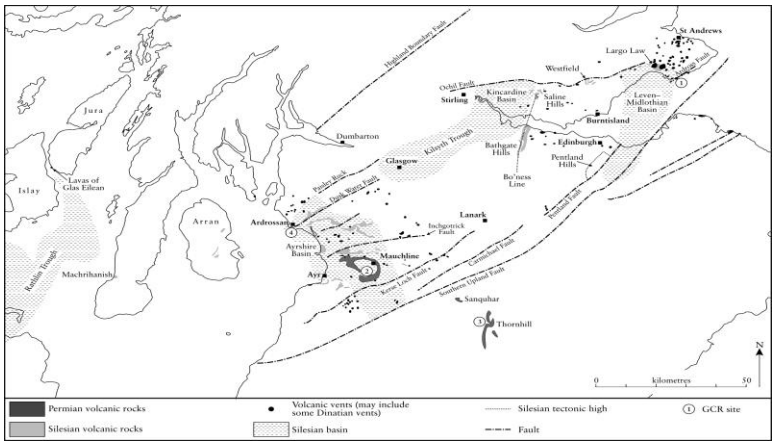
...were almost entirely related to extensional thinning and faulting of the plate to relieve pressure from the underlying mantle – hence the sills and dyke swarms.

...occurred (320 – 300 Ma BP) in a low-lying, often waterlogged, landscape, which led to repeated explosive steam-driven events.

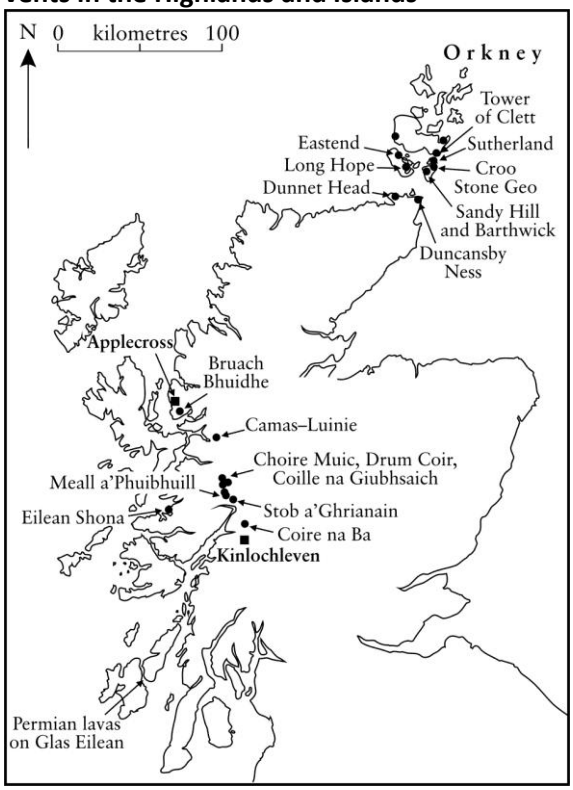
...occurred (295 – 290 Ma BP) in a sandy desert landscape overlying the wet sediments, still giving explosive activity.

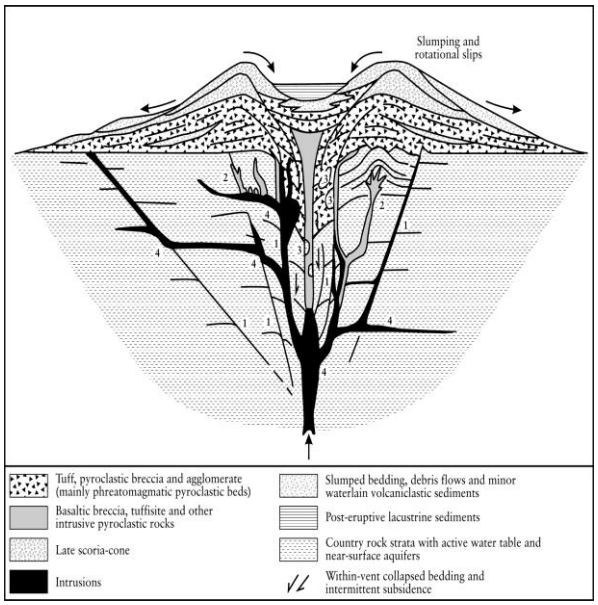
...which created a distinctive type of small vent called a **diatreme** which had a relatively short lifespan.

...and left a legacy of several hundred diatremes, now seen as eroded remnants of their deep cores.



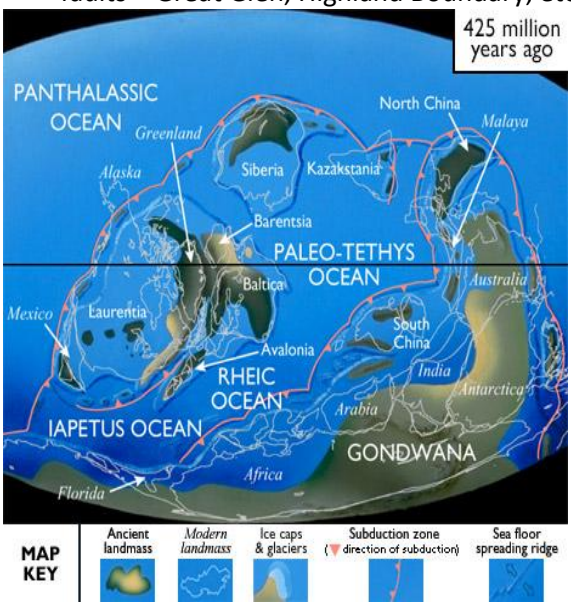
Upper Carboniferous and Permian plugs and vents in the Highlands and Islands

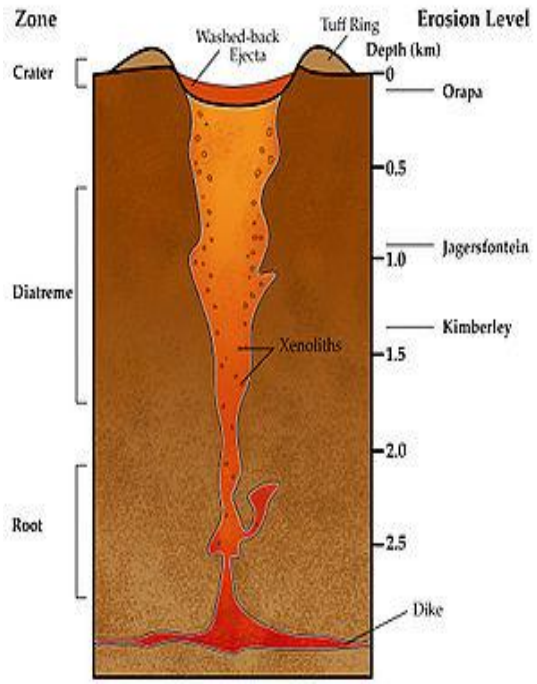


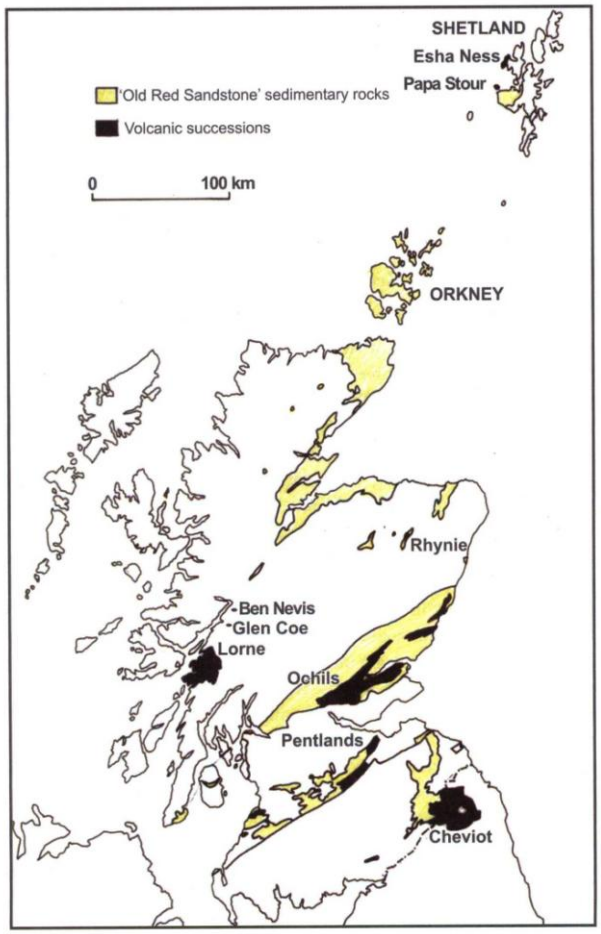


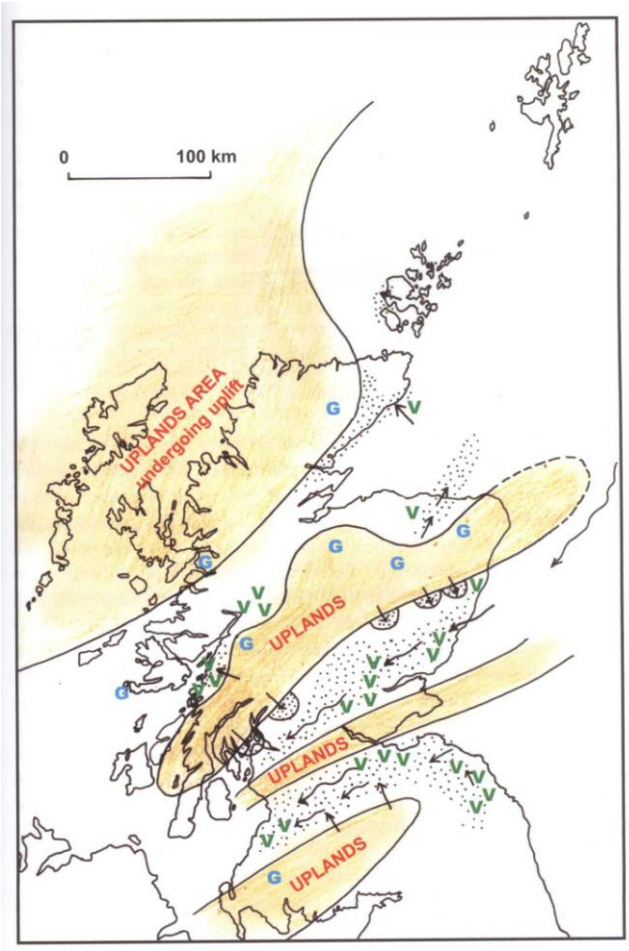
Volcanoes and the Old Red Sandstone Continent

- Active in the period 425 – 360 Ma BP
- Scattered from Shetland to Cheviot
- Wide variety of scales of activity
- Many inferred from feeder intrusions - erosion has removed direct evidence of extrusive events.
- Volcanoes widespread after Caledonian mountain building caused by plate collision as the Iapetus Ocean closed.
- As previously, volcanic activity relates to plate extension and thinning due to underlying mantle pressures, with magma feeding up deep faults.
- Major movements of blocks along major faults – Great Glen, Highland Boundary, etc.









Supra-Subduction Volcanism

- Recall the modern type-example of supra-subduction volcanism – the Andes of S America.
- Magma generation for this involves material from the subducting plate melting and rising through the continental plate above, giving andesites, dacites and rhyolites – generally more viscous giving more explosive volcanism.
- Erosion has largely removed the volcanic evidence, but possible to infer from the underlying intrusive materials that remain.
- But a few clear examples of such volcanism can be found...

<u>Some examples of inferred volcanoes</u>

Cheviots – 395 Ma

The deep remnant of a giant volcano, possibly 60 km in diameter, up to 3 km high, which produced andesite, dacite and rhyolite lavas, and left a core of diorite and granite.

Distinkhorn, Ayrshire - 413 Ma BP

Rhyolite intrusion surrounded by extensive baked sedimentary rocks, implying that overlying extrusives have been eroded away.

<u>Lorne Lavas – 420-415 Ma BP</u>

Basalt and andesite lava flows originating from NE-SW fissures across Lorn, possibly sourced from the descending subducted Iapetus oceanic slab.

The Big Boys!

Glen Coe

- The classic example of caldera collapse
- Caldera is roughly oval, 14 x 8 km
- Subsiding fault blocks initially produced a graben.
- A river flowed along the graben, and rising magma reacted explosively with this water, creating ignimbrite eruptions.
- This happened 5 times, creating a succession of ash layers.
- Sills were intruded into the ash layers as the caldera floor subsided.
- The caldera continued to subside 0.5 km per million years.

The Etive Complex

- Two shallow, concentric intrusions with surrounding lavas, probably of Lorne origin.
- Later than Glen Coe
- Possibly the last stage of NE to SW migration of magmatic activity from Rannoch Moor granite to Etive
- If so, all this may represent the deep structure of an enormous siliceous volcano, with a diameter ~70km

Ben Nevis

- 7km diameter suite of intrusive granite and diorite surrounding a 2km diameter central volcanic plug
- Plug forms the mountain summit
- Ring dyke indicates caldera subsidence
- So original volcano must have been at least 1000 m higher than the present mountain

Volcanoes during the Iapetus Ocean period

- Highland Boundary Complex – from Arran and Bute to Stonehaven (430-420 Ma BP). Related to the welding together of the Midland Valley and Grampian terranes.
- Ballantrae Complex (576-470 Ma BP). Related to southern margin of the Midland Valley terrane and its collison with other plates in the history of the Iapetus Ocean.
- Southern Uplands – Moorfoot and Lammermuir Hills, among others
- Tayvallich Volcanics (600-595 Ma BP). Related to opening of the Iapetus Ocean
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Volcanoes in the earlier Precambrian

- Such a long time ago! So much evidence has been eroded and recycled, so little is left in such fragmentary form!
- Moine volcanism: rocks with basaltic composition and relict gabbro textures, called amphibolites. Indications of a major magmatic event ~870 Ma BP
- Torridonian times: some evidence for magmatic events in the Stoer Group, perhapos ~1200 Ma BP
- Early Proterozoic volcanism – Loch Maree and Gairloch area, but only tantalising hints around 2000 Ma BP.
- Scourie dyke swarm – but what was that all about around 2200 Ma BP?
- ...what a remarkable collection of the best landscape features of Scotland have been produced by volcanism
- ...so when you go touring, take a good guide to the volcanoes of Scotland with you, and see if you can make the connection between ancient volcanic events and the wonderful scenery

But the other key influence on our landscape is yet to come... ICE

Books

Volcanoes and the Making of Scotland: Brian Upton, Dunedin Academic Press
Geology and Landscapes of Scotland: Con Gillen, Terra Publishing
SNH/BGS Landscape Fashioned by Geology series:

- Scotland: The Creation of its Natural Landscape
- East Lothian & Borders
- Edinburgh
- Skye
- Fife & Tayside
- Loch Lomond to Stirling
- Mull & Iona
- Orkney & Shetland
- Rum & Small Isles

Mull in the Making: Rosalind Jones (private publication)
Volcanoes: Susannah Van Rose & Ian Mercer, Natural History Museum, London

Field trips and holidays with volcanoes in mind

Geosupplies (www.geosupplies.co.uk) for Iceland, Tenerife, UK (leader: Chris Darmon)
Geowalks (www.geowalks.co.uk) for Scotland (leader: Angus Miller)
Shetland Geotours (www.shetlandgeology.com) for Shetland (leader Allen Fraser)