

## **The Geology of Lundy**

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### **Introduction**

Lundy, although a small island, has attracted and intrigued geologists since the nineteenth century, as it is formed from rocks that are of a very different type and age to the nearby rocks of Devon and South Wales. It is formed mainly of granite (a coarse-grained igneous rock, composed of the minerals feldspar and quartz, often with biotite and amphibole) intruded into metamorphosed sedimentary rocks. Both of these rocks are themselves intruded by dykes, sheet-like intrusions of igneous rock that have a vertical or near-vertical orientation.

The metamorphic rocks occur in the south-east peninsula of the island, around the Landing Beach (Plate 1). They are correlated with the Upper Devonian Morte Slates or Pilton Shales of North Devon which form Morte Point south-west of Ilfracombe. The Lundy granite appears similar to the granites of Devon and Cornwall, which were emplaced in Carboniferous times, 362-290 Ma (million years ago) and was originally thought to be the same age. However, radiometric dating of the Lundy granite showed that it was much younger (59-52 Ma), belonging to the Tertiary period. This makes it part of the British Tertiary

Volcanic Province (BTVP) which is composed of intrusive complexes and their associated dykes, mainly located in Scotland and Northern Ireland (Fig. 1). Lundy is therefore of special interest in that it is the southern-most complex of the BTVP. It also differs from the Scottish part of the BTVP as it is emplaced into rocks of Hercynian age (345-245 Ma), which are younger and compositionally different to those in the North.

### **The Lundy granite**

The Lundy granite is easily visible in the quarries on the east side of the island and in the tops of the cliffs. The granite has been studied by a number of researchers, in particular Dollar (1941), Edmonds *et al* (1979) and Thorpe *et al* (1990) and this summary is based on their accounts.

The Lundy intrusion is mainly a coarse-grained granite, containing large white alkali feldspar crystals about 20-30 mm in size surrounded by a groundmass of alkali feldspar, quartz, plagioclase, biotite and muscovite of about 1-2 mm grain size (Plate 2). The main granite can also appear as a very coarse-grained pegmatite, composed mainly of alkali feldspar and tourmaline. The granite crystallised from a relatively water- and fluorine-rich magma. As it did so, the less volatile components crystallised first changing the composition of the remaining magma as it cooled. This fractionation concentrated the volatiles into the late stage magma, forming the pegmatites, and also thin

sheets and veins of fine-grained aplite and microgranite which intruded the main mass.

The accessory minerals of the granite are similar to those found with the Devon and Cornwall granites, including anatase, arsenopyrite, apatite, beryl, cassiterite, a columbite-tantalite series mineral, cordierite, epidote, fluorite, garnet, magnetite, molybdenite, monazite, pyrrhotite, rutile, sphene, topaz, tourmaline, uraninite, xenotime, wolframite, zircon and zoisite.

The Lundy granite has been dated by methods that use ratios between naturally occurring radioactive isotopes in the rock; potassium-argon, argon-argon and rubidium-strontium. The results give the age of the granite between 52 and 59 Ma, of Palaeocene-Eocene age within the Tertiary period. This confirms the granite as part of the BTVP, despite being physically closer to the older Devon and Cornwall granites.

Strontium and neodymium isotope data show that the Lundy granite originated from fractional crystallisation of a mixture of material, partly derived from a basic (alkaline) intrusion and partly from melting of the lower crust that also formed the source of the Devon and Cornwall granites. This explains the similarity of the Lundy granite to the granites of Devon and Cornwall. The basic intrusion would have been generated by partial melting of the mantle caused by stretching at the same time as, but distant from, where the North Atlantic was opening. Lundy is associated with positive gravity and magnetic anomalies,

which are consistent with the presence of an underlying gabbro intrusion (composed of the minerals feldspar and pyroxene) below Lundy and with a larger volume than the granite. After mixing of the basic and crustal magma, and fractional crystallisation, the magma rose and then cooled in the upper crust, where it assimilated some of the country rock, indicated by xenoliths (inclusions) of the metasediments in the granite near the contact of the rocks.

### **Lundy dykes – remnants of a volcano?**

The Lundy granite and the metasediments to the south are intruded by a swarm of dykes (Plate 3). These dykes have been studied by Dollar (1941, 1968), Mussett *et al* (1976), Edmonds *et al* (1979), Thorpe and Tindle (1992) and Roberts and Smith (1994) amongst others.

The dykes were emplaced into joint fractures within the granite and metasediments. They are slightly younger than the granite, with radiometric ages of 45-56 Ma. They range in thickness up to 2.3 m, and erode readily, forming prominent gullies within the sea cliffs.

Most of the dykes are dark-grey dolerites (a medium-grained igneous rock composed of feldspar and pyroxene), but with about 10 per cent of the dykes intermediate or acid in composition: trachytes or rhyolites. Field relationships indicate that the dolerites and trachytes/rhyolites were emplaced contemporaneously, with both dyke-types cutting the other in differ-

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ent places. They both often show evidence of hydrothermal alteration and may contain gas cavities, indicating emplacement at a high level near the Earth's surface. Some of these gas cavities have been infilled by secondary minerals such as chlorite, calcite, analcite, natrolite and thomsonite.

The main trend of dykes in the BTVP is northwest-southeast (Fig. 1), due to the northeast-southwest regional extensional stress field at the time of emplacement, associated with the opening of the North Atlantic Ocean. Some of the dyke trends in the BTVP are locally also related to central intrusive complexes, and do not follow the main dyke trend. As the plateau of Lundy is covered with superficial sediment, dykes can only be mapped directly in the sea cliffs around the island, which does not allow their trend to be ascertained. Instead, the presence of dykes has been inferred from magnetic measurements, as dolerite dykes (but not the trachytes or rhyolites) have a much higher magnetic susceptibility (degree of magnetisation) than the granite or metasediments, so these dykes produce magnetic anomalies. These have been mapped around Lundy (Fig. 1) and on the island (Fig. 2).

The trend of dykes around Lundy is similar to the BTVP northwest-southeast trend, but the dykes mapped on Lundy also show a radial trend, mainly northwest-southeast towards the south end of the island, but east-west at the centre and northeast-southwest towards the north end. Extrapolation suggests a focus and source for the dykes 2 to 3 km to the

west of Lundy.

This is consistent with the origin of the dykes as interpreted from their mineralogy and chemistry. Basaltic magma (the same composition as in gabbro) was formed from partial melting of the mantle (the layer beneath the crust), with minor crustal contamination. Fractional crystallisation of the basaltic magma produced trachytic and rhyolitic magma. Most of the rhyolite dykes have a peralkaline composition (rich in sodium and potassium), but rarer subalkaline rhyolites were also formed from the basaltic magma through a separate fractional crystallisation path. There is only minor evidence of any interaction of the dyke magmas with the granite into which they were intruded, and the intrusion must have occurred rapidly, at a high level in the crust.

The origin of the dykes is connected to the granite through the initial basaltic magma chamber. Following emplacement of the granite, the basaltic magma chamber remained active and during further fractional crystallisation yielded dolerites, trachytes and rhyolite magmas emplaced as dykes into the cooler, jointed granite. The chemical characteristics and silica distribution within the dolerite/ trachyte/ rhyolite association reflect fractional crystallisation of compositionally varied basaltic magma and the rapid transition from basalt to rhyolite over a relatively small crystallisation interval. This process was accompanied by rapid emplacement of the dyke magmas into joints within the cool Lundy granite, accompanied by minor crustal-

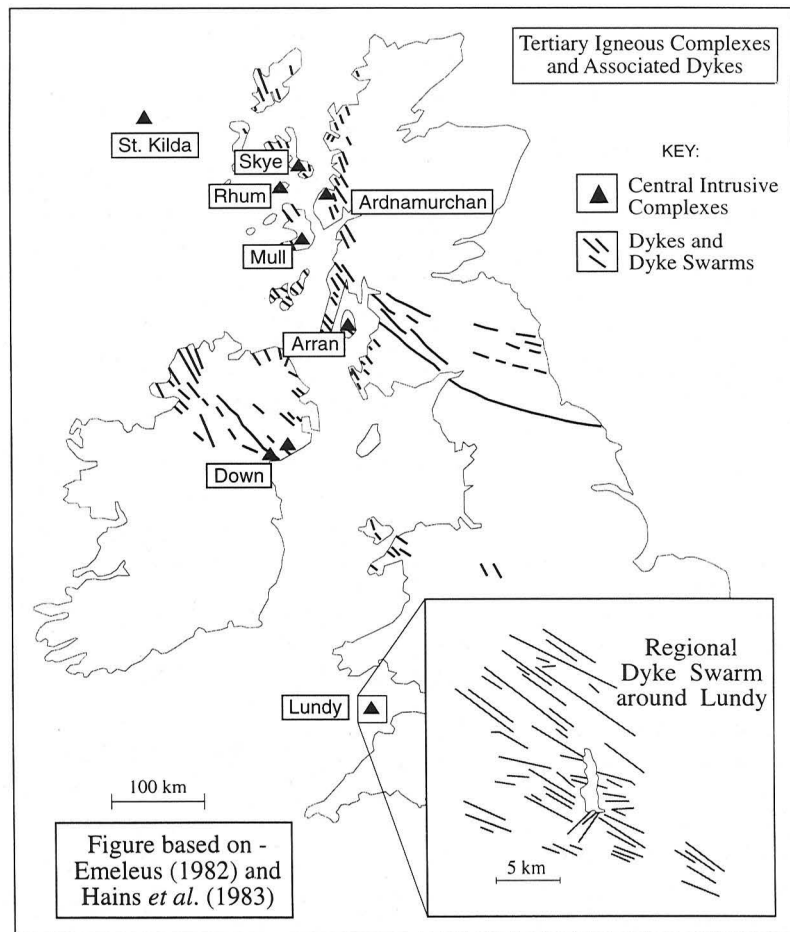


Fig. 1

granite interaction. The focus of the dyke swarm to the west of Lundy and the positive gravity anomaly to the west suggest this was the site of the basaltic magma chamber.

This rapid emplacement of the basalt, trachyte and rhyolite magmas at a high level in the crust makes it possible that the magma erupted at the surface, forming a volcano above Lundy. This would be consistent with the extrusive volcanic rocks at other BTVP centres. By similarity with volcanoes in similar settings, the Lundy volcano would have been 10-20 km in diameter, and composed of rhyolite and trachyte pyroclastic (fragmental) flows and airfalls associated with rhyolite domes and basaltic cones and flows. This Lundy volcano would have been one of the most spectacular geological events in this area.

### Geomorphology

The subsequent geological history of Lundy is one of erosion, eventually leaving the harder granite protruding and now surrounded by the sea. The island is a relatively flat plateau, sloping from a height of 140 m in the south to 90 m in the north, surrounded by steeply-inclined sidelands, at the base of which are near-vertical cliffs. The geomorphological history of Lundy is confused and in many ways, unresolved. The top of the island clearly displays planation surfaces and relatively flat platforms, but whether these are of a marine, glacial or even subaerial origin is debatable. Mitchell (1968) reported gravels in the north-east of

the island and assigned them to the effects of a retreating ice sheet, which also "carved" Gannets' Combe. He also noted the occurrence of *roche moutonnées* and glacial erratics as further evidence of an ice sheet. However, many of the rounded erratics over the northend are composed of locally derived Lundy Granite, which (*sensu stricto*) should not be termed erratic material. Glacial erratics normally consist of rock types such as Scottish granites and Welsh slates, that have been transported great distances, for example to North Devon, by slow moving ice sheets, of a type seen in present day Antarctica and Northern Canada.

It is likely, however, that ice sheets did reach the North Devon coastline (and presumably Lundy as well) in either the Middle Pleistocene Wolstonian stage (128,000 – 195,000 years ago) as proposed by Kidson (1977) or the Anglian stage (251,000 – 297,000 years ago) as postulated by Bowen *et al* (1986). Recent research indicates that age relationships around these periods are complicated, but at least this gives a crude indication as to the age of glaciation.

The glaciations and warmer interglacials (including the present one) were accompanied by sea level changes as water frozen on the land was not returned to the sea. This is complicated by the rising of the land. Absolute sea level around the coast of south-west England has been much lower than the present day level for much of the last 1 million years (Heyworth and Kidson 1982). Possible marine features now seen

above sea level are therefore good indicators of how Lundy (and indeed most of south-west England) has moved vertically over time. This has mostly been the result of powerful Earth movements and it is interesting to note that the Lundy granite crystallised from a molten magma at a possible depth up to 10 km below ground level. Although erosion has removed an unknown thickness of overlying sediments above Lundy, these recent land movements are small compared to those in the Tertiary period after Lundy was formed.

Cullingford (1982) summarised the consensus of opinion on the existence of marine platforms and raised beaches in Devon and listed them at about 210, 180, 130, 100, 85, 45, 15, 7, 4 and 0 m OD. The two highest could not be expected on Lundy but to what extent the last eight can be seen is unclear. Queen Mab's Grotto at Brazen Ward correlates with the 15 m platform and wave-cut features can be detected at both 4 and 7 m in the same region. Langham (1985) correlates bluffs around the Cheeses and Jenny's Cove to the 85 m horizon and the flattened island surface to 130 m level. A more detailed investigation of geomorphological features over the island may unravel more of the complicated recent sequence of events. Weathering and erosion have certainly destroyed much of the evidence.

The orientation of the streams that drain the island depends on the features of the underlying rocks. Some of the streams develop along the line of the softer

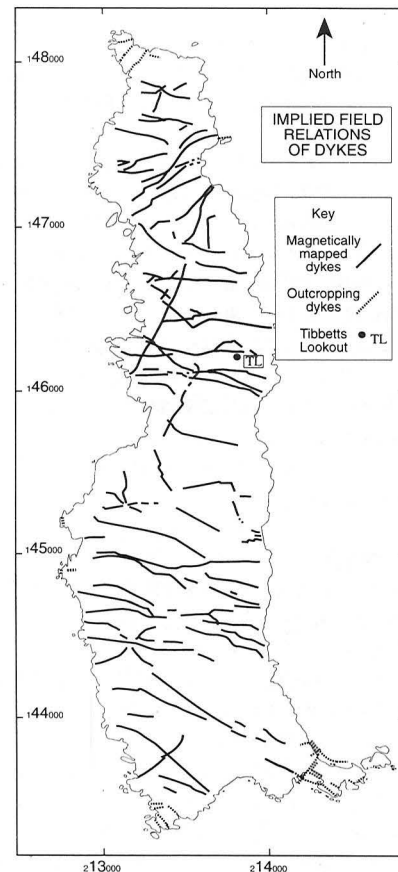


Fig. 2

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dykes (most of the Gannets' Combe streams follow, or partly follow, dykes) and, in the south-east, streams are influenced by linear features in the metasediments.

**Quarrying** The Lundy granite is an excellent and easily available building stone, and was used for the lighthouses, castle and other buildings on the island. The Old Light is an excellent example of granite masonry, formed of carefully curved blocks. The quarries on the east side of the island were used not only to supply stone for use on Lundy, but also elsewhere by the Lundy Granite Company, registered in 1863; blocks were lowered down the cliff face to Quarry Beach, then transported to the mainland by ship. Most of the stone was used in Devon. Unfortunately for Lundy this export of stone became uneconomic by 1868.

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Plate 1 Metamorphosed sedimentary rocks on Lundy, near the landing beach. (Jill Lang)

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Plate 2

The Lundy granite; white alkali feldspar megacrysts in a groundmass of alkali and plagioclase feldspar, quartz, biotite and muscovite. (Jill Lang)

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Plate 3 Dykes intrude the Lundy granite. (Jill Lang)

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