2 Britain's oldest rocks: remnants of Archaean crust

2.1 Introduction

Owing to the complex nature of extremely old deformed rocks, the standard methods that are used to establish a stratigraphic evolution cannot be applied. Instead, geologists are reliant upon establishing the sequence of deformation, metamorphism and intrusion of igneous rocks, and the isotopic dating of these events. The application of ever more sophisticated isotopic-dating techniques is changing our perception of the evolution of these extremely old rocks. The interpretation of data from such rocks is often complex and subtle, and is invariably of a controversial nature. As a consequence, this Section only provides a broad overview of the current state of knowledge of the events and processes recorded in Britain's most ancient rocks.

2.2 The Lewisian Complex

The oldest rocks of the British Isles are Mid- to Late Archaean in age and are exposed on the mainland of north-west Scotland, and on the Inner and Outer Hebrides (Figure 2.1). These rocks are mainly deformed and metamorphosed igneous rocks – orthogneisses (Figure 2.2) – and are collectively termed the Lewisian Complex, after the Isle of Lewis in the Outer Hebrides.

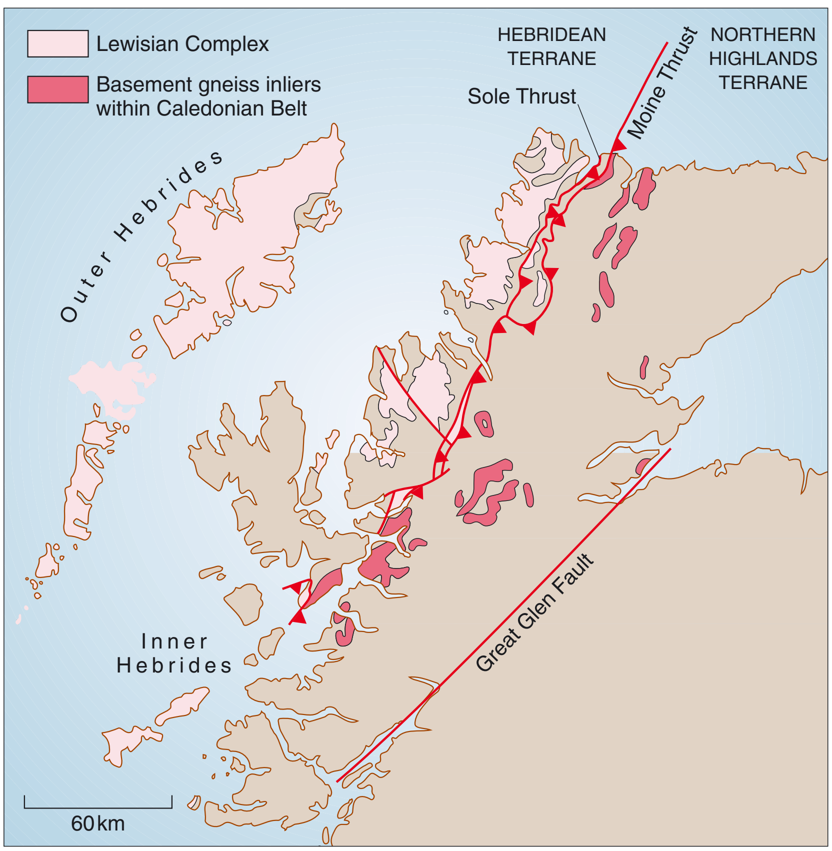


Figure 2.1 Location of Archaean rocks of the Lewisian Complex and Archaean inliers in north-west Scotland.

Figure 2.2 Typical Lewisian gneisses showing intense deformation, Pollachar, South Uist, Outer Hebrides.

Recent studies have established that the Lewisian Complex exposed on the Scottish mainland comprises a series of crustal blocks (terranes) that evolved separately before they were welded together by collision during the Palaeoproterozoic. At least four terranes are now recognized: from north to south they are the Rhiconich, Assynt, Gruinard and Southern Region Terranes (Figure 2.3).

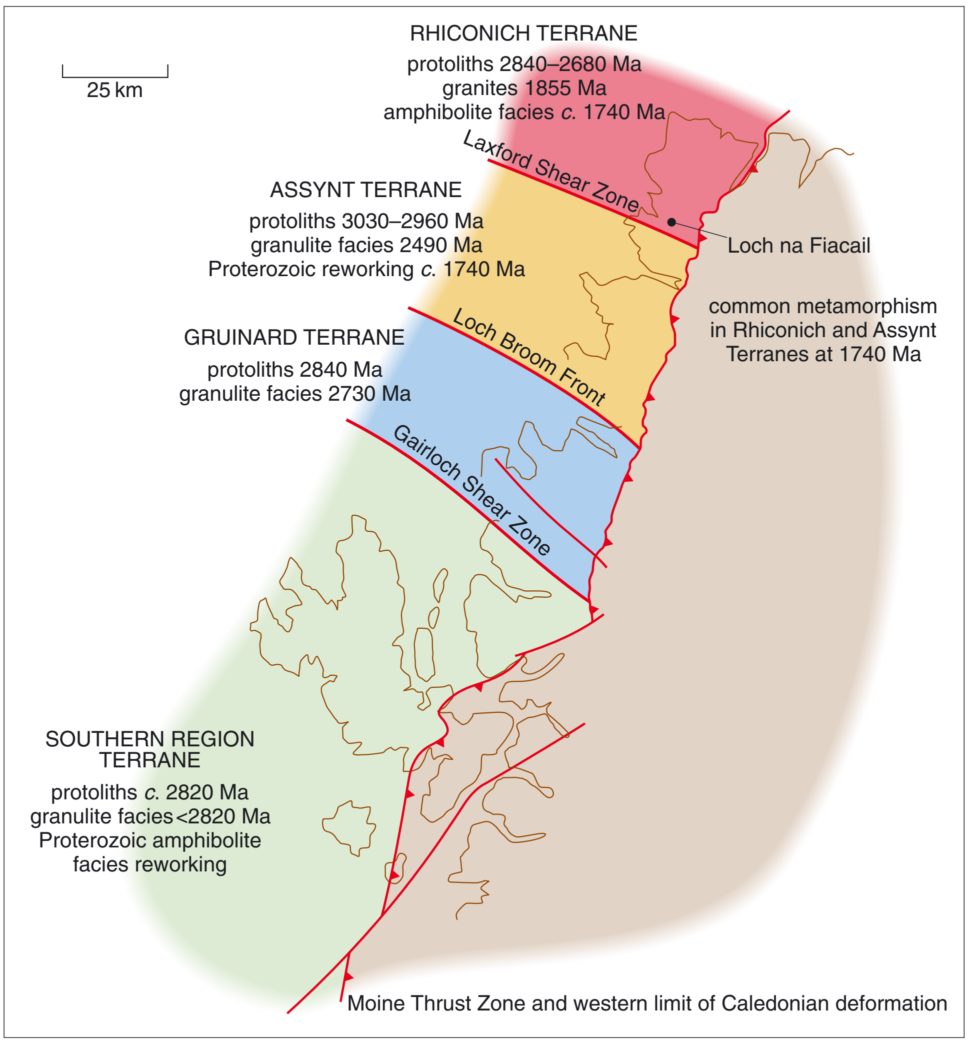


Figure 2.3 Sketch map of the Lewisian Complex exposed on the Scottish mainland. The ages of the protoliths or parent rocks and the main metamorphic events used to constrain the boundaries between the terranes are shown.

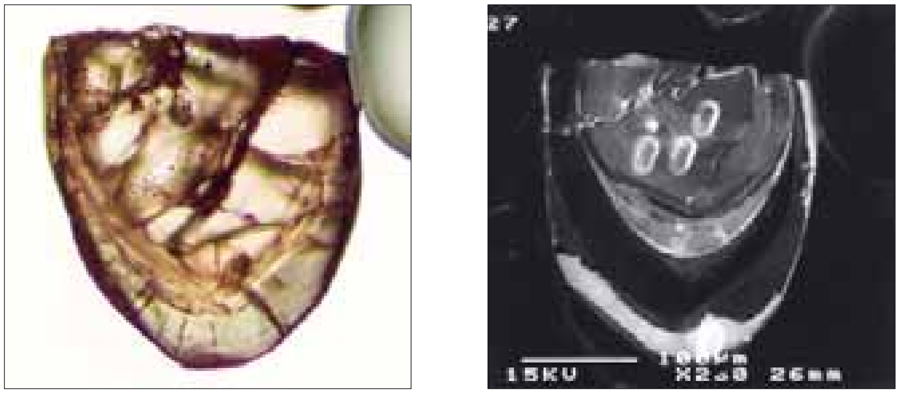
Each of the terranes has its own individual history, yet collectively they record a sequence of geological events spanning some 1300 million years. The individual terranes are separated by steeply dipping shear zones: the Laxford Shear Zone, Loch Broom Front and Gairloch Shear Zone. The magnitude of displacement across these shear zones, and hence the original relationships between different terranes, is uncertain and the subject of much debate.

2.2.1 The nature, age and origin of the gneiss protoliths

The parent rocks, or protoliths, of the gneisses exposed in the Assynt Terrane have been identified using field evidence and geochemical evidence. In areas of low tectonic strain, intrusive cross-cutting relationships are still preserved (Figure 2.4), pointing to an igneous origin for these Assynt gneisses. Their chemical compositions reflect their origin as mafic and acidic plutonic rocks: gabbros, granodiorites, tonalites and trondhjemites. These rocks are often referred to as basement complexes.

Figure 2.4 Primary intrusive relationships from the Lewisian Complex, Gruinard Bay. The early mafic intrusives are invaded by veins of later granodiorite.

Radiometric dating (using U and Pb isotopes) of zircon crystals from the protoliths of the gneisses in the various terranes have yielded a variety of Late Archaean ages (*c*. 3030–2680 Ma, see Figure 2.3) that are interpreted as recording the time of magmatic crystallization. Interestingly, the core of one zircon crystal from a suite of gneisses from Loch na Fiacail, in the Rhiconich Terrane (for sample location see Figure 2.3), has given an age of *c*. 3550 Ma, and represents the oldest dated mineral from this region (Figure 2.5). The origin of this older core is enigmatic.



(a) (b)

Figure 2.5 Is this the oldest mineral in Britain? Photomicrograph (a) and cathodoluminescence image (b) of a single zircon crystal from Loch na Fiacail. The core of this crystal has given an age of *c.* 3550 Ma, whereas the rim gives a much younger age of *c.* 2840 Ma and is interpreted as dating the time of magmatic crystallization. Three kidney-shaped pits in the core of the crystal and one on the rim, visible in (b), were formed when the sample was bombarded by a beam of ions during analysis. The scale bar in (b) represents 100 µm.

The chemical compositions of the gneisses indicate that they are related to magmas generated at subduction zones, whereas mafic and ultramafic rocks that are found in association with minor metasedimentary and metavolcanic rocks are broadly comparable with modern tholeiitic basalts. The rocks are therefore thought to have originated in oceanic island-arc environments.

2.2.2 Deformation and high-grade metamorphism

The Archaean protoliths of the Assynt, Gruinard and Southern Region Terranes suffered intense deformation and metamorphism (often referred to as crustal reworking) that led to the formation of gneisses and crystallization of high-grade granulite-facies metamorphic assemblages (Box 2.1). These gneisses are collectively termed the Scourian gneisses. Isotope geochronology has indicated that deformation and granulite-facies metamorphism occurred at different times within the individual terranes during the Late Archaean to earliest Proterozoic, *c.* >2820–2490 Ma (Figure 2.3).

The most complete record of granulite-facies events is preserved, albeit locally, in areas which have escaped subsequent reworking by later events. In the Assynt Terrane, intense deformation led to the formation of a sub-horizontal gneissic foliation, strong lineation and isoclinal folding. Here conditions of metamorphism have been estimated at 1000 °C and 1100 MPa, and isotopic dating of metamorphic zircons, thought to have grown during granulite-facies metamorphism, has given ages of *c.* 2490–2480 Ma. The achievement of such high temperatures and pressures probably resulted from tectonic thickening during a collisional orogenic event. The gneisses are also depleted in U, Th, Rb and Pb, a characteristic feature of many terranes metamorphosed under granulite facies. This chemical signature indicates that the rocks are the residues left behind after partial melting and melt extraction accompanying granulite-facies metamorphism. Subsequently, the granulites experienced amphibolite-facies metamorphism, where conditions fell to 500–625 °C and 300–600 MPa, indicating considerable cooling and uplift/erosion of the crust.

In contrast, the Rhiconich Terrane preserves no evidence of having been reworked under granulite-facies conditions during the Late Archaean to early Palaeoproterozoic. For example, granulite-facies mineral assemblages and geochemical evidence of melting processes are lacking. The rocks of this terrane have clearly not experienced a granulite-facies event and must therefore have evolved in a different tectonic setting or crustal level.

Box 2.1 Metamorphic facies

Metamorphic facies is a term used to embrace all possible metamorphic minerals in rocks metamorphosed under the same conditions of pressure and temperature. Individual facies correspond to the range of pressure (*P*) and temperature (*T*) conditions under which a particular set of minerals is stable. The position of the facies on a *P*–*T* diagram represents the experimentally-determined stability fields of mineral assemblages in rocks of a range of bulk compositions (Figure 2.6). Metamorphic facies therefore provide a general range of *P*–*T* conditions over which the rocks have crystallized.

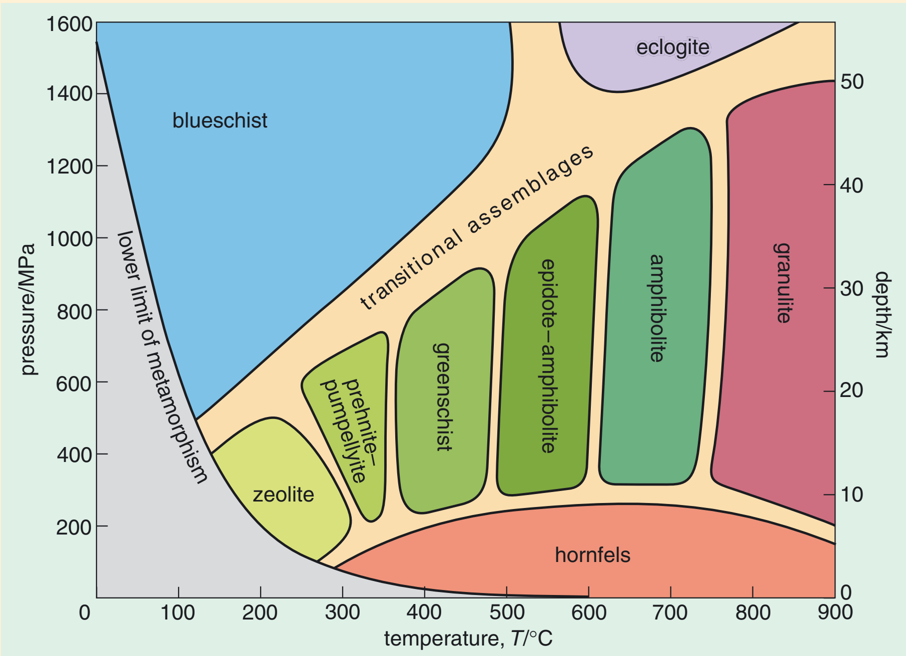


Figure 2.6 The *P*–*T* fields of the major metamorphic facies.

2.3 Basement inliers in the Moine Supergroup

A series of orthogneisses and associated minor metasediments occur as inliers within rocks of the Moine Supergroup, to the east of the Moine Thrust (Figure 2.1). These inliers are thought to represent examples of the high-grade basement upon which the Neoproterozoic Moine Supergroup was deposited (Section 3.6.2). An Archaean protolith age of *c.* 2800 Ma has been obtained on one of the basement inliers from the north coast of Scotland. The conventional view, based simply on the similar appearance in the field of these gneisses, has been that these rocks belong to, and once formed part of, the Lewisian Complex, yet there is no sound geological reason to assume this is the case. These rocks may in fact belong to one of several different Archaean basement terrane(s) which are entirely unrelated to the Lewisian Complex, and further research is needed to resolve this issue.

2.4 Summary of Section 2

- Isotopic and geochemical evidence indicates that the Archaean continental crust grew by the separation of magma from the mantle, probably as a result of subduction processes, over a time span of about 350 million years.
- The Lewisian Complex is composed of a series of disparate terranes each having an individual history. The earliest orogenic events, high-grade metamorphism and intense deformation, occurred at different times within each terrane. Mineral assemblages and pressure and temperature estimates indicate that metamorphism resulted from considerable crustal thickening.
- Several basement inliers, Archaean in age, of uncertain affinity are exposed to the east of the Moine Thrust.