BALMAHA AND ARROCHYMORE POINT

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Introduction

The Balmaha and Arrochymore Point GCR site at the SE end of Loch Lomond contains readily accessible exposures of altered ultramafic members of the Highland Border Complex (HBC). They range from massive and sheared serpentinite, locally silicified, to fragmental serpentinite, typically highly carbonated. Related fragmental rocks with a limestone matrix contain chitinozoa that suggest an Arenig age. The HBC is bound to the NW by the Highland Boundary Fault and to the SE by the Gualann Fault (Bluck, 1992). Precambrian Dalradian metagreywackes and slates occur farther to the NW, and Lower Old Red Sandstone conglomerates to the SE. The ultramafic rocks form two belts, some 800 m apart, termed the Northern and Southern belts (Henderson and Fortey, 1982). They are separated by lithic arenites, part of the 'Loch Lomond Clastics' (Figure 2.20), that are interpreted as a younger component of the HBC. The HBC rocks are overlain unconformably by Upper Old Red Sandstone red-brown conglomerates and sandstones (Rosneath Conglomerate) and just NE of the site these beds overlap the Highland Boundary Fault.

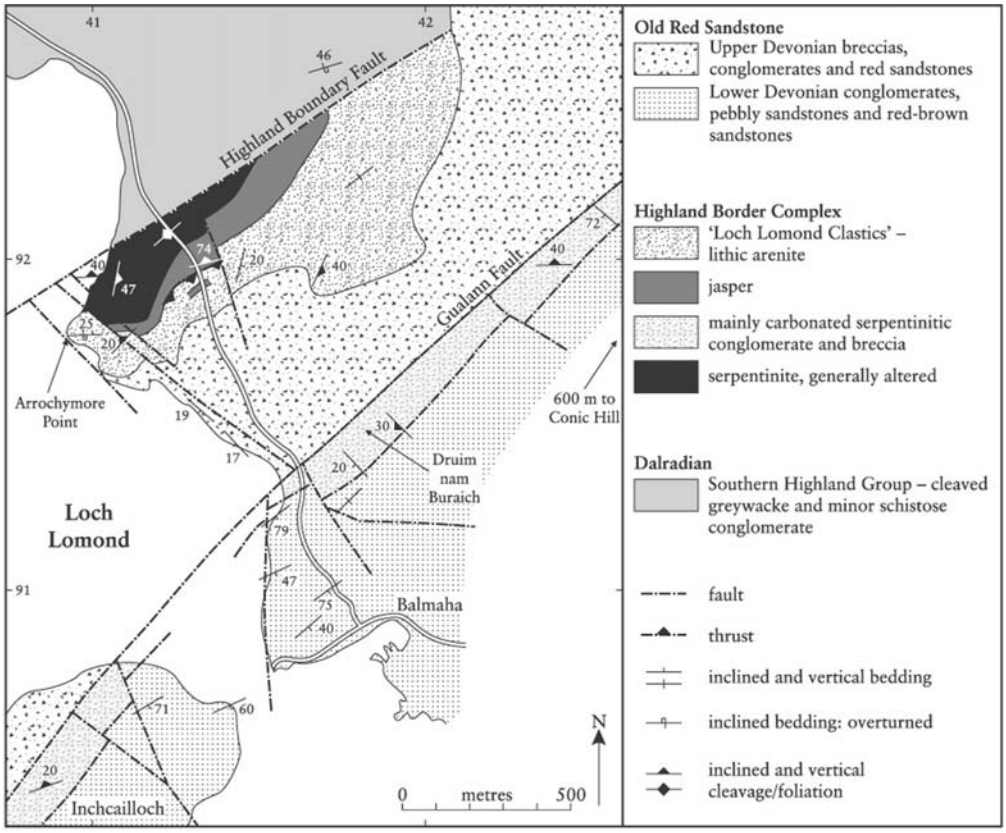

Figure 2.20: Map of the Balmaha and Arrochymore Point area (after Henderson and Fortey, 1982; Bluck, 1992).

The serpentinites are the oldest exposed components of the HBC, and are probably of early Ordovician (Tremadoc or Arenig) age. They range from massive altered peridotite through to sheared, fragmental, highly carbonated and highly silicified varieties. The adjacent metasedimentary 'Loch Lomond Clastics' show mineralogical and geochemical evidence of derivation from both ultramafic/mafic and quartzo-felspathic units.

The area was mapped by the Geological Survey in the late 19th century and was included in

later studies of the HBC by Jehu and Campbell (1917) and by Anderson (1947). More recent work by Henderson and Fortey (1982), Henderson and Robertson (1982), Curry *et al*. (1982, 1984) and Bluck (1992) has described the nature of the HBC at Balmaha and in adjacent areas, notably in the Bofrishlie Burn section and the Lime Craig Quarry areas near Aberfoyle. These authors have discussed the relationships between the various component lithologies of the HBC and placed them in an overall stratigraphical and tectonic context.

Description

The southern serpentinite belt is exposed on Druim nam Buraich on the SW flank of Conic Hill (Figure 2.21). The serpentinite here is extensively altered, recrystallized, brecciated and veined by carbonate and silica. It is dominated by rounded to subangular pebble-like clasts typically 2–3 cm across and up to 15 cm long in places. In the least altered exposures (4254 9212) the clasts lie in a finer-grained (*c.* 2 mm diameter) matrix of altered serpentinite. Henderson and Fortey (1982) described these rocks as serpentinite conglomerate, derived by marine erosion from adjacent exposed intrusive serpentinite. Basic igneous rocks and quartz grains form minor clasts within the rock. Variations in fragment size and alignment of clasts is thought to reflect bedding with units typically about 50 cm thick. In other parts of the outcrop the texture of the rock is more variable and only a crude bedding structure is discernable. Only a weak gently dipping cleavage affects these lithologies. Thin-section studies (Henderson and Fortey, 1982) show that olivine ‘mesh' and orthopyroxene ‘bastite' textures are preserved in the larger clasts. Lizardite is the only serpentine mineral now present but tremolite, talc and chlorite are the dominant minerals and with further alteration they are replaced by ferroan dolomite and quartz. Chromite occurs both within the clasts and as separate detrital grains.

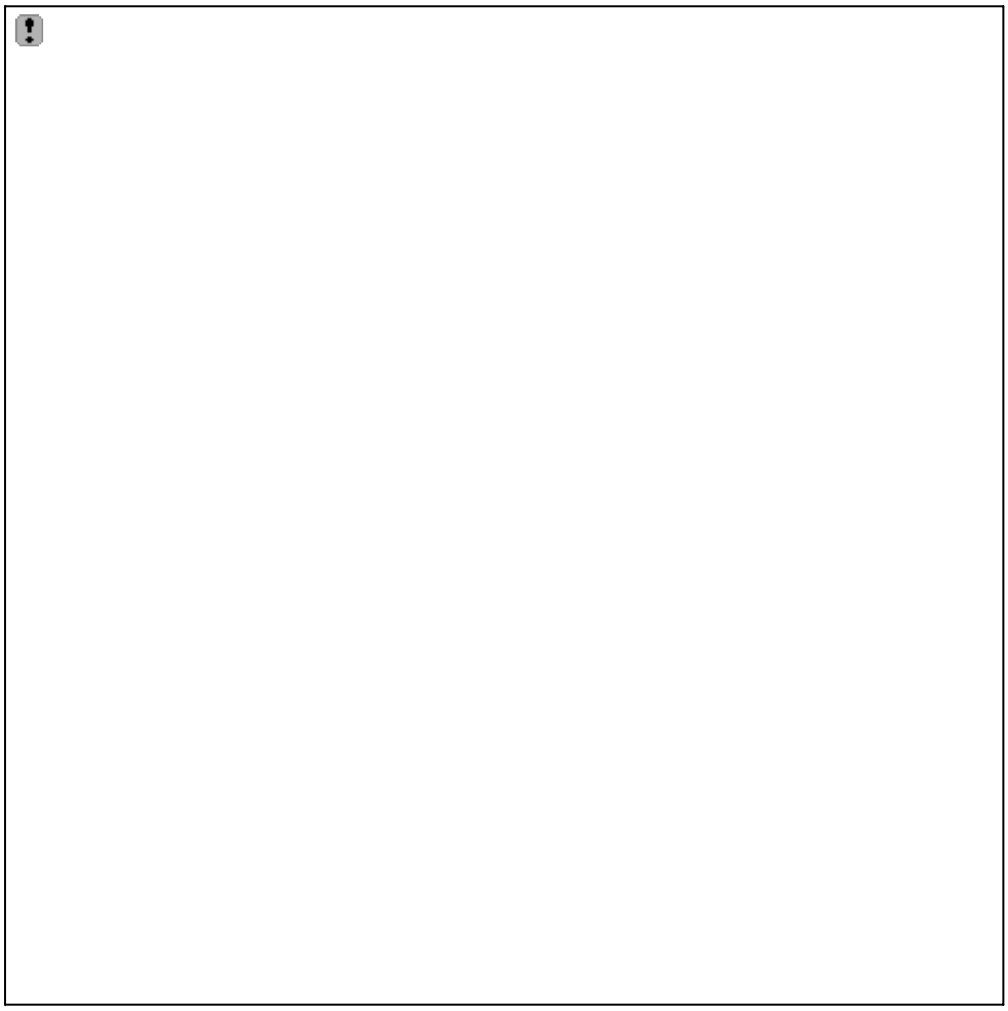

Figure 2.21: Looking SW from Conic Hill across Loch Lomond. Druim nam Buraich (foreground, right of centre) shows exposures of the southern serpentinite belt. (Photo: BGS no. D5406.)

South-west along strike from Druim nam Buraich, exposures were noted byBluck (1992) on the shore of Loch Lomond around 4156 9124. Normally below water-level, they comprise distinctive crystalline limestones and conglomerate containing clasts of dolerite, gabbro, spilite and well-rounded quartz arenite. The dolomitic limestone matrix has yielded chitinozoa suggesting an Arenig age. A similar lithology at Lime Craig Quarry near Aberfoyle (15 km to the NE) has yielded a silicified trilobite and ostracod fauna of early Arenig age from the Dounans Limestone. At this locality serpentinite is overlain by a serpentinite conglomerate with a dolomitic limestone matrix, that in turn passes upwards into the Dounans Limestone (Bluck *et al*., 1984; Curry *et al*., 1982; Ingham *et al*., 1985). Similar serpentinite conglomerates are found on the Loch Lomond islands of Inchcailloch, at 4062 9010 adjacent to altered and brecciated basic volcanic rocks and serpentinite, and on Creinch (394 888). They also occur 90 km farther NE in the Highland Boundary Fault zone at Alyth, near Blairgowrie.

The northern serpentinite belt consists of variably foliated and altered serpentinite. Mesh, bastite and vein textures imply that it was initially a peridotite but the only non-serpentinized rock recorded, at a now-obscured locality near Arrochymore Point, is a pyroxenite composed mainly of chromian diopside (Henderson and Fortey, 1982). Antigorite, lizardite and chrysotile are present in the serpentinite seen elsewhere in the Arrochymore Point area. Deep-red altered chromite grains rimmed by opaque iron oxides and green, fine-grained, felted growths of chromium mica, chlorite and clay minerals are ubiquitous in the serpentinite. The foliation, defined mainly by ramifying sub-parallel fractures but locally by a mylonitic texture, is more marked adjacent to the northern faulted contact. The serpentinite was largely foliated prior to alteration to talc-magnesite and ferroan dolomite-quartz but, locally, subsequent deformation has caused the formation of cataclasite in the carbonate-quartz rocks.

Jasper, mainly dark red in colour, lies immediately SE of the serpentinite in the northern belt, but contacts are not exposed. Henderson and Fortey (1982) note that despite abundant brecciation and quartz veining relict pyroxene and olivine textures are visible, preserved by the fine-grained mosaic quartz. Early tectonic fabrics are also pseudomorphed by quartz and the jasper seems most likely to be the product of pervasive silicification of serpentinite. However, chert is commonly associated with black slates in other parts of the HBC andBluck (1992) inferred that in these cases it is of sedimentary origin. In respect of the jasper, he commented particularly on the lack of interbedded red or black shales, the dearth of fossils, and the distinctive colour.

Immediately SE of the serpentinite and jasper forming the northern belt, cleaved gritty arenites show grading and immature grains indicative of deposition from turbiditic flows relatively proximal to their source area. The arenites are seen to be thrust over the jasper in the road cut at 4131 9194. Bluck (1992) reported that a soft green serpentinite conglomerate crops out just below the beach gravels on Arrochymore Point at 4095 9183, probably close to the arenite–serpentinite contact. This arenite unit, termed the Highland Border Grits by Tremlett (1973) and the 'Loch Lomond Clastics' by Henderson and Robertson (1982), consists of pink to grey, medium- to coarse-grained lithic arenite. In thin section Henderson and Fortey noted that it is composed of quartz, plagioclase feldspar, biotite, white mica and subsidiary chlorite, carbonate and accessory chromite. It also contains abundant grains and larger fragments of slate, chert, and ultramafic and mafic igneous rocks. Minor fine-grained acid volcanic clasts are also recorded. Development of kaolinite and extensive haematitic reddening was probably a late-stage alteration occurring in Early Devonian times. Cross-bedding is common and near Arrochymore Point, where the beds dip *c.* 25° to the NNW, it clearly shows that they are inverted. The cleavage in the arenites is marked by grain flattening, quartz pressure shadows and phengite mica trails. Henderson and Fortey (1982) noted that the angle between bedding and cleavage is very small so that the facing direction cannot be determined by that means. Bluck (1992) suggested that these rocks are Caradocian in age, correlating them with the similar Aberfoyle arenites from which chitinozoa have been obtained (Bluck *et al*., 1984).

Interpretation

The Arrochymore Point outcrops are of massive, to foliated, serpentinized harzburgites and minor clinopyroxenites, commonly altered to talc-magnesite and ferroan dolomite-quartz

assemblages. Pervasive silicification has altered part of the serpentinite to jasper. Farther south, the outcrops on Druim nam Buraich, near Balmaha, are resedimented serpentinite conglomerate, now almost entirely replaced by ferroan dolomite and quartz. Elsewhere these conglomerates apparently pass upwards into bedded limestones, although only limestone conglomerates are seen at Loch Lomond.

The serpentinite and serpentinite conglomerate outcrops are interpreted as the basal units of the HBC. They represent small fragments of sub-ocean-floor mantle and the detrital deposits formed by its erosion, under marine conditions, immediately following its thrust emplacment at the surface. The serpentinite assemblage is thought to be either Late Cambrian or early Ordovician in age. Basic intrusive rocks, now amphibolites, are associated with the ultramafic bodies near Aberfoyle and at Scalpsie Bay on Bute (Henderson and Robertson, 1982). They may represent original ocean-floor volcanic rocks subjected to dynamothermal metamorphism beneath the hot mantle slab as it was obducted. In this model the serpentinite conglomerates could have been generated by erosion at the active thrust front. Limestone deposition accompanied the later stages of serpentinite conglomerate formation and then continued under quieter marine conditions, in shallower water, as obduction was completed.

The overlying ‘Loch Lomond Clastics', here represented only by lithic arenites, are a varied sequence of conglomerates, gritty arenites, shales and limestones.Robertson and Henderson (1984) used geochemical evidence to constrain the possible origin of the arenites. Analysis of a specimen of cleaved arenite from 200 m east of Arrochymore Point (4091 9178) showed high nickel (561 ppm) and chromium (1234 ppm) values in a rock with 77.7% silica. They concluded that the ‘Loch Lomond Clastics' had been derived from erosion of ultramafic, mafic and quartzo-feldspathic rocks and hence deduced that they stratigraphically overlie the serpentinite, serpentinite conglomerate and succeeding limestone units. Indeed, they may be considerably younger than the serpentinite conglomerate and are possibly of Caradocian age.

Conclusions

The outcrops of the Highland Border Complex near Balmaha are of crucial importance in understanding its genesis. They provide examples of the oldest exposed parts of the complex, the serpentinite and serpentinite conglomerate, and reveal something of their relationships with overlying clastic strata. The serpentinite is generally regarded as of Late Cambrian or early Ordovician (Merioneth–Arenig?) age whereas the sedimentary rocks may range up to the late Ordovician (Caradoc?). Both the serpentinite bodies and adjacent clastic strata are fragments of the oceanic floor and sedimentary fill of small basins formed at the Laurentian continental margin. Much of the complex was emplaced both during collision of a large volcanic arc with the Laurentian margin in late Llanvirn times (c. 470 Ma), and by subsequent transcurrent faulting in the late Ordovician and Silurian. Some of the mafic and ultramafic elements may have been obducted during an earlier stage of this complex tectonic history.

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