GAMES LOUP

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OS Grid Reference: NX103880–NX107882

Introduction

At Games Loup a sub-vertical fault trends NE–SW and juxtaposes two components of the Ballantrae Complex ophiolite: pillow lavas, with the geochemical characteristics of an oceanic island arc, and a serpentinite body in which red and green varieties show an interfingering relationship. The ultramafic rock lies to the NW of the fault and forms part of the Northern Serpentinite Belt whereas, to the SE, the sequence of pillow lavas is assigned to the Balcreuchan Group (Figure 2.33). A very large displacement is required to bring together these two units, which originated at very different structural levels – the serpentinite as mantle ultramafic rock and the pillow lavas as sea-floor volcanic flows. However, the fault exposed is a brittle structure that probably formed late in the assembly of the complex as part of a plexus of faults that cut through its central part. Faults within this zone affect Old Red Sandstone strata confirming a continuing history of movement well after the early to mid-Ordovician obduction of the ophiolite. In this respect the fault exposed at Games Loup, which forms the local margin to the Northern Serpentinite Belt, contrasts starkly with the structure seen in theKnocklaugh GCR site farther NE which also illustrates the marginal relationships of the Northern Serpentinite. At Knocklaugh the faulted margin preserves slivers of high-grade metamorphic lithologies produced during obduction; these have been removed by the later generation of faults as represented by the Games Loup example.

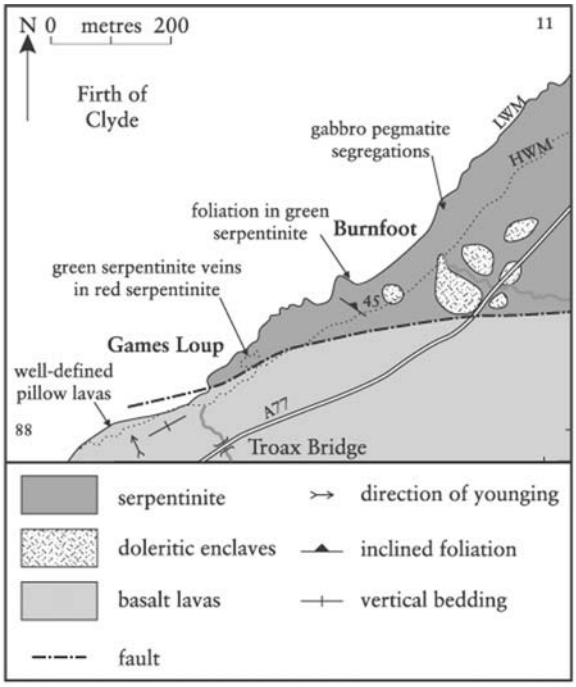

Figure 2.33: Map of the Games Loup area, after BGS 1:25 000 special sheet, Ballantrae (1988) and unpublished data.

The serpentinite to the NW of the fault has a number of distinctive features:Balsillie (1937) first drew attention to the foliation seen at a number of localities, including Games Loup, while Stone and Smellie (1988) described the veined relationships between green and red varieties. On the SE side of the fault the lava sequence provides good examples of pillow structure with only local brecciation and very little intercalated sedimentary rock. The geochemistry of the Games Loup lavas has been extensively studied and quoted in support of polygenetic interpretations of the Ballantrae Complex. The consensus view is that the lavas were erupted at an oceanic island arc (Wilkinson and Cann, 1974; Lewis and Bloxam, 1977; Thirlwall and

Bluck, 1984; Stone and Smellie, 1990). In addition, Thirlwall and Bluck gave a Sm-Nd radiometric age of 476 ± 14 Ma for the lavas, compatible with other evidence of an early Ordovician age for the complex as a whole. The outcrop of the Games Loup lava sequence continues southwards and its southern margin is included within theBalcreuchan Port to Port Vad GCR site.

Description

The serpentinite at Games Loup forms a series of low, rocky sea stacks and foreshore exposures on the NW side of the prominent fault gully. Adjacent to the fault the largest of the rocky areas consists mainly of red serpentinite but it is cut by prominent veins of green serpentinite up to about 15 cm across (Figure 2.34). The red serpentinite is slightly finer grained than the green variety but, that apart, the only difference is the dissemination of haematite in the serpentine crystal mesh, which imparts the red colouration. Both varieties were originally dunites consisting mainly of olivine with only a very sparse scattering of relict orthopyroxene and chrome-spinel grains. Running parallel to the vein margins are subordinate, very thin (mm-scale) veinlets containing fibrous chrysotile; these form an outer zone extending out for several centimetres from the principal vein margins (Figure2.34). Northwards, over about 50 m away from the fault, the proportion of green serpentinite increases until it is the red variety that appears to form sporadic veins. Other changes over the same interval include an increase in orthopyroxene relics (i.e. a more harzburgitic protolith) and the appearance of a faint and patchy foliation striking about NW and dipping moderately to the SW. Farther on, towards Burnfoot (108 882), highly altered doleritic enclaves several metres across occur within the green serpentinite, which there is also host to rare segregations of gabbroic pegmatite similar in lithology to that forming Bonney's Dyke within theSlockenray Coast GCR site.

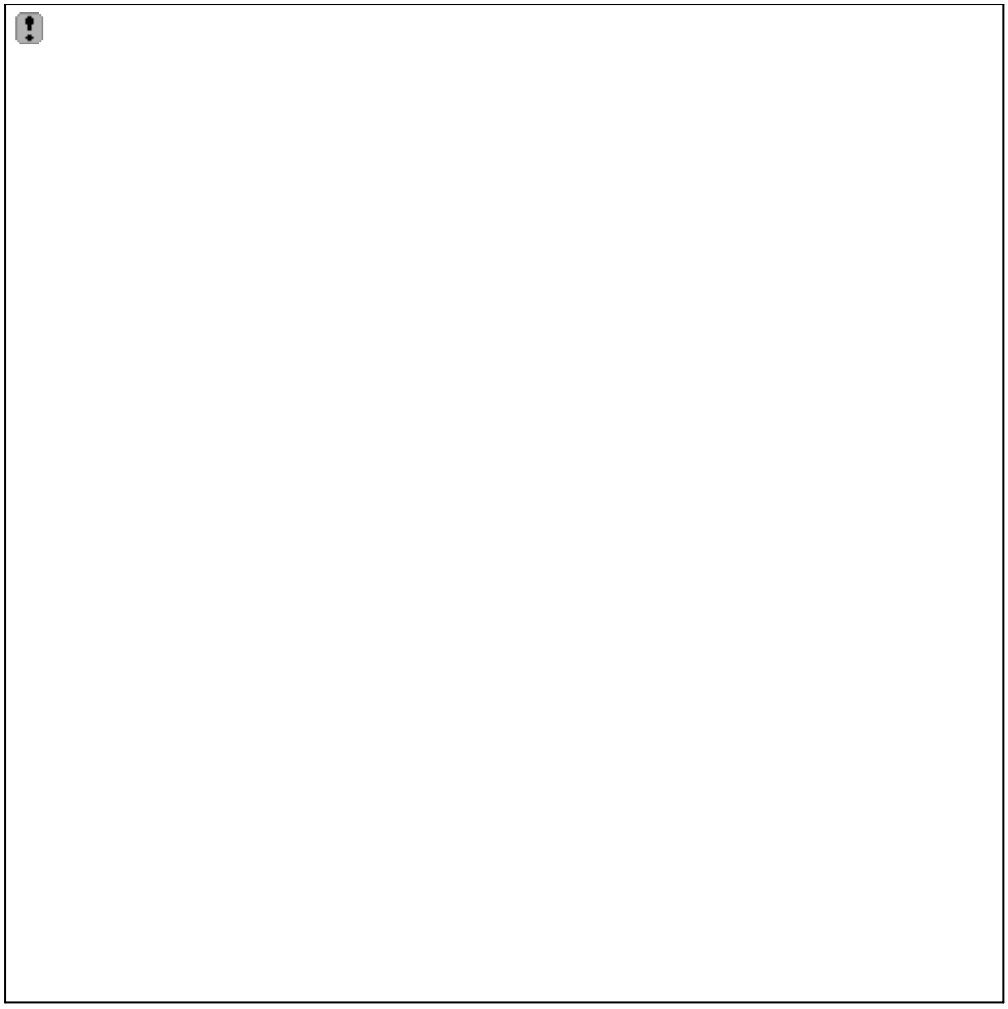

Figure 2.34: Green serpentinite veins cutting a red serpentinite host at Games Loup. Chrysotile veinlets are developed parallel to the vein margins. (Photo: BGS no. D3345.)

There is no fabric development or change in the appearance of the serpentinite close to the fault zone, which forms a shingle-filled gully several metres across. The SE side is a substantial cliff of brecciated lava. Some of the brecciation might be of original autoclastic origin and some volcaniclastic material may be present but much of the texture seen probably arose as a brittle response to faulting. The fault seen here was probably initiated late in the structural history of the Ballantrae Complex and was not part of the deep-seated ductile fault system developed during ophiolite obduction.

A few metres south, away from the fault zone, most evidence of brecciation is lost and well-defined pillow shapes dominate the lava sequence. The pillows are generally relatively small with long axes ranging up to about 1 m. There are no sedimentary interbeds but the regular trend of the pillows defines an original horizontal layering, now steeply inclined, striking approximately NE and younging towards the NW. Vesicles are generally sparse. The lava is tholeiitic basalt, now extensively spilitized. A fine-grained matrix contains a scattering of small plagioclase and unusually fresh augite phenocrysts which, in some specimens, form as much as 15% of the rock. Sporadic pseudomorphs of chlorite and serpentinite, usually reddened by iron oxide, are probably the remains of original olivine phenocrysts. Other secondary minerals present include titanite, epidote and prehnite, probably generated by low-grade burial metamorphism. Since all of the margins of the Games Loup lava sequence are either faulted or unexposed it is not possible to estimate the original thickness; at least 250 m are now preserved.

Interpretation

The fault at Games Loup separates spilitic pillow lavas from ultramafic rock and as such forms

the local margin of the Northern Serpentinite Belt within the Ballantrae Complex ophiolite. Elsewhere in the complex, as for example the Knocklaugh GCR site, this margin is marked by a zone of intense ductile faulting generated during the obduction of the ophiolite and the resulting juxtaposition of mantle and upper crustal lithologies. At Games Loup only brittle deformation is seen and this particular structure can best be regarded as a post-obduction fault locally cutting out the original structural boundary between the two Ballantrae Complex components.

The green serpentinized harzburgite and dunite seen in the Games Loup section are fairly typical of the common rock types within the Northern Serpentinite as a whole; the veined relationship with the red variety is, however, quite unusual. It may reflect original differences in the ultramafic protolith that have survived or been accentuated by serpentinization or alternatively it may be an entirely secondary effect developed during serpentinization. The subsidiary chrysotile veins might support the latter since their fibrous nature would require formation of the serpentine minerals in a dilational environment. The significance of the sporadic foliation is also uncertain. It is picked out by an elongation of the serpentine crystal lattice but it is not clear whether this reflects an original fabric in the protolith (hence perhaps a mantle tectonite) or whether subsequent deformation has been imposed following serpentinization.

The Games Loup lava sequence is exposed as a strike section south-westwards for about 750 m to the Balcreuchan Port area where it is terminated by a major fault zone. This part of the sequence contains an important lithological variation and falls within the Balcreuchan Port to Port Vad GCR site. Exposure is very poor inland but within 500 m of the coast volcaniclastic breccia and sandstone, containing only aphyric clasts, appear to be dominant. This transition may be stratigraphical, with the Games Loup lavas overlying an older clastic succession, or a fault may intervene. In a wider context the relative freshness of the lavas has allowed their use in geochemical characterization of geotectonic settings of eruption during the evolution of the Ballantrae Complex. Overall this has proved a controversial exercise but for the Games Loup lavas, almost uniquely, a succession of studies based on different element combinations has produced a consistent result (see the Balcreuchan Port to Port Vad GCR site report). Eruption of the lavas at an oceanic island arc was first proposed by Wilkinson and Cann (1974) based largely on Ti–Zr–Y–Nb relationships. A similar conclusion was then reached by Lewis and Bloxam (1977) using rare-earth element distributions. Thirlwall and Bluck (1984) used multi-element comparisons coupled with an assessment of Sr and Nd isotope ratios to interpret the lavas as primitive island-arc tholeiites similar to modern examples from the South Sandwich Islands. Data presented by Stone and Smellie (1990) are almost indistinguishable from those of Thirlwall and Bluck. Overall there is a selective enrichment in large ion lithophile elements (e.g. Rb, K, Ba, Sr) and a marked depletion in the high field strength elements (e.g. Y, Zr, Ti, Nb).

A Sm-Nd age of 476 ± 14 Ma was obtained by Thirlwall and Bluck (1984) from internal isochrons on the lavas and their separated clinopyroxene phenocrysts. The relatively large error overlaps with most other age determinations from the Ballantrae Complex and gives a time range compatible with its generally accepted early to mid-Arenig generation.

Conclusions

The Games Loup GCR site exposes several important geological features pertinent to interpretation of the Ballantrae Complex as an ophiolite. At Games Loup itself, the SE margin of the Northern Serpentinite Belt is a late brittle fault that juxtaposes the ultramafic rock against pillow lava. This structure has locally cut out the major ductile shear zone, which originally brought the two lithologies together during obduction of the ophiolite. To the north of the fault, serpentinized harzburgite and dunite occur as distinct red and green variants that have an interfingering relationship. In the largest exposures, adjacent to the fault, red serpentinite is dominant and is cut by veins of green serpentinite; to the north the proportion of the green variety increases sharply. South of the fault a sequence of basaltic pillow lavas has the tholeiitic geochemical characteristics of a primitive, oceanic island arc. The lavas have suffered relatively little alteration which has allowed their use in producing a Sm-Nd radiometric age of 476 ± 14 Ma, compatible with the Arenig age of the Ballantrae Complex as a whole.

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