Excursion 26 Knocklaugh

Key details

Author	B.J. Bluck
Theme	The metamorphic sole produced beneath the ophiolite during its emplacement (obduction); some of the ultramafic rocks of the overlying ophiolite; the dykes which cut these metamorphic rocks.
Features	Metamorphism, mylonites, greenschists, amphibolites, garnet-metapyroxenite, olistostromes, dykes, pyroxenites, serpentinites.
Maps	O.S. 1: 50 000 Sheet 76 Girvan O.S. 1:25 000 Sheet NX 19 B.G.S. 1: 50 000 Sheet 7 Girvan 1: 25 000 Sheets NX 08, 18 and part of 19 Ballantrae
Terrain	Moderately rough open ground, excursion begins with a steep walk.
Distance and Time	2 km: 4 hours walking.
Access	Permission should be requested from Knocklaugh Farm. Short Itinerary: stops 1–6

Introduction

The base of the northerly serpentinite belt runs from near the coast at Carleton Port, south of Lendalfoot to roughly the base of Cairn Hill, NE of Loch Lochton (Figure 25.7). In places this contact is marked by a metamorphic aureole comprising a zone of structurally bounded slices of rocks with highly contrasting metamorphic grade. The zone is not always well exposed and has often been totally cut out by a fracture which brings serpentinite in contact with spilite and olistostrome (Figure 25.7), (Figure 26.1). This can be seen in the vicinity of Knocklaugh, on the NE and SW margins of (Figure 26.1).

The component rocks which make up the aureole vary in thickness along strike. Here the amphibolites are well exposed and quite thick but elsewhere, as near the coast, the epidote mylonite rock is thick. Garnet metapyroxenite is particularly well exposed in this locality but is so thin everywhere that it should not be collected.

Locality 1. [NX 1692 9183]: Olistostromes (Figure 26.1)

At the base of the waterfall sheared black shale is faulted against sheared serpentinite. The black shales have yielded graptolites to Peach and Horne (1899), and form part of a thick unit which comprises most of the immediate hillside. These black shales have thin graded beds of lithic-arenite and large clasts of basic and ultra-basic rock, carbonates and other sedimentary rocks. The graded beds comprise mainly grains of basic volcanic rock implying a source in a basic volcanic terrane. This unit, which is widespread in the ground to the SE of the serpentinite contact zone, is an olistostrome formed when large clasts roll or are otherwise displaced into an area where finer-grained sediments are accumulating. This type of deposit is typically generated near areas of submarine tectonic activity.

Commonly, at the top of the olistostrome unit where it is in contact with the metamorphic zone there are spilitic lavas which are often greater than 30 m thick. These have not been mapped as a separate unit although one interpretation of the metamorphic sole would require that they should be (see below). Within the ground covered by the map (Figure 26.1) there are places where the metamorphic aureole is in contact with shale.

Locality 2. Banded epidote-mylonite rock (Figure 26.1)

Banded epidote mylonitic rock, grey-green in colour is exposed in a small waterfall and adjacent banks. The rock has in many places a classical mylonitic texture with coarse augen of epidote, albite and quartz. Small-scale folds are associated with the augen, and larger scale folds are up 30 cm in amplitude. The epidote rock is composed of actinolitic-hornblende, chlorite, albite porphyroblasts, epidote (sometimes as porphyroblasts) and mica. They are seen elsewhere to interleave with sheared shales and phyllites and no doubt are partly derived from them; but some of the epidote rocks have the chemistry of basalts, suggesting that they had a basaltic protolith.

Locality 3. Amphibolite (Figure 26.1)

Amphibolite, sometimes with excellent foliation, forms small exposures in the river banks and scattered over the hillside. The foliation generally dips to the NW but there is sufficient regional and local variation to suggest that there have been episodes of subsequent refolding which may be both ductile and brittle (see Spray and Williams (1980). Folded amphibolite is also fairly well seen at Locality 7. Garnets up to 20 mm in diameter occur in this amphibolite. The amphibolite is seen outside this area to interleave with the epidote rock and Spray and Williams (1980) have further subdivided the amphibolite into a lower, and an upper, the latter distinguished by having fairly abundant garnets. The amphibolites have a chemistry suggesting a protolith in basaltic rocks. The temperature-pressure regime under which the amphibolites formed is thought to be a minimum of 7kb and 850 °C. This pressure is equivalent to a depth of burial of 21 km.

Locality 4. Serpentinite and garnet metapyroxenite (Figure 26.1)

Sheared, tough, platy tremolite-bearing serpentinite outcrops in this and many other sections along strike. These rocks are replaced upstream by unsheared, banded serpentinite which represents the sheared base of that segment of the oceanic lithosphere which was involved in the obduction event. A few metres upstream from this point is the outcrop of the garnet metapyroxenite, although there are only a few scattered small blocks now to be seen. This rock is thought to have formed under pressures greater than 10 kb (= >30 km of burial depth) and temperatures of about 900 °C (Treloar et al 1980).

Altogether the rocks exposed at Localities 2–4 represent the sheared slices of the metamorphic sole to the ophiolite.

Locality 5. Pyroxenite (Figure 26.1)

This bold feature on the hillside to the NW comprises altered pyroxenite. It has a pod-like outcrop, is bounded by shears and is probably a structurally detached block caught up during the obduction of the serpentinite and incorporated into it. The rock is an olivine websterite with evidence of banding produced by tectonic granulation.

Locality 6. Serpentinite (Figure 26.1)

Serpentinite, which forms much of the high ground in this area, is exposed at a variety of places. It is a fairly tough foliated rock with foliations being almost N–S and striking into the zone of metamorphism at the base of the serpentinite. This discordant foliation is probably the result of tectonic overthrusting and rotation of an original foliation which may have been produced in the mantle during the movement of the oceanic plate away from the ridge where it developed. The original ultra-mafic rock was mainly a lherzolite comprising olivine, enstatite, diopside and picotite. However, plagioclase-bearing ultramafic rocks associated with these lherzolites would certainly not have formed in the same pressure-temperature regime. This evidence together with the granulation of the ultramafic rocks suggest structural interleaving within the serpentinite.

Locality 7. Dykes cutting aureole (Figure 26.1) & (Figure 26.2)

Returning now to the metamorphic sole it is possible at this locality (Figure 26.2) to study the rocks of the thermal aureole cut by dykes of the type seen along the coast (Excursion 25 Locality 14) and also at Carleton Bridge. The dykes are porphyritic and have distinct chilled margins against the amphibolite and serpentinite into which they intrude. In outcrop they clearly cut across the metamorphic zones with no displacement, thus indicating that both the development of the zones and their reduction in width were accomplished before dyke intrusion. It is also clear that the serpentinite was fairly cold at the time of dyke intrusion. Chemical and mineralogical analyses of these dykes indicate that they belong to the second phase of intrusion as identified by Holub et al (1984). At this locality it is possible to see some well developed banding and preferred mineral growth in the amphibolite and also some metre-scaled folds. The amphiboles from this locality yielded ages of 476+14 Ma which represent the cooling time of the amphibolite during its obduction.

Here, as elsewhere along the outcrop, there is a zone of sheared tremolitic serpentinite between the outcrop of amphibolite and the meta-pyroxenite. The serpentinite and metapyroxenite may belong to the late stage history of the thermal aureole, being emplaced during the time when the originally much thicker aureole was being sheared down to the thin representative now present. The metapyroxenite at this locality has a cooling age of 505+–11 Ma.

From this position it is possible to see Grey Hill and the tops of Byne and Mains Hill to the NW. These are gabbros, diorites and trondhjemites which have intruded into the serpentinite. To the SE lie the lavas of Aldons, the southern serpentinite and pods of sheeted dykes of Millenderdale and Fell Hill and beyond that the higher hills of the Southern Uplands.

There are some paradoxes concerning this thermal aureole which need discussion.

1. In most metamorphic complexes, where there has been no tectonic inversion, the pressure-temperature path increases downwards in the sequence. This example records the reverse of this: the rocks indicate a pressure-temperature decrease down section from the serpentinite to the black shales and olistostromes.
2. In a distance of <100 m the metamorphic grade changes from low grade, graptolitic shales to high grade metapyroxenite. This change in metamorphic grade, would normally have taken place over vertical distances of >30 km, so that the boundaries between the various Ethological units here must be greatly compressed. The faults which bound each of the metamorphic slices are therefore considered to have substantial throws.
3. One interpretation suggests that as the oceanic pile was being thrust onto the continental edge, shear planes developed within the ocean lithosphere and detached slices of lithosphere from differing levels along the subducting plate brought them together as a condensed sequence within the aureole (Figure 26.3) B. These slices were then attached to the upward moving hot plate and became the metamorphic sole to the ophiolite.
4. The protolith to the amphibolite and garnet meta-pyroxenite is mafic rock similar to that found in layer 2 of the oceanic crust. If the PT conditions of formation of these rocks require that they come from > 20–30 km depth, then how can layer 2 occur that deep in the lithosphere? The obvious solution is to have it descend down a subduction zone and then become detached as outlined in (Figure 26.3) B. There are, however, many other ways of effecting the obduction, and these can be followed up in the literature.

Return to the road and travel west to Lendalfoot. At Lendalfoot turn left at the A77 and then immediate left again to take the narrow road south towards Garnaburn, which is NW of Colmonell. After passing Carleton Castle and Little Carleton stop at the first cattle grid where there is a stretch of broad open marshy ground. Park south of the cattle grid. The exposures form the high northern edge to the low ground.

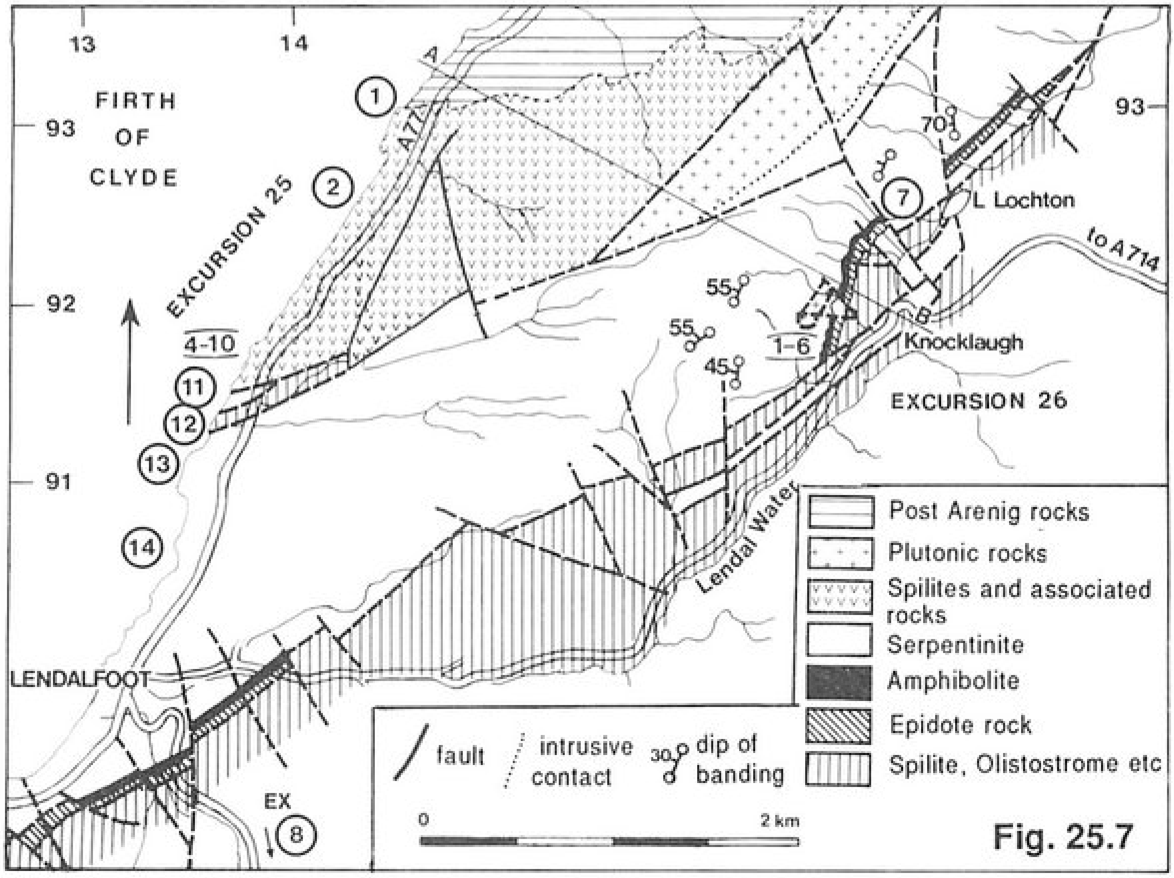
Locality 8. [NX 1375 8890]. Blue-schist, pyroxenite and wehrlite (Figure 26.4), (Figure 26.5)

The whole of this poorly exposed ground is characterized by blocks of granulites, lavas, limestones, cherts, granites, blue-schist, pyroxenites, serpentinites and wehrlites. In some instances these blocks are clearly in a highly deformed and mylonitic matrix; in others they are associated with less deformed black shales. It therefore seems reasonable to interpret the unit in which the blue-schist occurs as a mélange into which a wide variety of different rock-types have been emplaced.

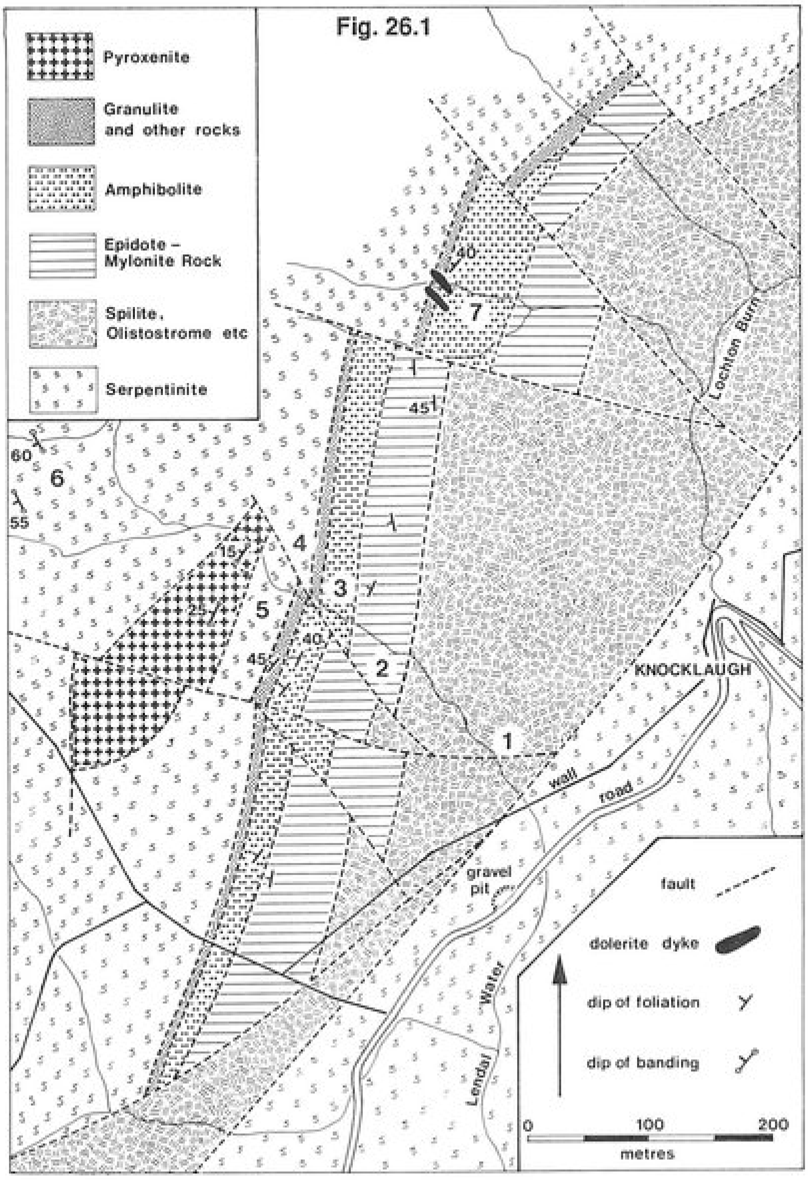
Blue-schist is exposed in the river section to the west (a) and in the field to the east are crags of blue-schist (b), and some 200 m to the east of these are further blocks of pyroxenite and wehrlite (c) (Figure 26.5)).

References

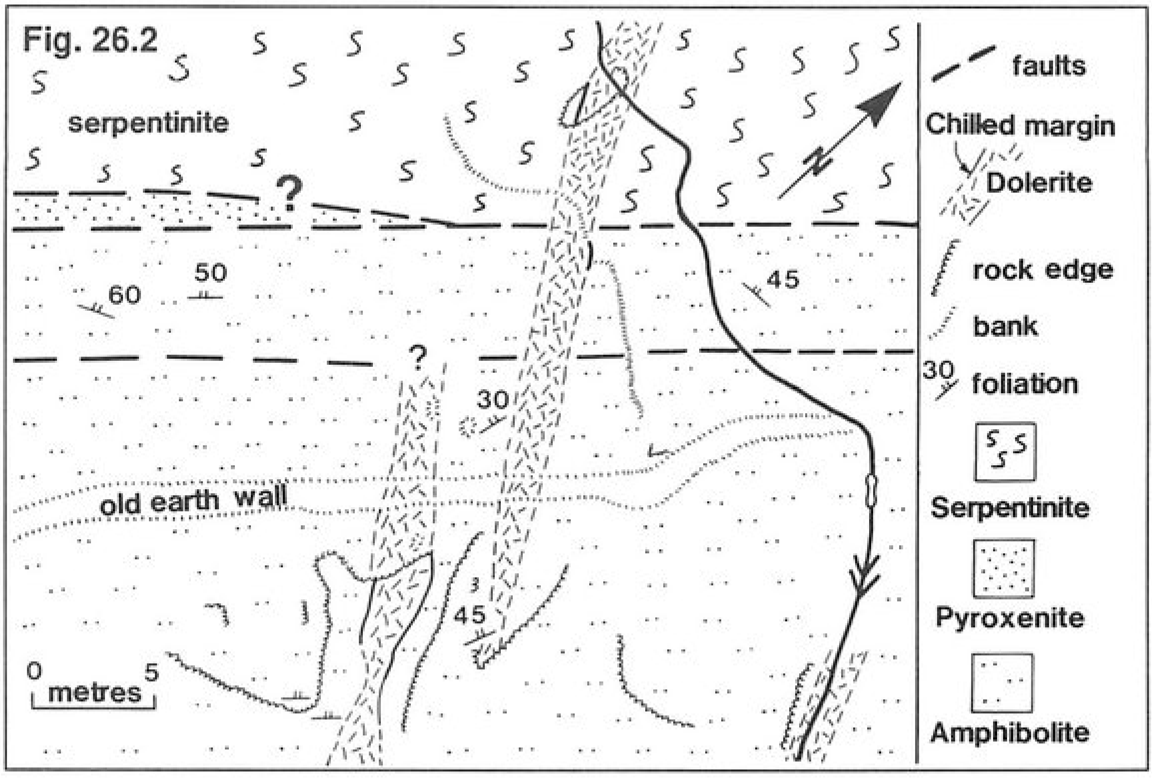
[References for excursions 25–31]



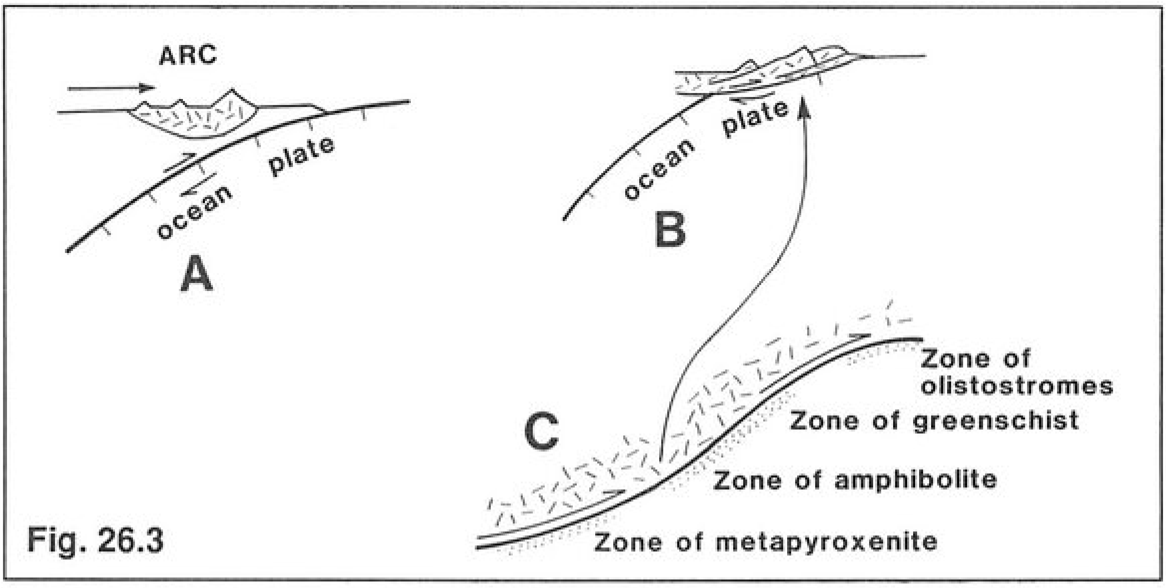
(Figure 25.7) Simplified map of the northern part of the Ballantrae Complex, with positions of localities mentioned in Excursions 25 and 26.



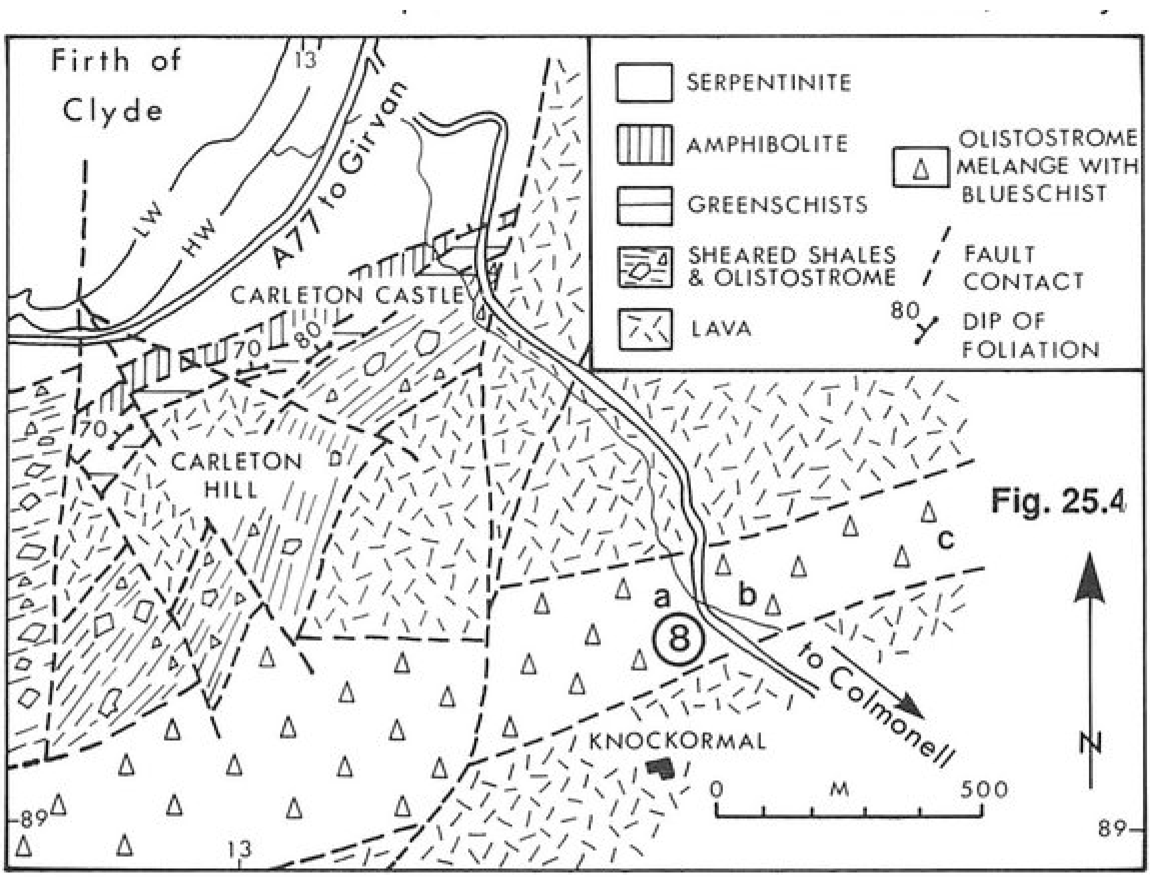
(Figure 26.1) Map of the metamorphic sole at Knocklaugh, Excursion 26.



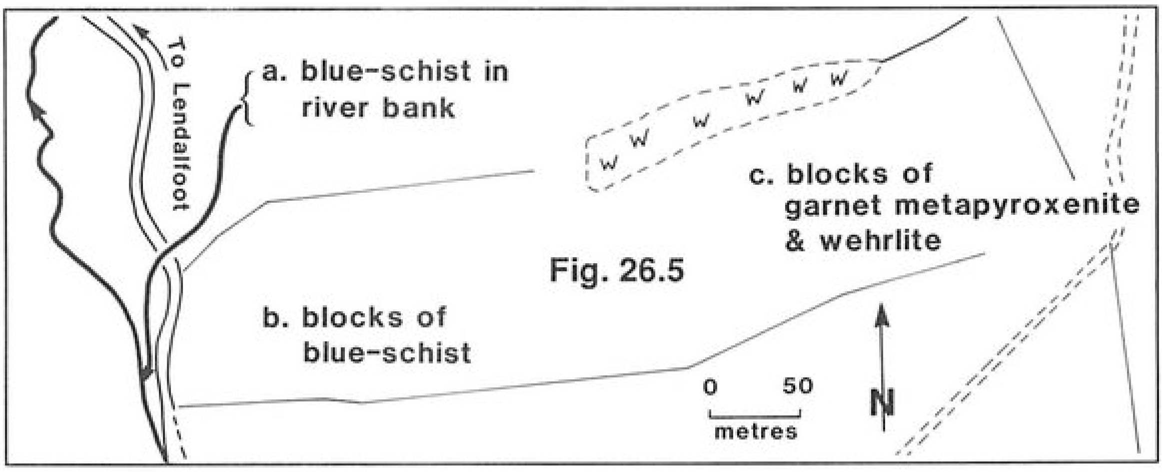
(Figure 26.2) Detailed map showing the relationship between the dykes and the metamorphic sole at Knocklaugh (see Locality 7).



(Figure 26.3) Possible explanation of the metamorphic sole to the ophiolite. A an arc, because of changes in the location and sense of subduction, is driven towards the source of the plate which created it. In colliding with the under-riding plate it underplates onto it the high pressure rocks belonging to this oceanic plate (B) But only fragments of this plate are accreted to the sole of the arc (C).



(Figure 26.4) General map of the Carleton Hill–Knockormal area, Locality 8.



(Figure 26.5) Detailed map showing the locations of the outcrops discussed (Locality 8).