Excursion for day 3

The purpose of this excursion is to examine the contact metamorphism of the abundant pelitic country rocks in the aureole, and, as outlined in (Figure 7), the day is divided into two separate excursions:

Day 3, Part 1: Fraochaidh prograde sequence - Metamorphic zones in pelitic hornfelses on the SSW side of the igneous complex.

This excursion provides a continuous section from low to high grade in metapelitic rocks on the NW flank of Fraochaidh hill, and illustrates in Creran Succession rocks the most common sequence of metamorphic zones in the aureole (see introduction). (Figure 10) gives the relevant geological and topographic maps.

Day 3, Part 2:Chaotic Zone migmatites on W side of the igneous complex.

This excursion examines the area where the most extensive migmatisation in seen in the aureole - the Chaotic Zone on the west flank of Beinn a' Bheither above Lagnaha Farm. The localities are shown on the geological and topographic maps of (Figure 11).

Both parts involve moderately short hill traverses, with: ca. 4 km walking and 250 m elevation gain for Part 1 (Fraochaidh prograde sequence); and ca. 2 km walking and 200 m elevation gain for Part 2 (Chaotic Zone). A compass and altimeter are recommended in both cases. Part 1 typically requires about 4 hours of time, but if you wish to examine and collect extensively, or follow the optional extensions to the excursion, it can occupy a whole day.

Note for both excursions: To drive all the way to the starting point of each of the traverses, it will be necessary to drive along the Forestry roads, for which a key to open the Forestry gates is necessary and must be obtained from the Forest Enterprise office in (see section on Logistics for Field Excursions). However, you can walk all the way from the Forestry gates, which will add an extra 2-3 km to the length of each excursion.

Table 3a. Itinerary of stops for Day 3, Part 1: Fraochaidh prograde sequence

	Grid ref.(sheet NN)	**Features**
Stop 3-1 Below (S of) A'Chruach	[NN 0140 5340]	Fissile cordierite-spotted phyllites of Zone II
Stop 3-2	[NN 0170 5290]	Hardened cordierite-spotted phyllites of Zone III
Stop 3-3 Coire na Capuill	[NN 0195 5275]	Massive cordierite-rich hornfelses of Zone III
Stop 3-4	[NN 0210 5280]	Cordierite+K-feldspar hornfelses of Zone IVb with honeycomb structure
Stop 3-5	[NN 0215 5275]	Andalusite+K-feldspar hornfelses of Zone Va
Stop 3-6	[NN 0225 5280]	Corundum-bearing hornfelses of Zone Vb)
Stop 3-7	[NN 0235 5270]	Different types of veins in hornfelses: onset of partial melting
Stop 3-8 Coire Dubh	[NN 0245 5265]	Garnet+cordierite-bearing and spinel-bearing hornfelses
Stop 3-9 Coire Dubh	[NN 0250 5265]	Biotite+hornblende quartz monzodiorite of the igneous complex

Excursion for Day 3, part 1

Fraochaidh prograde sequence

(Figure 10) gives the relevant geological and topographic maps

Directions to start of traverse: From the A828 road. take the Auchindarroch turnoff, about 300 m north of the Duror Hotel (see Coloured Map (Map 1)). Set odometer to zero at turnoff. Proceed along the paved road for about 0.25 miles (0.4 km), at which point you will reach a cross-roads where the roads/tracks to left and right are on the bed of the old railway line. The right-hand track is untarred, but is signposted "Home of James of Glen in 1752”. Follow this track, crossing over two small bridges, and continuing on to a junction at 0.55 miles (0.9 km) from the A828. There the line of the old railbed is taken by a track carrying straight on under a bridge, whilst the main track to Acharn Farm and the home of James of the Glen swings strongly around to the left. You take a middle, more-elevated track, which leads to a gate after 50 m. The gate is usually locked, but may be opened if you have obtained a Forestry key (see above). Proceed beyond the gate.

Note: The track that you are now following was built in 1993, and so does not appear on the 1978 Ordnance Survey map, although it has been added to the Coloured Map (Map 1) (Map 1) and (Figure 7) and (Figure 10).

Keep to the main track/road, passing numerous exposures of Appin Quartzite. Starting at about 2.0 miles (3.2 km) front the A828, there are several exposures of the Leven Schist from Zone III of the aureole showing good cordierite-spotted phyllites (see (Photo 7)). At about 2.2 miles (3.7 km), cross a small bridge over a burn and park in the lay-by (approximately [NN 0130 5375]).

Walk along a bike path leading south-eastwards for about 140 m, at which point the bike path begins to swing downhill to the north-east. Leave the bike path at this point and cross an overgrown area (in 1999) to the south-east for about 30 m, to join an obvious but rough brashed path by a burn. Climb up this steep path through the forest (ca. 150 m of elevation gain and general direction SSW) until you reach a low fence near the edge of the forest. This fence trends roughly on contour in a south-easterly direction. Set altimeter to 330 m The route followed since the parking place is indicated on (Figure 13). The traverse begins on the open grassy slopes above the fence.

Stop 3-1. Fissile cordierite-spotted phyllites of Zone II. [NN 0140 5340], 360m.

Directions: After having climbed over the fence, proceed southwards uphill for 100–150 m, on a grassy slope with boulders, to the lowermost of many exposures.

Description: These exposures are of green-grey crenulated phyllites and locally show well-developed spots, best seen on clean surfaces parallel to the main schistosity or cleavage. The spots are (pale) brown on clean weathered schistosity surfaces, and darkish grey on fresh schistosity surfaces, with ovoid shapes and diameters of 2-7 mm (see (Photo 7)).

The spotting is more easily seen in hand specimen than in thin section. In thin section, the spots vary in appearance from irregularly-shaped, brown, scaly film-like patches to fine-grained mixtures of chlorite and muscovite that overprint the foliated matrix. Based on the similarity in size, shape and mode of occurrence of these spots with cordierite spots found in Zone 11 elsewhere in the aureole, they are interpreted to be pseudomorphous after cordierite. Chlorite of regional origin is present in the matrix, resulting in the diagnostic Zone II assemblage Ms+Chl+Crd+Bt+Qtz (ca. 560 °C). The cordierite is thought to be introduced by reaction P1 (Ms + Chl + Qtr = Crd + Bt H_2O; see Introduction).

Location of the cordierite (spotting) isograd. The spotted phyllites of Stop 1 are in Zone II of the aureole. Owing, to poor exposure in the direction of lower grade (WSW), it is difficult to pinpoint exactly where cordierite spotting first appears (i.e., pinpoint the cordierite isograd) in this vicinity. If one walks westwards and uphill from Stop 3-1 towards where a fence heads up a small valley to the south-west, the frequency of spots decreases and they may become absent just before the fence ([NN 0125 5335]; 390 m), which is also where exposure dies out. Climbing straight uphill southwards from Stop 3-1, the spots decrease in abundance and disappear within 50 to 100 m.

Stop 3-2. Hardened cordierite-spotted phyllites of Zone III. [NN 0170 5290], 420m.

Directions: From Stop 3-1, proceed south-eastwards parallel to the south-east-trending, fence above the trees, examining the lowermost exposures of the grassy hillside. Throughout much of the interval between Stops 3-1 and 3-2, the traverse runs parallel to metamorphic grade within Zones II and III. Spots continue to be readily seen in crenelated green phyllites, which form the dominant rock type with interbeds of semipelite and psammite. At [NN 0150 5320] (shown on (Figure 10)), there is a prominent exposure beyond which the hillside above the forest becomes less steep. At about [NN 0155 5315], the edge of the forest swings sharply away to trend ENE, but the fence carries on south-eastwards but now runs obliquely uphill. Continue on, heading gently uphill south-east and keeping just above the fence, for about 300 m until some low, knobbly exposures surrounded by grass, on the other side of a small burn, are encountered in a relatively level area down slope of the steeper, craggier part of the hillside. This is Stop 3-2. On the way at [NN 0160 5300] (indicated on (Figure 10)), a short distance up the slope to the south, some prominent platy exposures may be examined that contain psammitic beds.

Description: The rocks are generally more spotted (cordierite-richer), and tougher and greyer (less green) in colour than at Stop 3-1, but they still preserve clear evidence of schistosity, and some layers are still readily fissile. Many layers contain fresh cordierite. The most common assemblage is Ms+Crd+Bt+Qtz, diagnostic of Zone III of the aureole. In these samples, there is no evidence of the primary chlorite present at lower grade (Zone II); the chlorite is interpreted to have reacted out by reaction P1 (Ms + Chl + Qtz = Crd + Bt + H_2O).

Location of the chlorite-out (Zone II/III) isograd and the width of Zone II. Pinpointing the Chl-out isograd between Stops 3-1 and 3-2 is difficult to do in the field. Based on thin section analysis (unpubl. data), the last appearance of primary chlorite occurs around the exposure at [NN 0160 5300]. Combined with thin section analysis of other samples in the vicinity, the overall width of Crd+Chl-hearing Zone II is 50–100 m.

Stop 3-3. Massive cordierite-rich hornfelses of Zone 111. NN 11195 5280, 430 m

Directions: From Stop 3-2, the fence keeps a roughly SE trend, with some wiggles, until [NN 0180 5270] where it bends sharply to trend ENE and crosses a burn. In the interval before the sharp bend in the fence, you may wish to examine the lowermost exposures on the hillside above the fence; it is still obvious that the rocks were once crenelated phyllites, although they are now quite tough cordierite-spotted rocks from Zone III. Follow along below the fence trending to the ENE, crossing two deeply incised burns. Semipelitic hornfelses in the burns appear to be rather fractured with abundant oxide staining, possibly indicating a fault zone (Pass of Brander Fault? - Pattison & Volt. 1991). Exposures in between the burns are mainly quartzose with some spotting visible. About 100 m further on, the fence swings uphill to the south; do not follow the fence. Instead, bear NE and cross a small burn to a nearby low ridge with a series of good exposures forming Stop 3-3.

Description: The rocks here show a contrast with previous exposures in that they have a marked pitted structure on weathered surfaces (see (Photo 11)). The roughly equant pits are 2-7 mm across and mark the sites of weathered out cordierite crystals. Around the pits the rock matrix forms a network of paler-coloured material containing tiny dark pits. The pale matrix is rich in muscovite and the tiny dark pits are the sites of biotite crystals. Thin (ca. 1 mm) dark seams rich in biotite mark the presence of former crenulation cleavages. The rocks will still break along these surfaces occasionally. Although these rocks show a somewhat coarser grain size and more massive, pitted appearance than rocks at Stop 3-2, they still contain the same Zone III mineral assemblage (Ms+Bt+Crd+Qtz). Craggy exposures uphill to the south show extensive exposures of these pitted hornfelses.

Stop 3-4. Cordierite+K-feldspar hornfelses of Zone IVb with honeycomb structure. [NN 0210 5280], 430m

Directions: From Stop 3-3, bear east for about 150 m to very extensive exposures with large expanses of flat rock surfaces parallel to the ground surface, situated beneath prominent north-facing crags.

Description: Clean weathered surfaces commonly show a small-scale network structure of light-coloured ridges surrounding 0.2-0.3 mm pits, the latter representing weathered-out cordierite crystals (see (Photo 12)). The main distinction from the last locality is that in many rocks the network appears whiter and sharper here, reflecting the change in the matrix mineralogy from K-feldspar-absent (Stop 3-3) to frequently K-feldspar-rich. The presence of K-feldspar (Kfs) places these rocks in Zone IVb (ca. 620 °C). The full assemblage in the layers with the white network is usually Ms+Bt+Crd+Kfs+Qtz. However, not all rocks contain Kfs; most likely reflecting bulk compositional variations, especially Fe-Mg ratio (see (Figure 8) of Pattison & Harte, 1997). In rocks with Kfs, the modal amount of muscovite has decreased markedly from Zone III, consistent with production of Kfs by reaction P2b (Ms+Bt+Qtz = Crd+ Kfs+ H_2O).

An additional feature of these exposures, not seen previously, is the presence of some thin (< 2 mm wide) white, generally subvertical seams, several cms in length, which cut across foliation and other structures; these are dominantly composed of K-feldspar and trend generally in a NW-SE direction. A possible interpretation of these seams is that they represent the conduits for the upward escape of fluids generated during production of the Crd+Kfs-bearing Zone IVb assemblage at the expense of the lower grade Zone III Ms+Bt-rich assemblage (i.e., reaction P2b), with the conduits having formed due to fluid (hydro-) fracturing of the strongly recrystallized hornfels. The absence of comparable features at lower grade may have been due to the more fissile nature of the rocks, possibly allowing escape of fluids parallel to the preexisting schistosity. Although it is not an obvious characteristic of the rocks, one can still see evidence of relict dark cumulation cleavages (rich in biotite) along which the rocks may occasionally break.

Stop 3-5. Andalusite+K-feldspar hornfelses of Zone Va. [NN 0215 5275], 450 m

Directions: From Stop 3-4, proceed about 75 m upwards to the east to the craggy exposures at the top of the expanse of flat exposures.

Description: Layers containing andalusitc crystals are locally interbedded with hornfelses showing the white, Kfs-rich ribbed texture first seen at Stop 3-4. On weathered surfaces, the andalusite protrudes above the hornfels exposure surfaces, occurring as small sharpish points and sometimes in well-defined, 2-20 mm long, slender prisms (see (Photo 18)). Most rocks have lost all sign of primary, fine-grained muscovite. The loss of muscovite in conjunction with the development of And+Kfs represents the Zone IVb/V isograd, and is ascribed to reaction P3 (Ms+Qtz = And+Kfs+ H_2O; ca. 640 °C). Although not visible in hand specimen, volumetrically minor sillimanite also makes its first appearance at this grade in this vicinity.

Stop 3-6. Corundum-bearing hornfelses of Zone Vb. [NN 0225 5275], 440 m

Directions: From Stop 3-5, continue bearing about 100 m east at about the same height, examining prominent craggy hornfels exposures locally containing andalusite.

Description: Thin section examination reveals that a few andalusite-rich hornfelses also contain corundum. Identifying corundum in the field is not easy: it is relatively rare and typically occurs in andalusite-rich layers in small upstanding 'pimples' on the clean rock surfaces, typically less than 2 mm across, which are distinct from the larger, more prismatic andalusite crystals (see (Photo 19)). In thin section corundum occurs in irregularly shaped crystals typically surrounding ilmenite crystals. Corundum-bearing layers are quartz-absent, rarely have muscovite, and contain the assemblage Crn+And±Sil+Crd+Bt+Kfs. The first appearance of corundum corresponds to the Zone Va/Vb isograd, and is inferred to be due to reaction P5 (Ms = Crn+Kfs+ H_2O: ca. 670 °C). Interlayered quartz-bearing layers contain the assemblage Crd+Qtz+Bt+Kfs+Bt±And-±Sil.

Rocks in this vicinity show sub-vertical, NS- trending discrete white veins of 1-2 mm thickness which cut across layering and cleavage, forming a parallel set which do not interconnect very much with one another or with other layer-parallel structures. Although of a similar nature to the veins first noted at Stop 3-4, the length and continuity of these veins is generally greater than at Stop 3-4.

Note: More abundant corundum-bearing hornfelses are found in Coire Giubhsachain, as described in the Day 5 excursion.

Stop 3-7. Different types of veins in hornfels: onset of partial melting. [NN 0235 5270], 440–460 m

Directions: From Stop 3-6, continue ESE and uphill in the direction of a large light-coloured boulder. After 150–200 m, you will find yourself on the edge of a ridge below which Coire Dubh opens out immediately to the east, and where the major crags swing round to take a more NNW–SSE, rather than WNW-ESE, trend. The exposures of Stop 3-7 occur for about 100 m leading up to this point.

Description: The hornfelses have a generally similar appearance and mineralogy to those of Stops 3-5 and 3-6, with local andalusite- and corundum-bearing layers, but show a greater variety of mm-scale vein types. The veins appear to be a little wider and stand up as ribs on exposure surfaces. Some are sub-vertical, discrete and relatively sharp-margined like those seen at lower grade, whereas a larger proportion show a variety of orientations, are less continuous, and have less sharp contacts with the enclosing hornfels, in places merging with the matrix. Some sub-vertical veins interconnect with more shallowly-dipping veins. Many of the veins are of a fine-grained, granular Kfs+Qtz-rich composition and resemble migmatitic leucosomes, contrasting with the thin Kfs-dominated mineralogy of the veins noted in Stops 3-4 to 36. In thin section, the more diffuse veins show a range of igneous-like textures similar to those observed in migmatites elsewhere in the aureole (Haile et al., 1991a). Taken together, these features are tentatively interpreted to be indicative of localized partial melting in the hornfelses. The temperature of these rocks was probably ca. 700 °C (see Introduction).

Stop 3-8. Garnet+cordierite-bearing and spinel-bearing hornfelses. [NN 0245 5265], 430–450 m

Directions: Standing on the edge of the corrie, one sees just below and to the east on the lip of the corrie floor, a low smooth rocky whaleback ridge lying just beyond a small gravel/boulder landslip area of similar size. This low rocky whaleback is Stop 3-8.

Description: Granular, medium-grained, biotite-rich hornielses show variably abundant red garnet porphyroblasts around 4 to 7 mm across. The full assemblage in these rocks is Bt+Crd+Grt+Kfs+Qtz+Pl+Ilm. Interlayered light-coloured quartz-absent hornfelses may contain corundum and green hercynitic spinel (not visible in exposure). Although these exposures show few obvious leucosomes or flow structures, thin sections show several of the igneous-like textures found elsewhere in the migmatite zone of the aureole (Harte et al.. 1991). These rocks are among the highest grade hornfelses in the aureole, having formed at temperatures of 750–800 °C (Pattison. 1989).

Stop 3-9. Biotite+hornblende quartz monzodiorite of the igneous complex. [NN 0250 5265], 450 m

Directions: Proceed about 50 m SE of Stop 3-8, examining low exposures.

Description: The rock is clinopyroxene+biotite±hornblende-bearing quartz monzodiorite of the igneous complex, locally showing fine-grained, schlieren textures.

Options from Stop 3-9.

1. Retrace your route back to the vehicle.
2. Explore further the high-grade cordierite-rich hornfelses of Coire Dubh, many of them contain hercynitic spinel (refer to (Figure 10) for the details of the geology in Coire Duhh).
3. A more scenic and correspondingly more strenuous option, and one which allows examination of another transect into the aureole, is to hike to the summit of Fraochaidh which forms the head to Coire Duhh.

The best route for option (c) is to ascend the broad shoulder of Fraochaidh to the east of Coire Duhh. Going up the shoulder, one passes from a xenolith-hearing diorite facies of the igneous complex into striped psammitic hornielses that have few distinctive contact metamorphic features. However, the rocks on this eastern shoulder of Fraochaidh fall just within the garnet zone of the earlier regional metamorphism ((Figure 10) and Coloured Map (Map 1)). Therefore, higher up the hill in the lower grade parts of the aureole, relict regional garnet may be seen, whilst cordierite-biotite pseudomorphs after such garnet are found in the higher-grade contact metamorphic rocks. The regional garnets are quite distinct to the contact metamorphic garnets found at the highest grade of contact metamorphism (e.g. Stop 3-9). The summit of Fraochaidh is underlain by cordierite-spotted pelites and semi pelites of Zone III. Regional grade Ms+Chl-bearing rocks of Zone I are found a short distance down the slope south of the summit.

For an easy, rambling descent from the summit of Fraochaidh, walk WNW and then NW down the ridge top to the small loch by A'Chruach, and from there descend to the brashed track at the start of the traverse. For a more geologically orientated descent, one can go clown down the NW-trending salient between Coire na Capuill and Coire Duhh. Going down the salient takes you more or less along strike in the Creran Succession, and upgrade past excellent exposures of Zone III Crd-spotted pelites and IVb massive Crd+Kfs hornfelses, rejoining the morning route around Stop 3-4 or 3-5.

End of part 1 Day 3

Excursion for Day 3, Part 2. Chaotic Zone migmatites

The aim of this traverse is to examine the extensively disrupted and migmatised pelitic and semipelitic Leven Schists occurring at the western margin of the igneous complex in the crags above Lagnaha ((Figure 7) and Coloured Map (Map 1)). In addition, some calsilicate and marble exposures are present in the same vicinity. This excursion, or parts of it, may be clone in 2-4 hours and combined with the Fraochaidh prograde traverse (Day 3, Part 1) to make a complete day. Alternatively, if it is desired to spend plenty of time exploring around the localities suggested, the traverse can occupy a full day. See (Figure 11) for the relevant location maps.

Table 3b Itinerary of stops: Chaotic Zone migmatites and nearby carbonates and calsilicates

	Grid ref. (sheet NN)	**Features**
Stop 3-10 Above Auchindarroch	[NN 0165 5525]	Hybrid granite of the igneous complex
Stop 3-11	[NN 0160 5530]	Disrupted pelitic and semipelitie rocks of the 'Chaotic Zone'
Stop 3-12	[NN 0160 5535]	Intrusive veins and dyke cross-cutting disrupted migmatites
Stop 3-13	[NN 0160 5565] to [NN 0160 5575]	Many good exposures of 'Chaotic Zone' migmatites
Stop 3-14 Above Lagnaha	[NN 0145 5590]	Striped calsilicates of the Ballachulish Limestone lithology
Stop 3-15	[NN 0135 5580] to [NN 0125 5560]	Marbles, calsilicates and semipelites of the Appin Limestone/Appin Phyllite lithology

Directions to start of Chaotic Zone traverse: The following directions take you by vehicle from the A828, by Duror, to the nearest point to the rock exposures that may be reached by car. The route involves entering the Glen Duror forest at [NN 0050 5515] to the east of Auchindarroch – as in the itinerary for Day 2. Note that to drive into the forest, you will need a key to the forestry gate (see section on Logistics for Field Excursions). If you do not have a key it is an extra walk to the exposures of approximately 2.5 km.

Starting from the A828 road, take the Auchindarroch turnoff, about 300 m north of the Duror Hotel. Set odometer to zero at this turnoff. Follow the main paved road 0.75 miles (1.2 km), to where a paved road forks oil to the right, whilst straight ahead the paving gives way to a dirt track which soon forks to give two tracks both barred by gates. You should proceed to the left-hand gate [NN 0050 5515], which is usually locked, but may be opened with the Forest Enterprise key (see above). From the gate follow the 'main' (most 'straight-on') forestry road/track, avoiding the road to the right at 0.9 miles (1.5 km). At 1.65 miles (2.6 km as measured from the A828) the road forks (the exposures on the N (left) side of the road comprise Stop 2-1). Take the left hand fork (not the right hand fork as in Day 2). After about 150 m the road bends around to the left and heads obliquely uphill. Follow the main ('straight-on') road up to the NE, as high as it goes, avoiding all small roads coining in from the sides, to an intersection with a prominent upper forestry road at [NN 0150 5490] (ca. 2.3 miles or 3.7 km from the A828). At this intersection the main road is tarred around the bend as it swings right, but you proceed left (close to straight-on), and continue for about 100 m to a lay-by, just beyond where the road crosses over a burn. Park in this lay-by [NN 0140 5500]. Set altimeter to 275 m.

Stop 3-10. Hybrid granite of the igneous complex. [NN 0165 5525], 400m.

Directions: From the lay-by where the vehicle is parked, ascend the hillside (a tree-felled area in 1999) beside the burn. There are extensive exposures in the burn of biotite- and hornblende-bearing granodiorite, with relic clinopyroxene. Continue upstream until a fence marking the boundary of the forested area is reached at about 350m elevation. Cross the fence onto open grassy slopes. Keeping on the left (west) side of the burn, climb uphill for ca. 150 m in a north-easterly direction to light-coloured exposures just to the west of the burn which cuts a deep gullet at this elevation.

Description: The light-coloured rock faces seen here are of hornblende- and biotite-bearing. pinkish-greyish, quartz-bearing monzogranite with mafic clots. They are in the marginal zone of the igneous complex.

Stop 3-11. Disrupted pelitic and semipelitic rocks of the 'Chaotic Zone'. [NN 0160 5530], 410m.

Directions: From Stop 3-10), head about 75 in to the NW. away from the burn, to some relatively dark and craggy exposures. Examine several exposures in this vicinity.

Description: Good, moderately clean exposures show many of the features characteristic of the Chaotic Zone migmatites (see (Photo 13) and (Photo 14)). The rocks belong to the Leven schist lithology. Two main rock types are seen: generally granular, relatively homogeneous, quartzofeldspathic rock with a relatively weak, diffuse foliation, which forms most of the volume of the exposures; and layered cordierite- and/or andalusite-rich hornfels lavers and fragments (schollen) which occur in various orientations in the granular matrix. The way that the rigid fragments are suspended at all angles in the granular material, gives the exposures a xenolithic igneous appearance. The mineral assemblage in the granular matrix is rich in Qtz+Kfs+Pl+Bt. with variable amounts of Crd+And, in thin section it shows a number of igneous-like textures (Harte et al., 1991a). The hornfels schollen are rich in Crd±And+Kfs with rare sillimanite. These mineral assemblages place the rocks in metamorphic Zone V.

Significant disruption and loss of cohesion of original sedimentary layering is evident everywhere, but varies in extent from exposure to exposure. The most striking extents of disruption are those showing disorientated fragments of hornfels 'floating' at all angles in the matrix. These features indicate that the granular semipelitic matrix responded to external stresses in a ductile fashion, whereas the hornfels schollen responded in a brittle fashion. In some localities, diffuse planar textures in the matrix that bend around hornfels fragments may represent a crude flow foliation (see (Photo 13) and (Photo 14)).

Locally, 2–10 mm wide veins of a dominantly subvertical, N- to NE-trending orientation, anastomose through the semipelitic matrix, forming upward-weathering ribs on the exposure surfaces (Photo 13). These may branch and interconnect but typically maintain a limited range of trends. The veins are granular and rich in K-feldspar and quartz with variable amounts of plagioclase, biotite and cordierite. The margins of the veins with the enclosing rock are generally well defined but not sharp.

The extensive disruption and range of migmatitic features in the Chaotic Zone is unique in the aureole. The disruption is attributed to widespread melting of the abundant quartzofeldspathic Leven Schist semipelite. The volume of melt produced in the semipelitic matrix appears to have exceeded the critical melt fraction for suspension-like behaviour of crystals in a fluid (melt), accounting for the semipelite's ductile characteristics and ability to flow. Melt-poor pelitic hornfels layers responded to the stress in a brittle way, leading to disaggregation. The most likely cause for the extensive inciting was the release of both heat and fluids from crystallization of quartz diorite which underlies these rocks (Pattison & Harte, 1988; Linklater et al.. 1994). Later intrusion of pink granite, which forms the igneous contact in this vicinity, may have been a source of stress contributing to the local disaggregation of hornfels layers and incipient bulk How of the partially molten semipelitic matrix. The veins are interpreted as relatively late-stage features in melting, segregation and crystallisation history of the migmatites, possibly representing pathways of late, volatile-enriched melts.

It is at first sight paradoxical that the Chaotic Zone migmatites, which are by far the most extensively melted country rocks in the aureole, achieved only modest temperatures within Zone V. The absence of high-grade minerals like spinel, garnet and hypersthene, the rarity of sillimanite, and the stability of chlorite+calcite in adjacent calsilicates (see below and Pattison & Harte, 1997) indicate that these rocks were heated to 670–700°C, only a little higher than the water-saturated granite solidus. This temperature range is significantly below the 750–800°C temperatures in other parts of the aureole (e.g. Fraochaidh. Sgorr Dhearg) where the pelitic and semi-pelitic rocks contain higher-grade mineral assemblages, yet generally show evidence for only small degrees of partial melting. The extent of melt formation in the Chaotic Zone migmatites is probably linked with fluid infiltration from the underlying, quartz diorite (Paulson & 1988: Linklater et al., 1994); and thus provides eloquent testimony to the effectiveness of fluid infiltration as a means of generating extensive melting, at relatively modest temperatures.

Stop 3-12. Intrusive veins and dyke cross-cutting disrupted migmatites. [NN 0160 5535], 420m.

Directions: From the first exposure of Stop 3-11, proceed about 75 m in NW and obliquely uphill, examining exposures along the way.

Description: A few cm-wide veins and a 2-3 m wide dyke of granitoid material from the igneous complex cut the disrupted metasediments in this vicinity. The dyke tapers to the SSE and widens upslope to the NNW to join with the main mass of granite: thus giving the impression of an apophysis.

The contrast between the light-coloured, medium-grained, granite-textured dyke material and the darker, finer-grained, granular semipelitic material with hornfels fragments is obvious. Although the veins and dykes make well-defined contacts with the metasediments, the contacts nonetheless vary from diffuse where in contact with the granular semipelitic material, to sharp where in contact with the hornfels schollen. In places, a few metasedimentary fragments have been entrained at the margins of the dykes.

These features demonstrate that there was negligible mixing and interaction of magma from the igneous complex with the nubile metasedimentary material, further indicating that the mobility of the metasedimentary material was due to internal processes, most likely internal melt generation fluxed by magmatic volatiles (see above). These features also suggest that although the granitoid material and granular semipelitic material were both ductile and able to flow, the two magmas were sufficiently viscous that they did not mix very much.

Stops 3-13. Many good exposures of Chaotic Zone migmatites enroute to and in the vicinity of [NN 0160 5565] - [NN 0160 5575], 470–500m.

Directions: From Stop 3-12, head northwards (azimuth (005°) obliquely uphill towards the shoulder of dark coloured exposures and grass. The route follows close to the contact of the metasediments with granite of the igneous complex, the latter revealed by light coloured exposures and boulders just to the west, which contrast with the dark outcrops of the migmatites (see (Photo 15)). At an elevation of about 470–480 m, near the top of the shoulder ([NN 0155 5555], marked on (Figure 11)), are numerous large, well-exposed outcrop surfaces that show the full range of 'Chaotic Zone' features described under Stop 3-11. Cm to m-scale pockets of white vein-quartz additionally appear in some exposures, sometimes in vaguely defined trains suggesting that they were mechanically broken apart and separated during disruption of the metasediments. Some very andalusite-rich hornfels occurs in the vicinity of, sometimes on the margins of, these quartz-rich segregations.

Continue heading north to some dark, south-facing exposures adjacent to a burn: the exposures along the burn and about 100m north of the burn at about the same elevation constitute Stop 3-13.

Description: These exposures allow examination in three dimensions of some of the most spectacular features of the Chaotic Zone migmatites described under Stop 3-11. The variable extents of disruption of primary layering are well displayed in this vicinity. Although there is an overall NS-trending, steeply E-dipping planar foliation/layering in the exposures, defined by trains of schollen and by the weak foliation in the granular semipelitic matrix, in detail the coherency of the primary layering is largely lost. There are a variety of vein types and schollen types. Some of the schollen are very rich in andalusite and/or cordierite.

Stop 3-14. Striped calsilicates of the Ballachulish Limestone lithology. [NN 0145 5590], 430m.

Directions: From the well-exposed disrupted migmatite exposures about 100 m north of the burn of Stop 3-13, bear about 320° downhill for 200 in to a prominent grassy, flat-topped ridge. This ridge has platy, slab-like, exposure along its flanks and lies immediately beyond a steeply incised burn. Descend the slope. crossing a boggy area en route to the ridge. Downslope to the WNW, beyond the boggy area and where a burn goes over a small waterfall ([NN 0145 5580], 430 m), are some more light-coloured platy exposures of the same rock type as that on the flanks of the ridge.

Description: The rocks are NS-trending, steeply cast-dipping (000–020/65-90E), fine-grained, white- and green-striped calcsilicate rocks, with many tight folds and some quartz pods. These calcsilicates belong to the lowermost part of the Ballachulish Limestone unit (see Coloured Map (Map 1) and (Figure 11)). A ca. 1.5 m-thick, shallowly dipping granitoid sill cuts the calcsilicates near the bottom of the outcrop.

The layering in the calcsilicates is on a mm to cm scale and is quite regular. The white layers are rich in diopside, with variable amounts of tremolitic amphibole, plagioclase and quartz, whereas the darker, green layers are rich in biotite and sometimes chlorite, with variable amounts of the above minerals. K-feldspar, calcite and wollastonite have been observed in some layers. Rare samples containing coexisting chlorite+calcite without spinel restrict the maximum temperature of these rocks to about 670 °C (reaction C17 of (Figure 6)).

Looking up slope from here, the location of the igneous contact can be seen where dark grey outcrops of the migmatitic metasedimentary host rocks pass uphill into lighter-coloured outcrops of granite and granodiorite (see (Photo 15)).

Stop 3-15. Marbles and calcsilicates of the Appin Limestone. [NN 0135 5580]–[NN 0125 5560], 410 - 340m.

Directions: From Stop 3-14, follow the burn down into an obvious gulley, and descend the NNE-SSW trending gulley for about 200 m until a fence is reached, examining the abundant carbonate and layered calcsilicate rocks along the way.

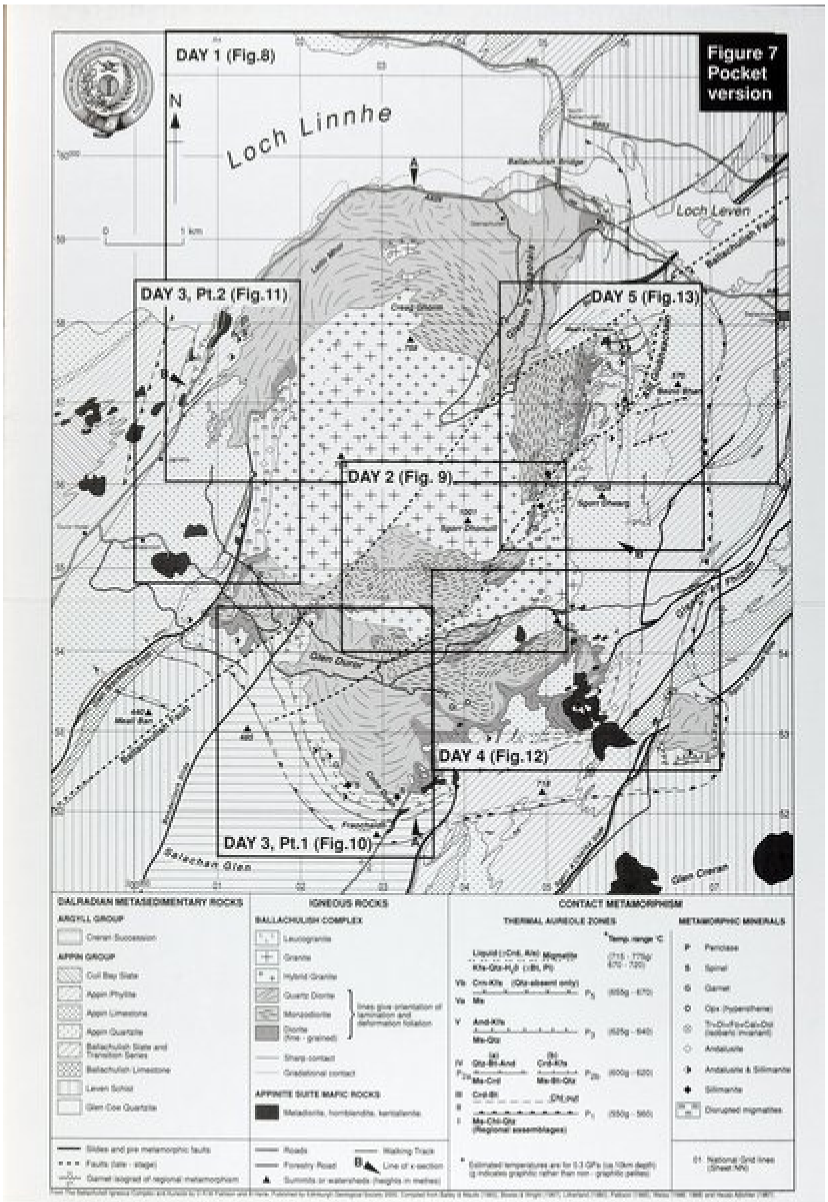
Description: Many varieties of carbonate-rich and calcsilicate rock, locally interlayered with psammitic and rusty-weathering semipelitic rock, are found in the steep gulley. The first, dark-weathering exposures are of yellowish-brown, dolomite-rich carbonate rock showing dissolution along fractures. Continuing down the gulley, various other carbonate, calcsilicate and semipelitic rocks are encountered, including dolomite-rich carbonate rocks with a mm to cm scale, downward-weathering calcite nodules. Strongly ribbed calcsilicate rocks, sometimes with dark micaceous or psammitic interbeds, are also common: these are distinguished from the striped calcsilicate rocks of the Ballachulish Limestone (Stop 3-14) by their less regular (mm-cm scale) thickness variations and the greater variability of the compositions of individual layers. Many rocks contain mm-cm scale veins, which are often quartz-rich, indicative of fracture-channelled fluid infiltration. In places, especially going up the slope to the west, the carbonate and calcsilicate rocks are interlayered with metapelitic and quartzitic rocks.

The marbles and calcsilicates belong to the Appin Limestone unit. Layering in the rocks overall has a steeply east-dipping, NNE-trending orientation (e.g., 025/60E), although there are many folds visible. Above the gulley to the immediate west is a thick expanse of Appin Quartzite, comprising the folded core of the Beinn Sgluich Anticline. The rocks above the gulley to the east, but downslope of the green- and white-striped calcsilicate unit of the Ballachulish Limestone unit, form an interlayered interval of carbonate rock, cordicrite-rich pelitic hornfels and quartzite, with carbonate increasing towards the gulley. This interlayered sequence comprises the Appin Phyllite and Appin Limestone units, and is equivalent to the mixed, calcsilicate/marble and pelite/semipelite sequence seen at Stop 1-7, which occurs on the other (west) side of the Beinn Sgluich Anticline (Figure 2). The mixed Appin unit here is separated from the green- and white-striped calcsilicates of the Ballachulish Limestone unit by a major fault, the Glen Stockdale Slide. This slide cuts out the Transition Series, Ballachulish Slate and most of the Ballachulish Limestone units (Figure 2).

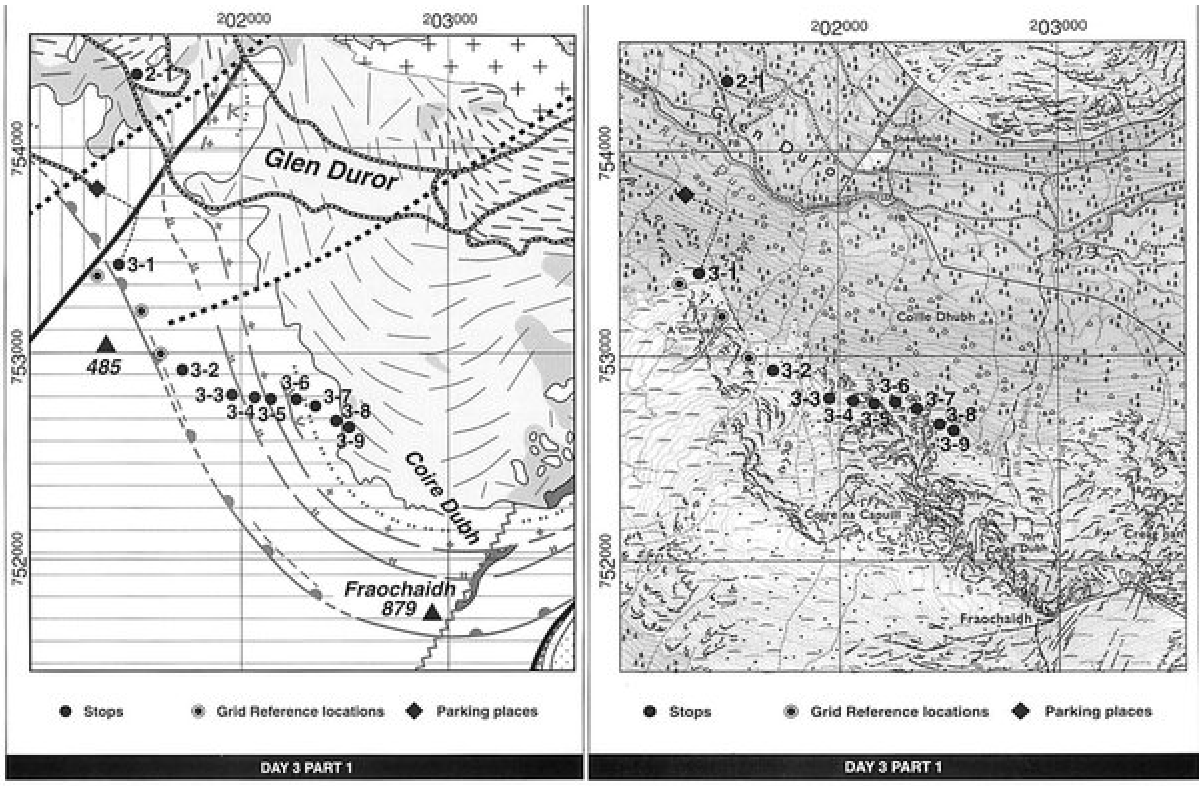
Thin-section analysis reveals that the carbonate-rich rocks typically contain calcite, dolomite, mid various combinations of forsterite (variably altered to serpentine and more rarely talc), diopside, tremolitic amphibole, epidote, chlorite. phlogopite, plagioclase and rarely spinel, wollastonite and quartz. Calcsilicate rocks contain variable combinations of calcite, dolomite, plagioclase, quartz, tremolitic amphibole, diopside, phlogopite, muscovite, K-feldspar and rarely wollastonite. The occurrence in close proximity of Spl+Fo+Cal+Dol-bearing and Chl+Cal-bearing marbles, and of Cal+Qtz-bearing and Cal+Qtz+Wo-bearing marbles, indicates local variations in fluid composition (Paulson & Harte, 1997). These variations were most likely caused by localised, channelled, water-rich fluid infiltration, consistent with the veining visible in many of the rocks.

Return to the vehicle by climbing cast out of the gulley and following the SE-trending fence back to the burn that was ascended to reach Stop 3-10.

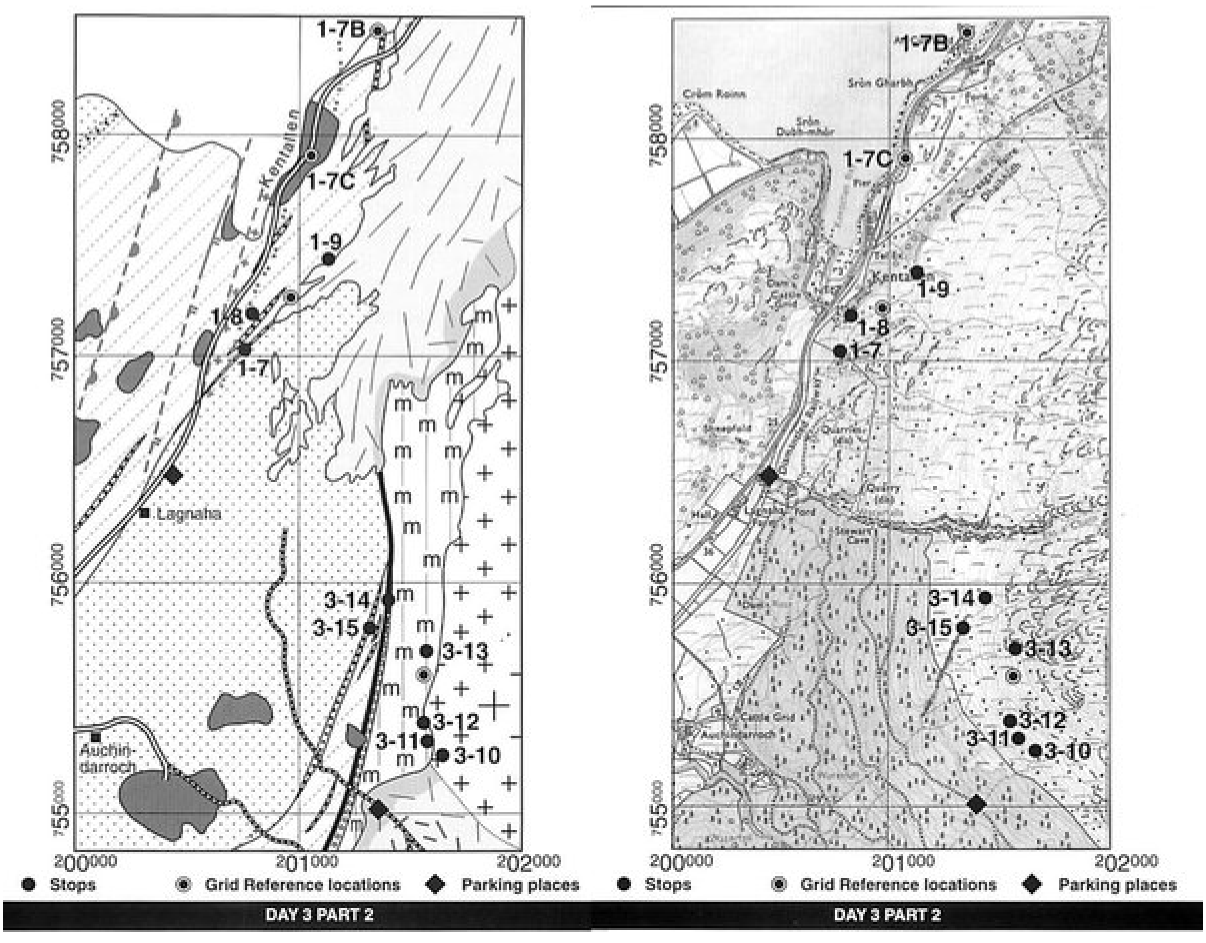
End of Part 2 of Day 3



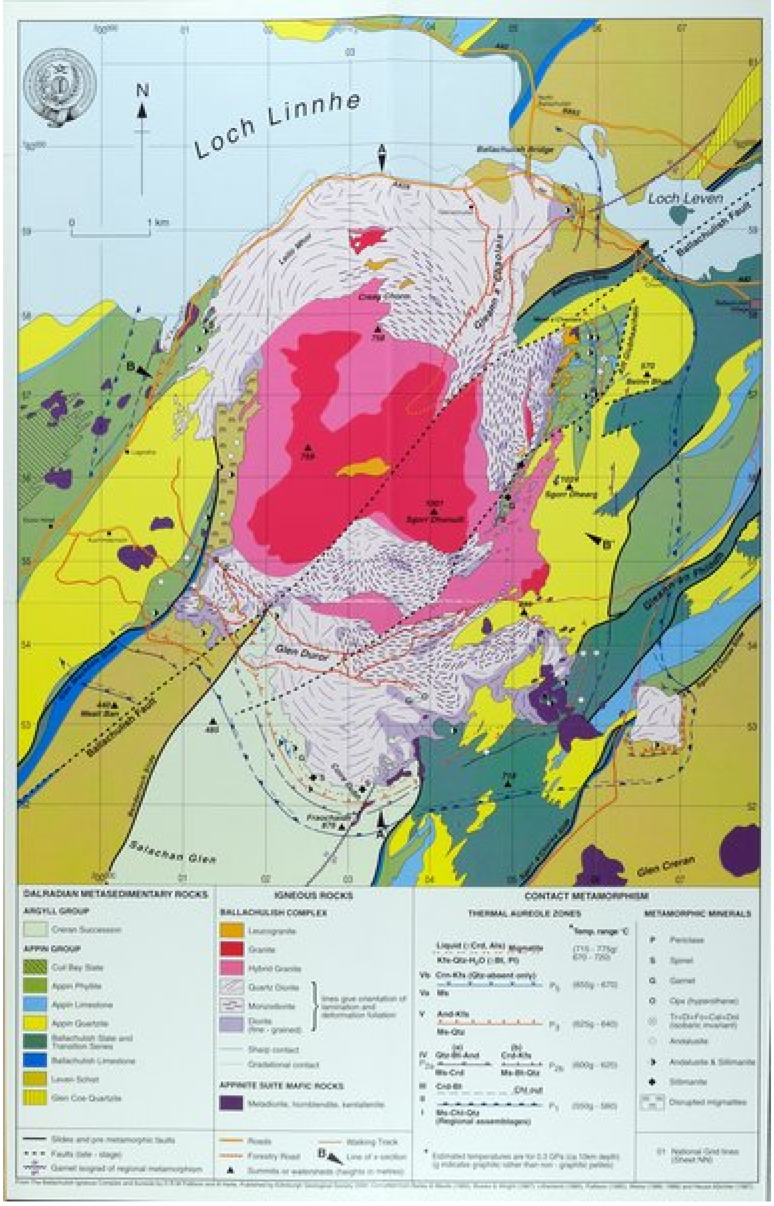
(Figure 7) Outline of area for field excursions. Geological map showing location of field stops for Day 1 (see (Figure 7) for key to geological map).



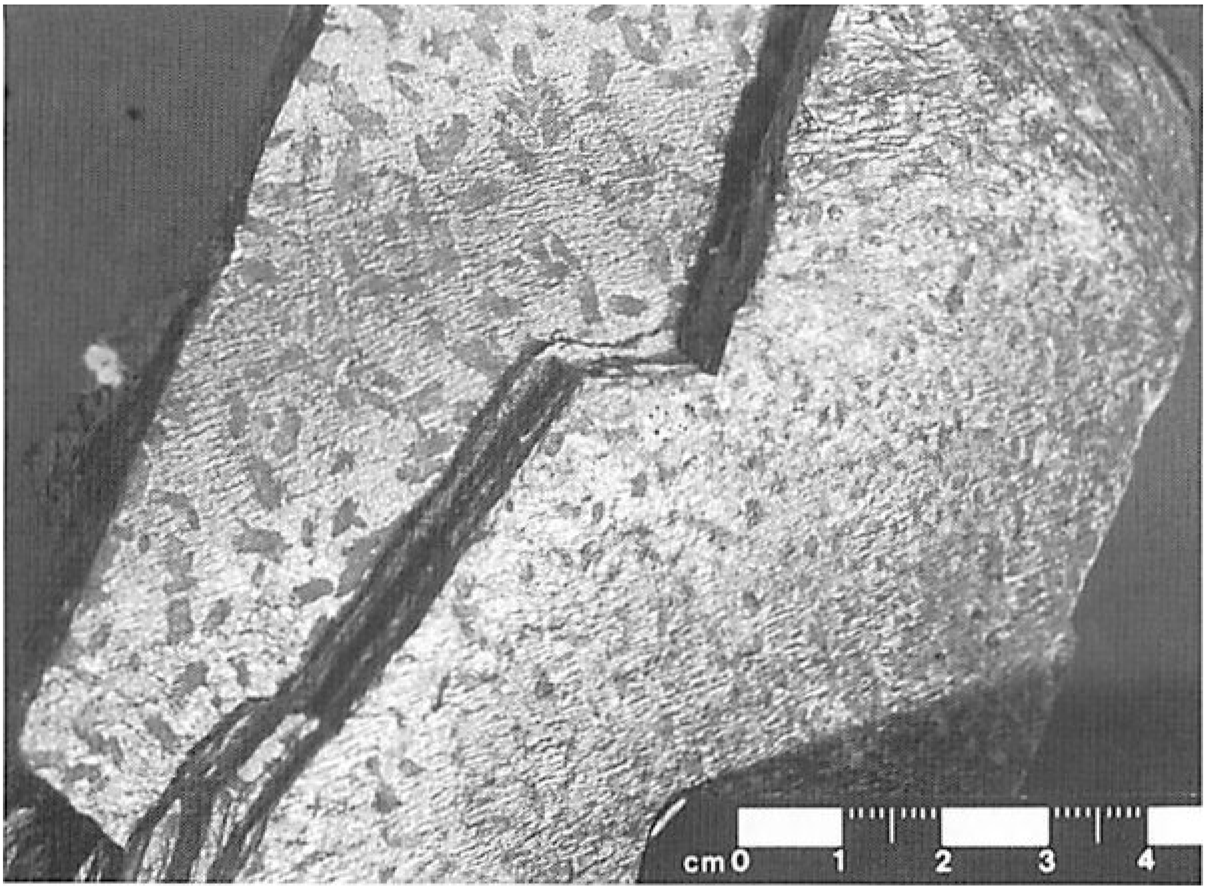
(Figure 10) (a) Geological map showing location of field stops for Day 3 Part 1, Fraochaidh traverse, (see (Figure 7) for key to geological map). (b) Corresponding topographic map showing location of field stops for Day 3 Part 1 (reproduced with permission of the Ordnance Survey).



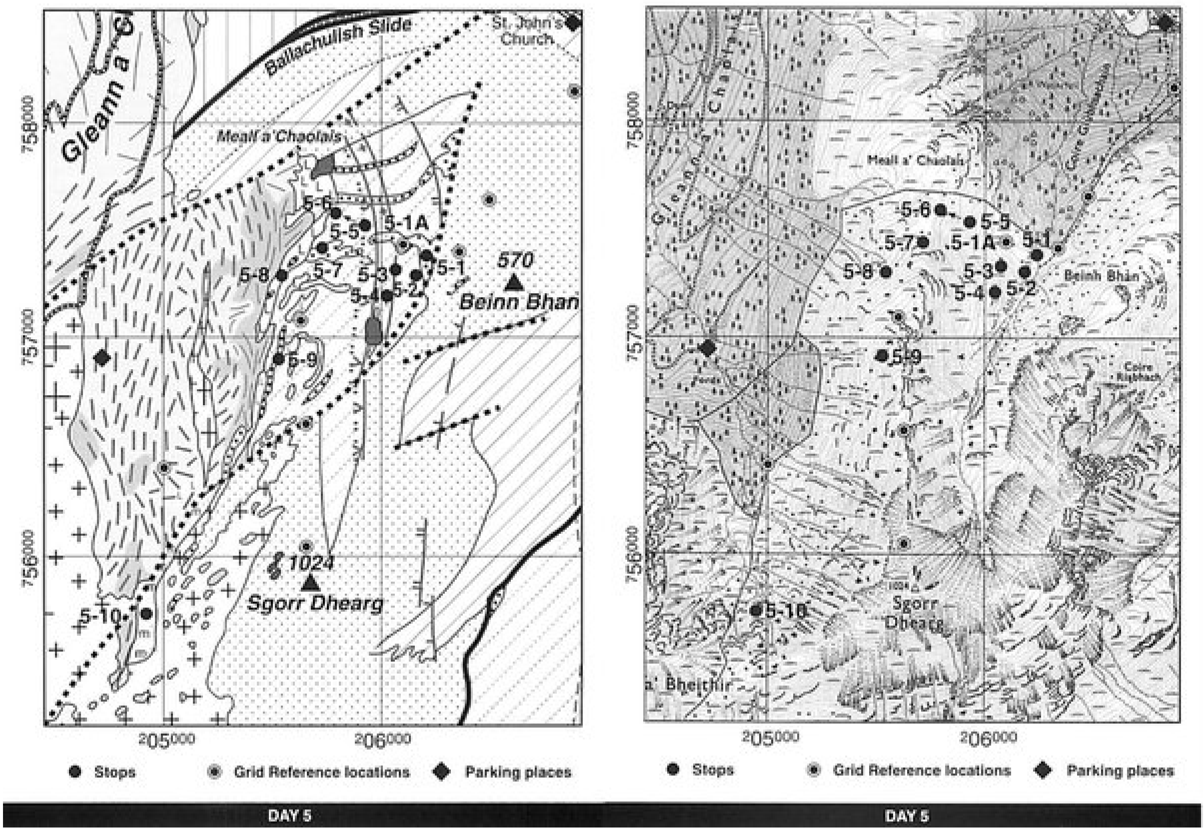
(Figure 11) (a) Geological map showing location of field stops for Day 3 Part 2, (see (Figure 7) for key to geological map). Also shows Day 1, Stops 1-7 1-8 & 1-9. (b) Corresponding topographic map showing location of field stops for Day 3 Part 2: (reproduced with permission of the Ordnance Survey).



(Map 1) Geological map of the Ballachulish Igneous Complex and aureole. (map in endpocket).

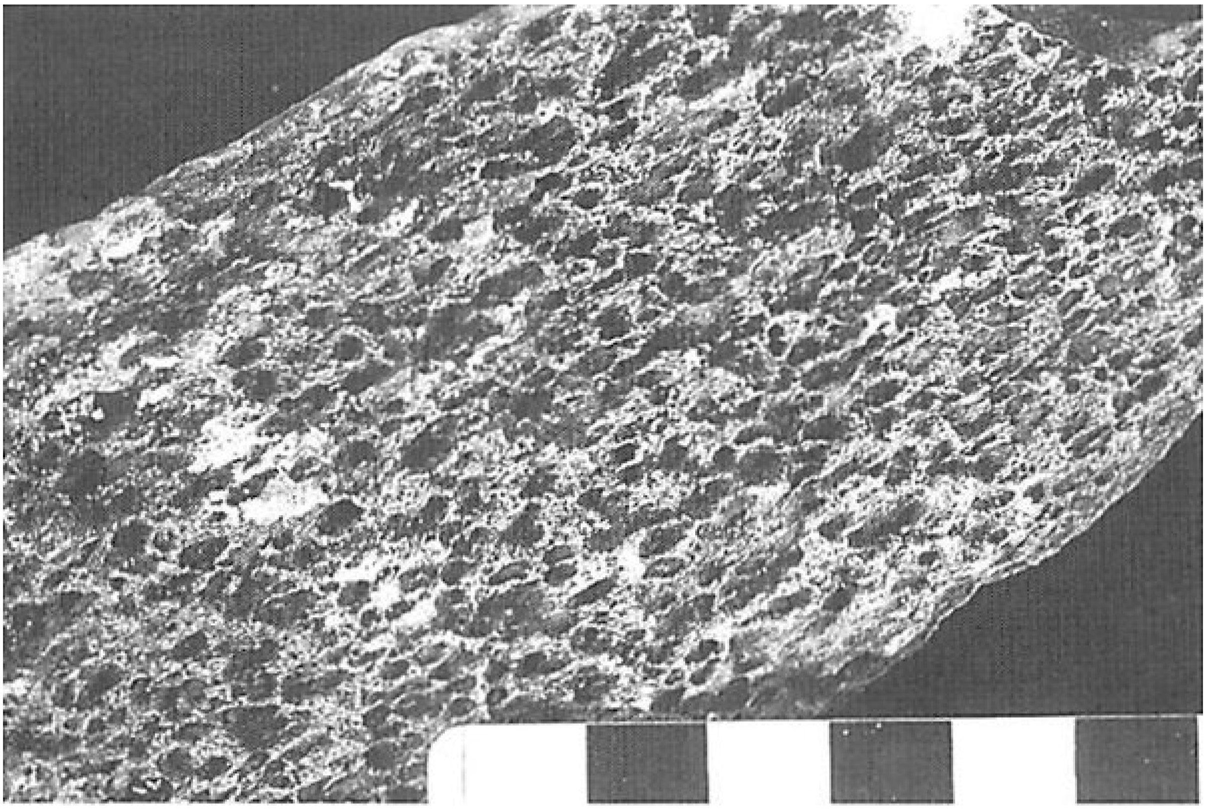


(Photo 7) Stops 1-3 and 3-1. Cordierite porphyroblasts visible as dark patches on cleavage planes of regional phyllites and schists. Note that the size of the patches varies in different parts of the rock. This sample comes from roadside exposures near the parking place for Day 3, Part 1, and shows a coarser development of cordierite patches than at Stop 1-3; but the style of development is similar at both these and other localities in the aureole.



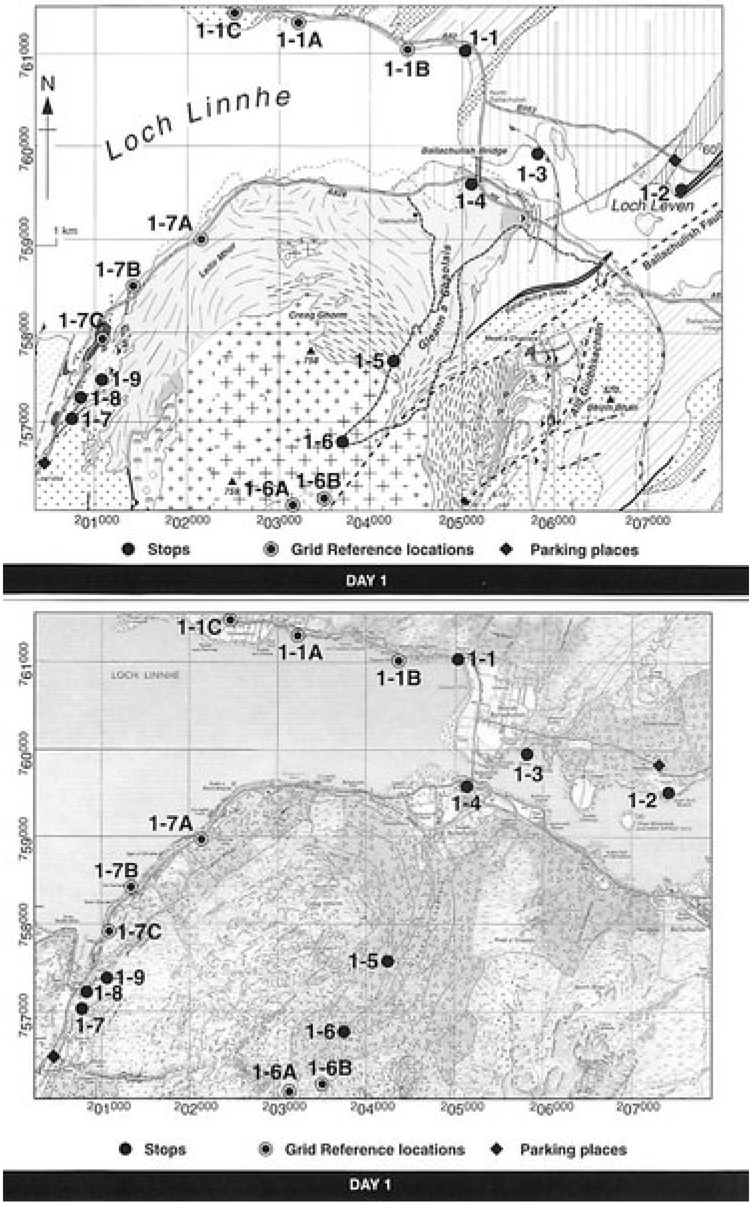
(Figure 13) (a) Geological map showing location of field stops for Day 5 (see (Figure 7) for key to geological map).(b) Corresponding topographic map showing location of field stops for Day 5 (reproduced with permission by the Ordnance

Survey).

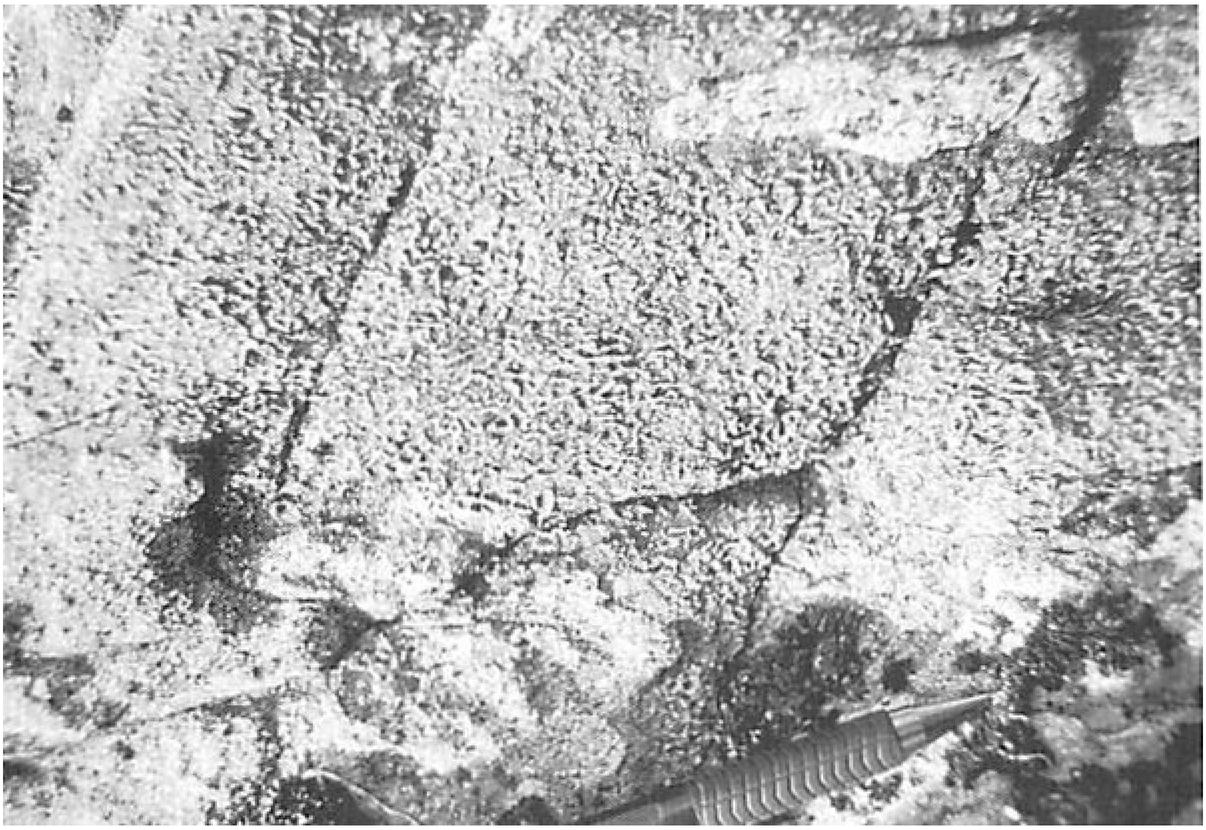


(Photo 11) Stop 3-3. Massive, pitted pelitic hornfels from the high grade end of Zone III. Fraochaidh transect. The pits represent the sites of weathered out cordierite crystals. The matrix surrounding the pits is rich in muscovite, biotite and quartz. Scale bar in cms.

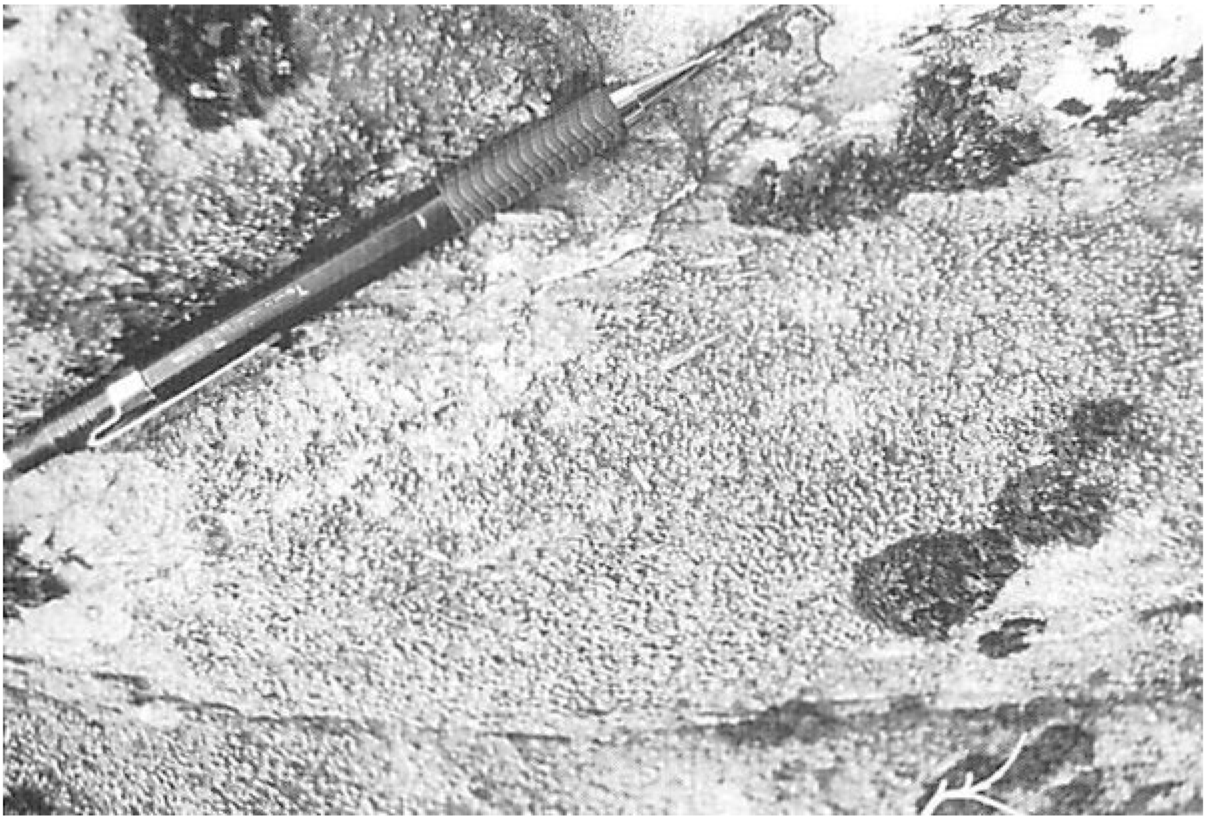
(Photo 12) Stops 3-4, 1-8, 5-2, 5-4 and 5-5. Massive Crd+Kfs-bearing pelitic hornfels characteristic of Zone IVb. The photograph was taken near Stop 5-5 in Coire Giubhsachain, but is representative of Zone IVb in many parts of the aureole. Note the mesh or honeycomb texture, defined by randomly orientated, weathered-out cordierite crystals (represented by pits) within a resistant, light coloured matrix rich in K-feldspar Note also that the matrix surrounding the pits is lighter colorant and more sharply defined than the matrix in hornfelses from Zone III (compare with (Photo 1)).



(Figure 8) (a) Geological map showing location of field stops for Day 2, see ((Figure 7) for key to geological map). Corresponding topographic map showing location of field stops for Day 1 (reproduced with permission by the Ordnance Survey).

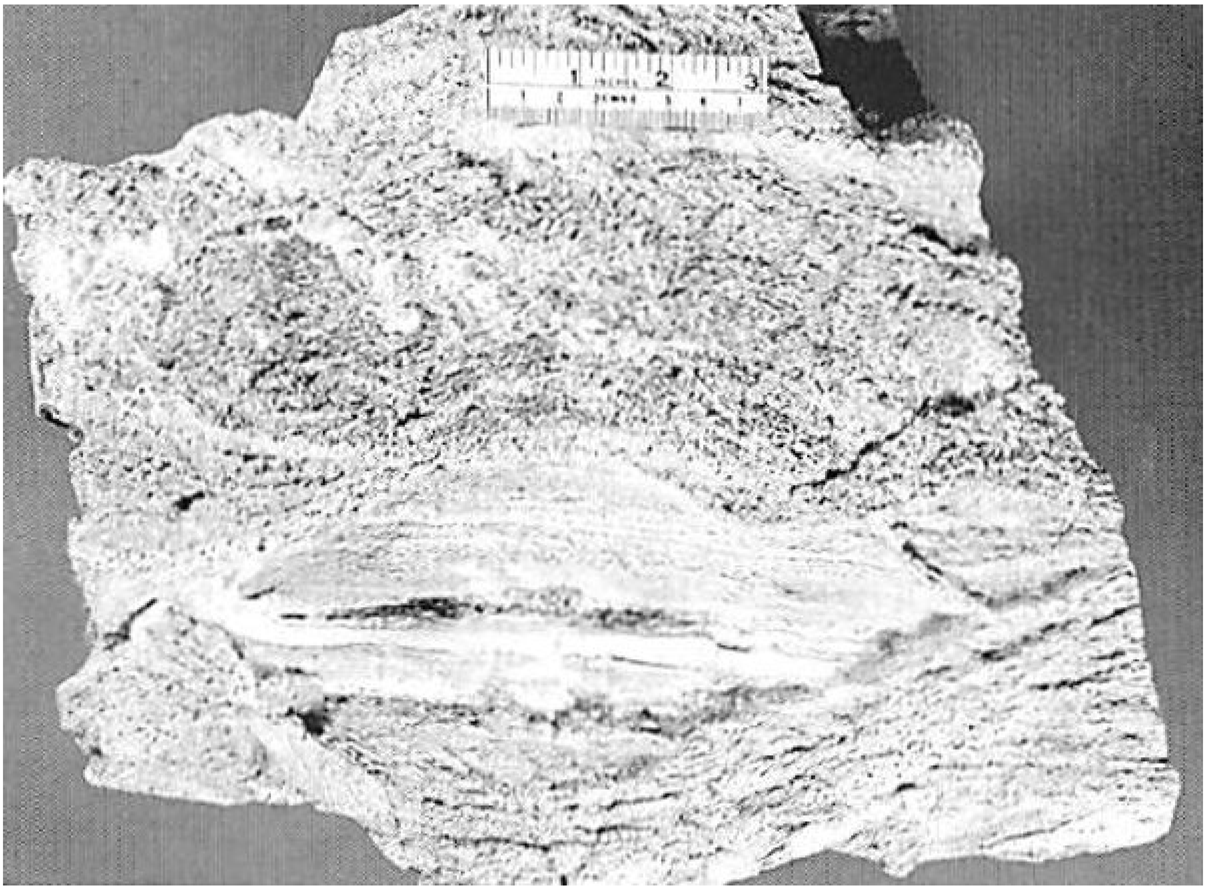


(Photo 18) Stops 5-3 to 5-6. 1-8 and 3-5. Randomly orientated andalusite prisms in a massive cordierite+K-feldspar-rich pelitic hornfels (Zone V). The photograph was taken at Stop 5-5.



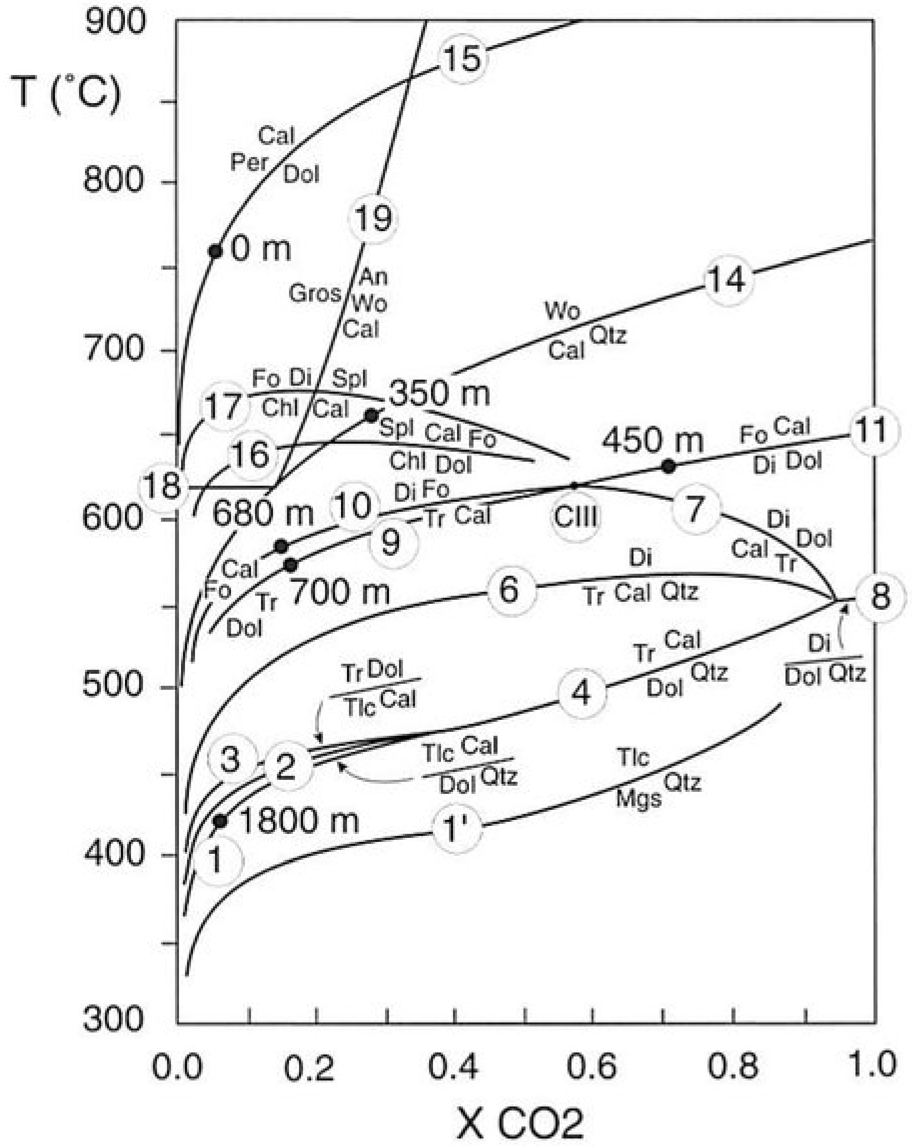
(Photo 19) Stops 5-5, 1-8 and 3-5. Corundum-rich, quartz-absent pelitic hornfels of Zone Vb. The corundum is risible as abundant small, rounded 'pimples' that contrast with the more prismatic andalusite crystals seen below the pencil (compare with Photo IS).

(Photo 13) Stops 3-11 to 3-13. View of a typical exposure of the Chaotic Zone migmatites. Note the isolated fragments of metapelitic hornfels randomly orientated within a granular matrix containing veins. See the description of Stop 3-11 for a fuller description and explanation of these features.

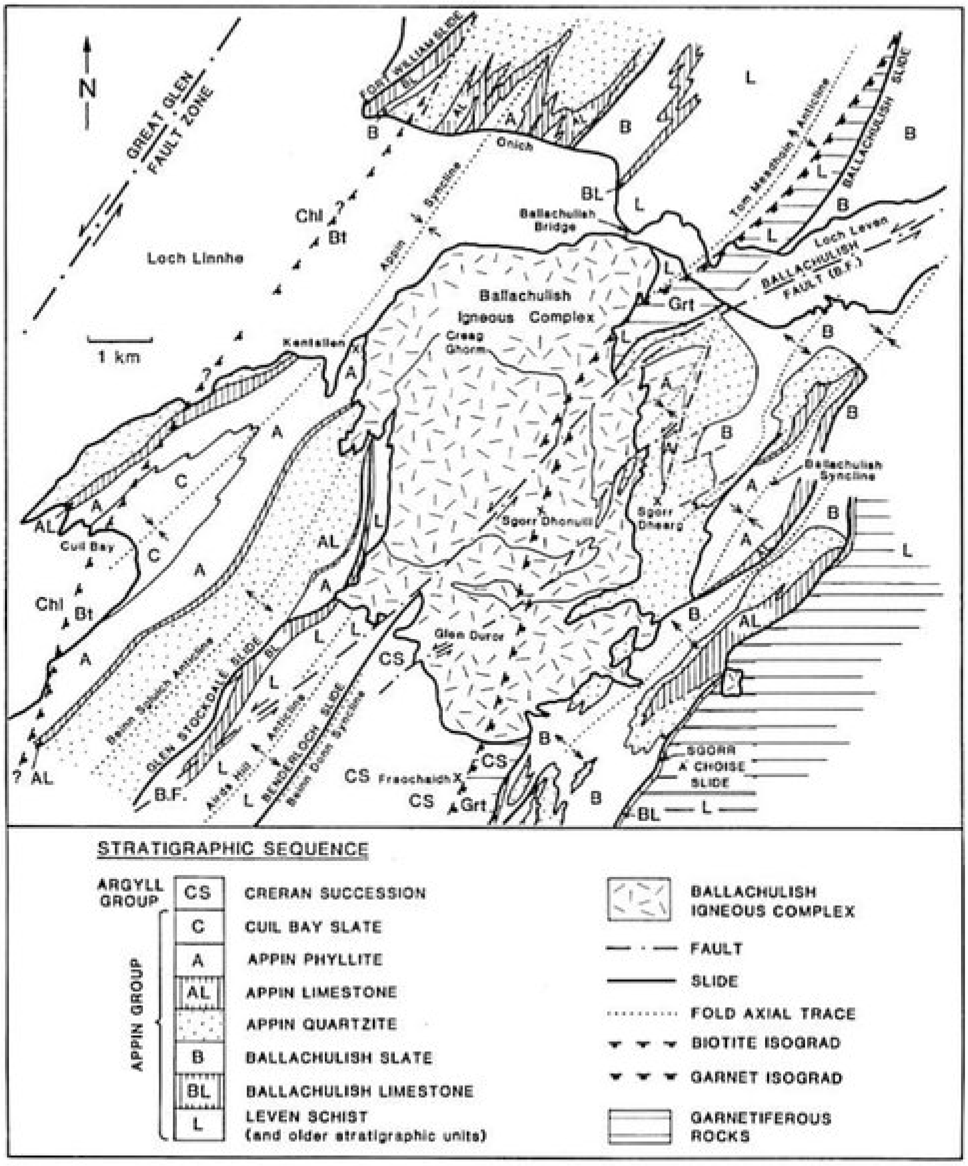


(Photo 14) Stops 3-11 to 3-13. Detail of the Chaotic Zone migmatites. An isolated metasedimentary schollen, with relic bedding still preserved, occurs in lower part and is surrounded hr a granular semipelitie matrix. An andalusite-rich domain occurs just below the scale bar in upper part.

(Photo 15) View of the contact between granite of the igneous complex (light coloured upper crags) and the Chaotic Zone pelitic migmatites (dark lower exposures).



(Figure 6) Isobaric T-X_{CO2}, diagram (3 kbar) for selected equilibria in the chemical system CaO-MgO-SiO_2-Al_2O_3-H_2O-CO_2, showing numbered reactions discussed in the text (Pattison & Harte, 1997: modified from Masch and Heuss-Aßbichler 1991). All reactions except C18 involve H_2O and/or CO_2. The unlabelled reactions are: Tlc + Cal + Qtz = Tr + CO_2 + H_2O. 18. Gros + Qtz = An + Wo (phases on the right hand side of the reaction are on the high-temperature side)



(Figure 2) Outline of lithostratigraphic units and major regional structures around the Ballachulish Igneous Complex. The position of the garnet isograd of regional metamorphism. Which formed prior to intrusion of the complex, is extrapolated across the area of the complex. From Pattison & Harte (1997).