MINERAL RECONNAISSANCE PROGRAMME

Report No.88

Mineral exploration for zinc, lead and baryte in Middle Dalradian rocks of the Glenshee area, Grampian Highlands

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BRITISH GEOLOGICAL SURVEY
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Mineral exploration for zinc, lead and baryte in Middle Dalradian rocks of the Glenshee area, Grampian Highlands

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DATA PACKAGE: DETAILED INFORMATION AVAILABLE FOR THE GLENSHEE AREA

A detailed information package is itemised below, comprising geological, geochemical and geophysical maps, data listings and written accounts. The geochemical data are available on magnetic tape or floppy disc as well as in the form of printouts.

A charge of £1000 will be made for a copy of this information, consultation with staff, examination of drillcores and for the time of staff required to make a short field visit to the area.

Item	Description
1	Folders of items identified below by *
2	Binders of items identified below by ≠
3	Roll of maps identified below by ≠
	A Regional
4	1:250 000 Tay-Forth map
≠ 5	Drainage geochemistry (printout and MM—see footnote)
6	Report on the airborne geophysical survey of the Blair Atholl-Glenshee area
	B Allt an Daimh district
*7	Introduction
≠ 8	Partial geological map (1:5000 scale)
*9	Drainage geochemical maps
≠ 10	Drainage geochemistry (printout and MM)
≠ 11	Overburden geochemistry (printout and MM)
*12	Report on geophysical surveys at Allt an Daimh, Glenshee
*13	Drilling results
*14	Borehole logs
≠ 15	Geochemical analyses of drillcores (printout and MM)
16	Graphic logs of drillcores (lithology and geochemistry)
*17	Mineralogical description of surface and core samples
	C Bad an Loin district
*18	Introduction
≠ 19	Partial geological map (1:10 000 scale)
*20	Drainage geochemical map
21	Overburden geochemical map
≠ 22	Geochemical data (printout and MM)
*23	Geophysical report (see Item 3 for relevant maps)
	D Gulabin district
*24	Introduction
–	Partial geological map (see item 19)
≠ 25	Overburden geochemistry (printout and MM)
–	Geophysical report (see item 23)
	E Coire Shith district
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–	Partial geological map (see item 19)
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–	Geophysical report (see item 23)
	F Glen Lochsie district
*28	Report on investigations in the Glen Lochsie district, Glenshee
≠ 29	Partial geological map (1:5000 scale)
*30	Geochemical drainage maps
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	G Meall Odhar district
*34	Introduction
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≠ 36	Geochemical map
≠ 37	Overburden geochemistry (printout and MM)

MM: Magnetic media—geochemical data can be made available on magnetic tape or floppy disc in a variety of formats.

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SUMMARY

Drainage surveys and airborne geophysical surveys of a 600 km^2 area from Blair Atholl to Braemar identified several targets near Glenshee within the Ben Eagach Schist, the host formation of the Aberfeldy deposits, lying 30 km along the Dalradian strike to the SW. Integrated geological, geochemical and geophysical surveys have been carried out over these targets. The extensive cover of peat and glacial overburden, particularly over the softer lithologies of the formation, hinders geological mapping and near-surface leaching has destroyed most of the sulphide. The presence of base metals and baryte is best shown by detailed drainage sampling and the sulphide-bearing graphitic schist can be traced through drift covered ground by VLF-EM, IP and SP surveys. Six shallow boreholes were drilled on the basis of the geochemical and geophysical anomalies and mapping of the available outcrops.

Zinc-lead mineralisation has been found in the clastic lower member of the Ben Eagach Schist as well as in the upper member of graphitic schist. Vein baryte with minor base metals is present in the Ben Lui Schist, a higher Middle Dalradian formation, in southern Glenshee.

The detailed information available for the Glenshee area is listed in the Data Package. A charge of £1000 will be made for a copy of this information, consultation with staff, drillcore examination and for the time of staff required to make a short field visit to the area.

INTRODUCTION

Glenshee lies on the southern side of the Grampian Highlands of Scotland, about 100 km NNW of Edinburgh (see inset to Figure 1b). It is a rugged mountainous area, reaching a height of over 1000 m, and is only cultivated in the lower valleys.

The area was initially covered by airborne geophysical (Burley and Howard, 1976) and geochemical drainage surveys, then discoveries of stratabound deposits at Aberfeldy (Coats, Smith and others, 1981) and elsewhere in the Middle Dalradian postponed follow-up until 1982. After detailed ground surveys, three boreholes were drilled in 1984 and three in 1985. Long cross-strike geophysical-geochemical traverses, developed to elucidate regional variations throughout the Middle Dalradian (Coats, Pease and Gallagher, 1984), have also been applied in the Glenshee area.

GEOLOGY

Rocks of the late Precambrian to Cambrian Dalradian Supergroup, making up most of the Glenshee area were laid down in an ensialic basin on the SE side of the North American plate. The sediments record a change from generally shallow water stable shelf conditions in the Lower Dalradian, through an increasingly unstable deepening basin environment in the Middle Dalradian to deep water conditions in the Upper Dalradian (Harris and others, 1978).

The geology of the Glenshee area is shown on the 1:250 000 Tay-Forth Sheet (BGSm 1986) and the relevant Middle Dalradian formations are listed in Table 1. Figure 1a is a summary of the geology and of the main zinc anomalies in the drainage while Figure 1b summarises the airborne geophysical data. Most of the detailed sampling has been carried out over the southern and eastern outcrop of the Ben Eagach Schist and adjacent parts of the Ben Lawers Schist and the Carn Mairg Quartzite.

In mountainous glaciated areas such as Glenshee, overburden thickness is very variable and dependent on the glacial history. On mountain summits periglacial features such as blockfields (felsenmeer), stone polygons and stripes are commonly developed but at lower altitude these features are covered by vegetation. Generally, however, the overburden resulting from this periglacial activity is local in origin. Away from the summits there is generally a covering of peat overlying a variable thickness of solifluction deposits, which are difficult to distinguish from true lodgement tills. The related soils are poorly stratified and only a weakly developed iron-rich 'B' horizon is usually present. Thick fluvioglacial deposits occur on the floors of the main Glenshee and Glen Beag valleys.

Table 1 Formations of the Middle Dalradian in the Glenshee area

Subgroup	Formation	Local name	Lithology
Crinan Subgroup	Ben Lui Schist	Duchray Hill gneiss	Grey mica schist often migmatised, minor ultramafic pods
Easdale Subgroup	Ben Lawers Schist	Caenlochan schist*	Calcareous mica schist often hornblendic with amphibolite and quartzite layers
	Ben Eagach Schist	Glas Maol schist*	Graphitic schist member
			Laminated quartzite member
	Carn Mairg Quartzite	Perthshire Quartzite (in part)	White massive quartzite with pebbly bands

* from Upton (1986)

REGIONAL GEOCHEMICAL SURVEY

Primary reconnaissance involved the collection of stream sediment and panned concentrate samples using standard BGS methods (Smith and others, 1984) at a sample density of 1 per km^2. The stream sediment samples has been shown (Plant and others, 1984) to give a good response to changes in whole rock geochemistry and the samples from Glenshee were analysed for a wide range of elements; Cu, Pb, Zn, and Ni by atomic absorption spectrometry after a hot nitric acid leach and Be, B, V, Cr, Mn, Fe, Co, Y, Zr, Nb, Mo, Sn, and Ba by optical emission spectrography. In mineral exploration, however, the presence of metals in a heavy mineral phase is often more indicative of mineralisation and a concentrate prepared by on-site panning was analysed by X-ray fluorescence for Ce, Ba, Sb, Sn, Pb, Zn, Cu, Ca, Ni, Fe, Mn, Ti, Ag, U, Rb, Th, Nb, Sr, Zr and Y.

When the survey was carried out little was known about the background levels in drainage samples from the Dalradian and threshold levels were calculated using the arbitrary convention of arithmetic mean + 2 standard deviations of data from this area and a second area of Dalradian rocks in the Western Highlands (Coats and

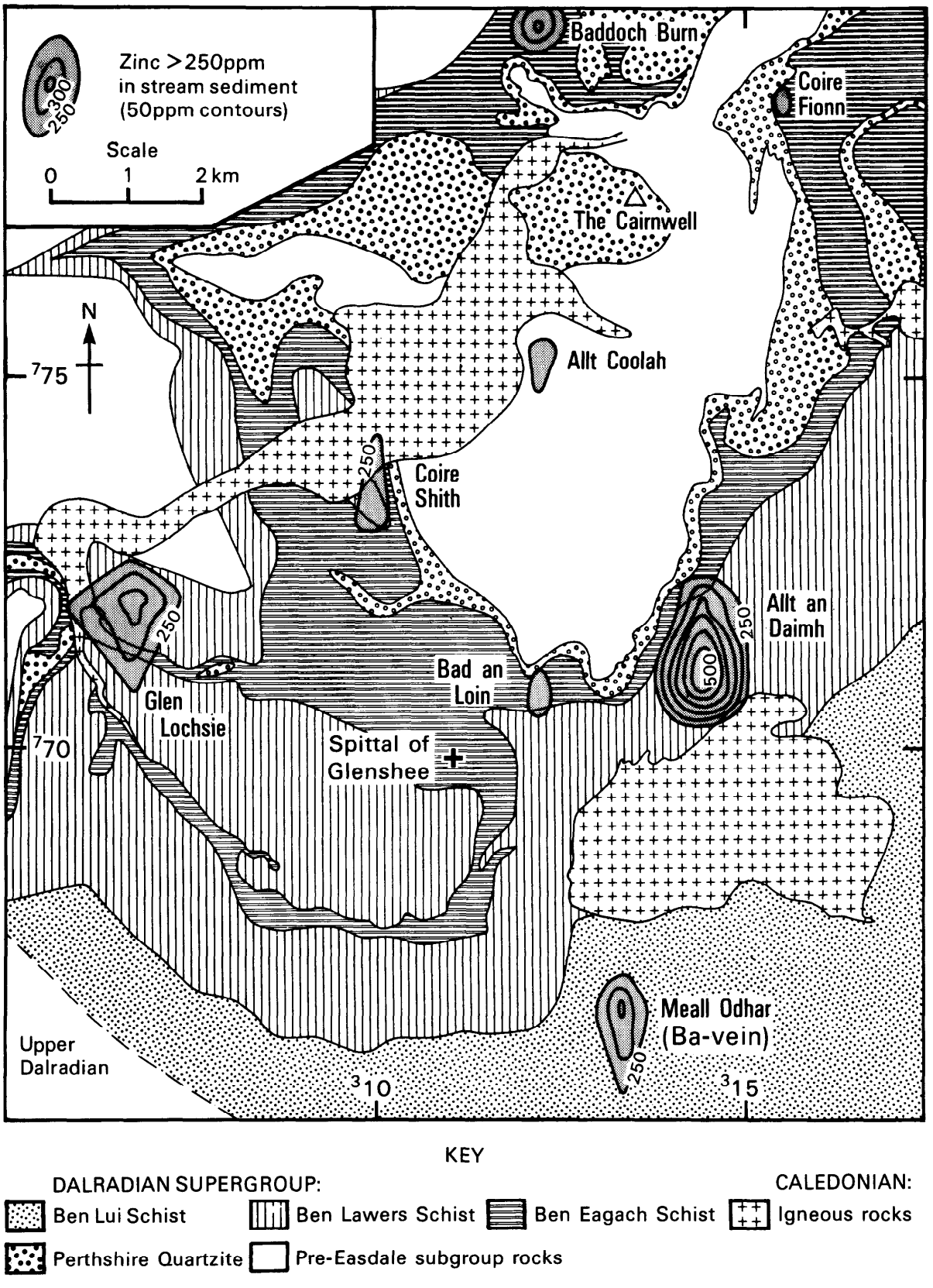

Figure 1a) Outline geology and zinc in stream sediments

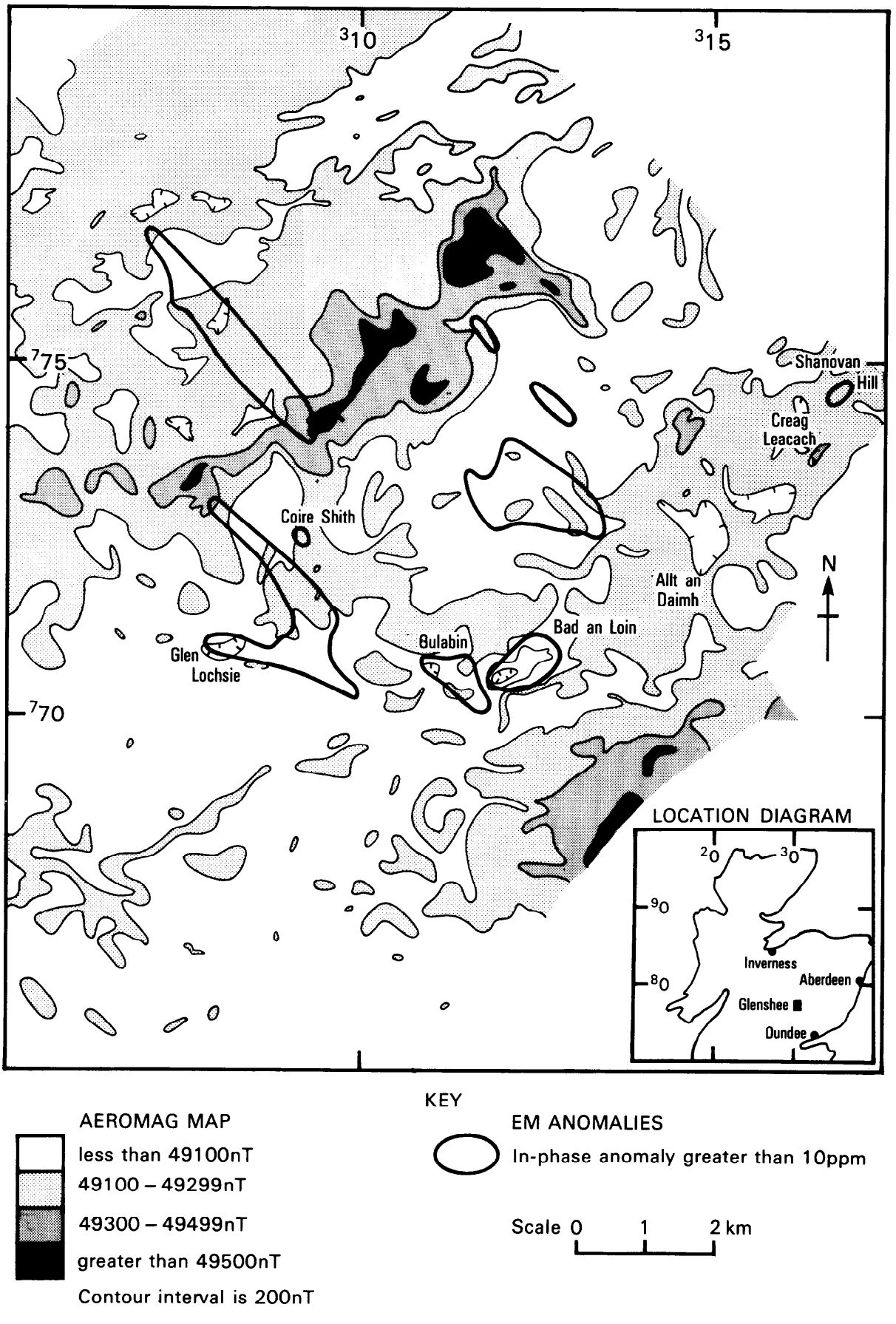

Figure 1b) Airborne EM and magnetic anomalies

others, 1982). Some threshold levels (e.g. zinc at 400 ppm) are now considered rather high and lower ones (zinc at 300 ppm) are calculated from breaks in the cumulative frequency—log probability curves (Smith and others, 1984). The distribution of zinc in stream sediments in the Glenshee area shown in Figure 1a is based on a computerised contouring methods which employs an exponential distance-weighted averaging technique over a search radius of 500 m. Using this method, a contour value of 250 ppm Zn includes all anomalous samples, and there are five such areas concentrated on, or down-stream of, the outcrop strip of the Ben Eagach Schist. The exception is the anomaly at Meall Odhar which is related to a sulphide-bearing baryte vein.

Other elements such as lead or barium do not give such a clear identification of stratabound mineralisation at the reconnaissance stage. Barium in panned concentrates is a sensitive indicator of baryte but this mineral occurs mainly in small veins. Lead in stream sediments has a poor peak to background contrast compared to zinc, and high values in stream sediments are found over large granitic intrusives. However, lead anomalies of 150 ppm are found in Allt an Daimh and the association of both lead and zinc anomalies is a good indication of sulphide mineralisation. The lead content of panned concentrates is influenced by human contamination sources such as the solder in tin cans and lead shot. Copper in the stream sediments and panned concentrates shows a separate areal distribution to zinc, with a zone of high values in the Ben Lawers Schist at a stratigraphy higher horizon, the 'Pyrite Zone' (Smith and others, 1978). The most useful element in the reconnaissance stage is zinc in stream sediment, but this situation changes in the follow-up stages where the less mobile elements, such as lead, become more useful in pinpointing sources of mineralisation.

REGIONAL GEOPHYSICAL SURVEY

A helicopter-borne electromagnetic (EM) and magnetic survey was flown in 1974 to investigate the mineral potential of the Middle Dalradian in the area from Blair Atholl to Glenshee (Burley and Howard, 1976). The largest and most extensive EM anomalies were found over the graphitic schists in Glenshee. The strongest magnetic anomalies are associated with the Carn Mor granite (which runs SW from the Cairnwell), the Glenshee diorite (SE of the Spittal of Glenshee), and large parts of the graphitic schists which often indicate reversely magnetised sources (Figure 1b). Ground follow-up was made of 14 anomalies, selected on the basis of the extent and amplitude of airborne EM anomalies and the proximity of aeromagnetic and geochemical drainage anomalies. The quality of the airborne EM data was not always satisfactory as the EM bird was badly affected by flexing caused by air turbulence. Many weaker anomalies may have been swamped by, or mistaken for, noise variations.

DETAILED SURVEY METHODS

Resampling of geochemically anomalous stream sites and collection of further samples upstream at intervals of approximately 200 m is the first stage in detailed exploration. Descriptions of the stream course, geology and features such as iron-rich seeps are recorded. This is the most effective way of confirming the original anomalies, assessing their relative importance and guiding subsequent overburden sampling. Shallow overburden samples are normally collected at 20 m intervals along lines spaced 100–200 m apart. A 1.3 m hand auger is used to sample the lowest accessible horizon of the overburden, normally the 'C' horizon, but in some areas only an organic-rich peat layer can be collected. Horizon, depth, colour, texture and vegetation are noted and stored in a portable microcomputer. Samples are air dried, sieved to $-200\ \mu m$ and analysed, in the early work, by atomic absorption using a hot nitric acid leach or latterly by X-ray fluorescence after further grinding with a binder. In general, shallow overburden sampling has been shown (Coats, Pease and Gallagher, 1984) to be effective in upland Dalradian areas such as Glenshee where bedrock lies beneath <2 m of lodgement till, but may not be effective where the till cover exceeds this figure.

Geophysical methods initially employed on the follow-up of the airborne survey were restricted to horizontal loop EM and magnetics. From 1982, surveys usually included VLF-EM, induced polarisation (IP) magnetics and sometimes self potential (SP), with readings every 10 m along traverses spaced 100–200 m apart. Traverse separation is reduced in more complex or interesting areas when IP is often used, with an expanding dipole-dipole array (50 m electrode spacing), or a gradient array (25 m spacing). The choice of configuration depends on the expected target depth and the nature of the local terrain.

The results of these detailed surveys are presented in the data package on which this report is based and are outlined below for six districts of the Dalradian strike in the Glenshee area. These are, from east to west, Allt an Daimh, Bad an Loin, Gulabin, Coirc Shith and Glen Lochsie, then further south, Meall Odhar.

ALLT AN DAIMH DISTRICT

A small airborne EM anomaly occurs in this district, some 4 km ENE of the Spittal of Glenshee, together with stream sediment anomalies of up to 700 ppm Zn and 150 ppm Pb (Figure 1a). Exposures are limited to the Perthshire Quartzite and the laminated quartzite of the Ben Eagach Schist formation. Shallow overburden sampling at 25 m intervals, accompanied by detailed geophysics, was used over a strike length of 3 km to trace the mineralisation. Scree and blockfields gave rise to overburden sampling problems, which together with the variable thickness of the solifluction deposits, cause noise in the metal distribution data. A computerised smoothing process, employing an exponentially weighted average over a search circle of 75 m radius, was used before contouring to suppress small scale variations along each line and to yield relatively broad patterns. Lead and zinc values each locally exceed 1000 ppm (Table 2).

Geophysical results show that the largely unexposed graphitic schist member of the Ben Eagach Schist can be traced by low resistivity and high chargeability values across most of the area. Four boreholes proved a highly graphitic unit at the stratigraphic top of the Ben Eagach Schist and two further holes were drilled in the laminated quartzite member beneath.

In the laminated schist and quartzite there is a rhythmic alteration of a moderately graphitic quartz-muscovite schist and pale fine-grained quartzite. The upper graphitic muscovite phyllite incorporates graphitic meta-sandstone and meta-greywacke rocks interpreted as

debris-rich mudflows. The rocks are sulphidic throughout, contain few mafic minerals, are non-garnetiferous, and sparingly calcareous, being largely comprised of quartz and muscovite, graphite and sulphides. Heavy mineral grains include zircon and monazite which is the probable source of the cerium anomaly in the drainage.

Table 2 Lead and zinc contents in shallow overburden samples from 5 districts in Glenshee, compared to Aberfeldy

	Pb (ppm)		Zn (ppm)		No. of
	Median	Max	Median	Max	Samples
Glenshee					
Allt an Daimh	61	1016	56	1329	568
Bad an Loin	40	530	80	1250	100
Gulabin	50	170	80	240	74
Coire Shith	40	120	180	1723	127
Glen Lochsie	35	243	55	503	420
Aberfeldy	60	22000	80	13000	692

BAD AN LOIN DISTRICT

Immediately SW of the Allt an Daimh district, there is a pronounced aeromagnetic low (Figure 1b) centred on the hill of Bad an Loin. Ground traverses show sharp positive and negative magnetic anomalies (+ / − 400 − 1000 nT) superimposed on an overall low. The EM traverses show complex large amplitude anomalies indicating shallow conductors. Correlation between EM and magnetic anomalies is not always good. A minor zinc anomaly in the drainage at Bad an Loin (Figure 1a) is accompanied by barium, lead and cerium anomalies in panned concentrates. Cerium reaches an unusually high content of 0.59% and high cerium values are associated with the Perthshire Quartzite and the laminated quartzite member of the Ben Eagach Schist. A minor stratabound base metal source is inferred within the Ben Eagach Schist. In the overburden sampling two samples are anomalous in zinc and lead (maximum values in Table 2).

GULABIN DISTRICT

On the mountain of Gulabin, 1.5 km W of Bad an Loin, ground traverses revealed several conductors in the Ben Eagach Schist, but magnetic profiles are noisy and difficult to interpret. Overburden sampling yielded few lead or zinc anomalies (peak values are given in Table 2). Very low values are found over the easternmost of the four lines which reflects the thick cover of till deposited by a major glacier which occupied the main Glen Beag valley.

COIRE SHITH DISTRICT

This district lies on the NW side of Gulabin, 3 km from the Spittal of Glenshee. Strong airborne EM and weak negative magnetic anomalies were traced on the ground and attributed to highly graphitic and pyrrhotitic bands within the Ben Eagach Schist. Shallow overburden sampling shows lead and zinc anomalies which coincide with VLF-EM and magnetic anomalies.

GLEN LOCHSIE

In the Glenlochsie area, about 2 km to the SSW of Coire Shith, the Ben Eagach Schist is represented by a narrow band of graphitic schist and laminated quartzite sandwiched within calc schist and amphibolite of the Ben Lawers Schist Formation. The structural relationship of the two formations is unclear because of poor exposure. The initial drainage anomaly was a high copper value of 70 ppm in a stream draining the Ben Lawers Schist, which did not increase upstream on re-sampling. However, a significant zinc drainage anomaly was obtained, comparable with samples from the Aberfeldy area (Coats, Smith and others, 1981) where the peak zinc content was 1340 ppm. However, metal values are relatively low in the overburden samples, compared with the Aberfeldy area (Table 2).

A large airborne EM anomaly is present over the Ben Eagach Schist in this district (Figure 1b). VLF-EM, SP and magnetic surveys were carried out, the strongest VLF-EM anomaly producing Fraser filter values over 200%, four to five times greater than typical anomalies over Dalradian graphitic schists. Magnetic anomalies over graphitic schists are + / − 200 − 400 nT and across-strike magnetic features are ascribed to later igneous dykes. The IP survey shows a weak chargeability anomaly over the laminated quartzite which could result from disseminated sulphide.

MEALL ODHAR DISTRICT

Drainage sampling in the Meall Odhar district (Figure 1a) revealed anomalies in barium and lead as well as in zinc. The district is heavily covered by morainic deposits but is probably underlain by gneisses assignable to the Ben Lui Schist formation (Table 1). At one point a thin baryte vein is exposed carrying minor amounts of sulphides and soil sampling suggests that the mineralised structure may extend for a few hundred metres.

CONCLUSIONS

Integrated geological-geochemical-geophysical investigations over the Middle Dalradian rocks of the Glenshee area have revealed evidence of stratabound base metal and vein baryte mineralisation. The stratabound mineralisation is of principal significance as it is hosted by the same formation, the Ben Eagach Schist, as the major deposits near Aberfeldy.

A fuller investigation of the Glenshee area for stratabound zinc-lead mineralisation is merited, using as a basis the detailed information which is separately available.

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