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CORRESPONDENCE AND NOTES

Spinel lherzolite and other xenoliths from a dolerite dyke in southwest Donegal

Abstract – A highly xenolithic dolerite dyke is described which contains a large number of spinel lherzolite xenoliths. The petrology of the dolerite and the xenolith suite is described and electron probe analyses presented for the mineral phases in one of the spinel lherzolite xenoliths. The dyke geochemistry is consistent with a Permo-Carboniferous age.

1. Introduction

An occurrence of a xenolithic dolerite dyke is described from near Inver, southwest Donegal (Irish grid reference G 810 810; Fig. 1), intruding Lower Carboniferous Arundian limestones. Geochemical and textural evidence to be presented below indicates a likely Permo-Carboniferous age. In this respect it may be grouped with some 26 other xenolith localities listed by Upton, Aspen & Hunter (1984) mainly from the Midland Valley of Scotland but also including two previously documented Irish localities: from Inishowen, north Donegal, some 70 km northeast of the occurrence described here (Murthy, 1958), and a number of localities 150 km further south in central Ireland, described by Strogen (1974).

The dyke is 30 m wide, and can be traced along a length of approximately 400 m. The xenoliths are exposed in a disused quarry, where it can be seen that they are restricted to a 5 m wide zone near the northern margin of the dyke. In the vicinity of this quarry the xenoliths constitute 5% by volume of the dyke, but in the xenolithic zone this proportion is locally over 50%.

Three distinct populations of xenoliths are present:

(a) Abundant xenoliths of spinel lherzolite, ranging in size from less than 1 cm to tens of centimetres.

(b) Less abundant xenoliths of other rock types. These include a range of igneous rocks of unknown provenance, two small fragments of pelite, and one xenolith of arkose which can be matched with Chadian sandstones within the local Carboniferous succession and which, in the vicinity of the quarry, lie 200–300 m below the surface.

(c) A varied population of xenocrysts. Some are clearly derived from disaggregation of spinel lherzolite xenoliths; there are also plagioclase crystals of unknown provenance, and a small number which cannot be identified optically.

2. Petrology

2.a. Host rock

The xenoliths are set in a fine-grained, often heavily altered dolerite with hypidiomorphic, hypocrystalline texture. The

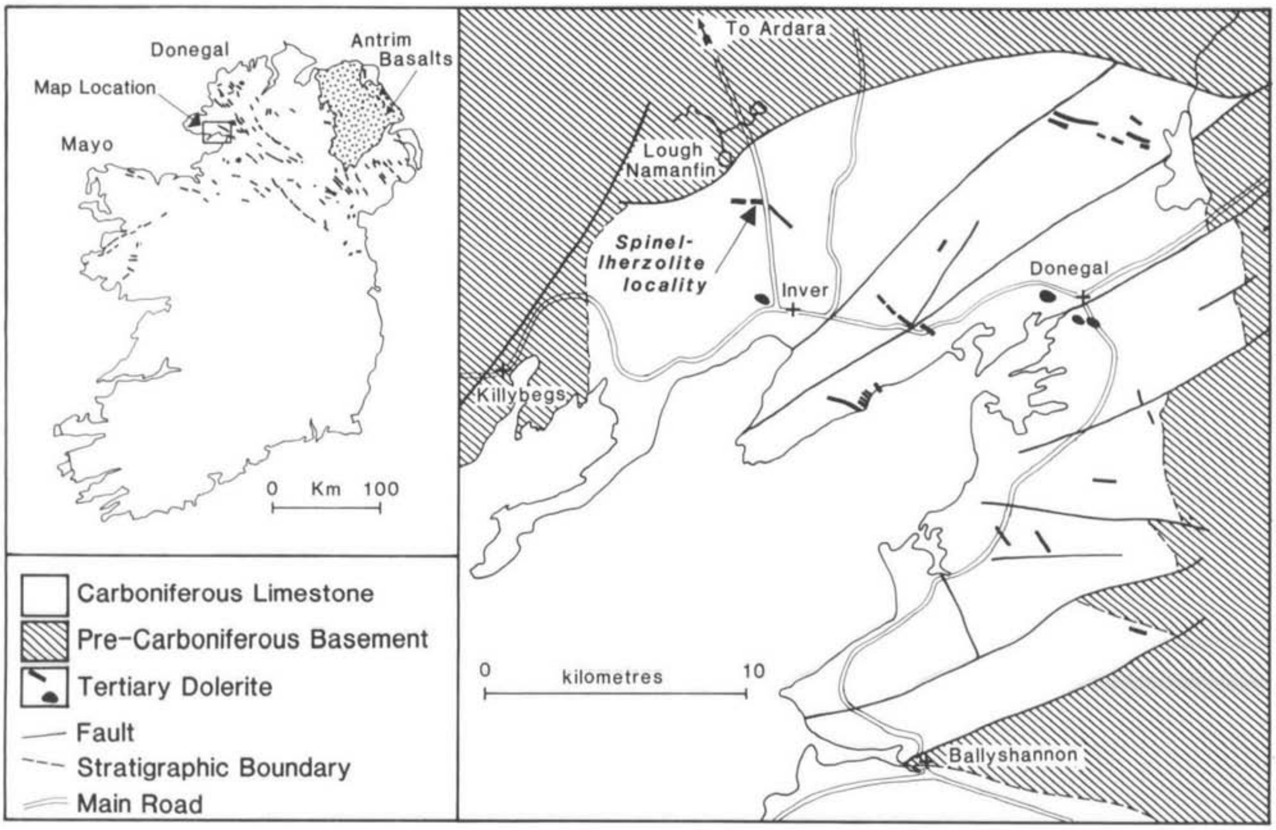

Figure 1. Simplified geological map of part of southwest Donegal, after George & Oswald (1957). Spinel lherzolite locality is indicated by the arrow.

Table 1. Chemical analysis of host dyke

Major elements		Trace elements	
SiO_2	51.23	Rb	48
TiO_2	1.56	Y	26
Al_2O_3	16.06	Zr	350
Fe_2O_3*	11.01	Sr	1553
MnO	0.18	Nb	82
MgO	7.63	Ni	187
CaO	6.54	La	40
Na_2O	3.58		
K_2O	2.04	La/Nb	0.49
P_2O_5	0.32	Zr/Nb	4.27

*Total Fe oxides expressed as Fe_2O_3. Results are means of 2 XRF analyses using JEOL JXA-100A spectrometer in the Geology Department, University College Dublin. Methods as described by Brown, Hughes & Esson (1973).

major component, slightly over 50% modal, is plagioclase (An_{45}) whose alignment imparts a well-developed flow texture. The next most abundant mineral is olivine; some crystals are euhedral, up to 0.5 mm in size, while others are seriate or angular, and slightly larger in size. These latter crystals are interpreted as xenocrysts (see section 3.a below). Prismatic pale brown augite occurs. Minor phases include magnetite and glass.

Major- and trace-element data are presented in Table 1. The dyke is considerably richer in K_2O, Rb, Sr, Nb and Zr than any of the Tertiary Antrim Lava Series basalts (Lyle, 1980, 1985*a*, *b*) or Tertiary dolerite intrusions from western Ireland (Mohr, 1982). However, the K_2O and Rb are closely similar to those of Carboniferous Logmor dykes from West Connacht, as are the high total Fe and low Na_2O/K_2O (Mitchell & Mohr, 1987). The La/Nb ratio, close to 0.5, is considerably lower than values for the Tertiary Antrim basalts (approximately 3; see Lyle, 1985*a*, *b*), or for Tertiary dykes from Ardgour (approximately 1.4; see Morrison, Hendry & Leat, 1987). In many respects the analysis in Table 1 has marked affinities with those of Permo-Carboniferous dolerite dykes from Ardgour (Morrison, Hendry & Leat, 1987) and with lavas of similar age from the Inner Hebrides (Upton, Aspen & Hunter, 1984); for example, the Ardgour intrusives have La/Nb ratios in the range 0.64–0.79, and Zr/Nb in the range 2.85–3.72 (Morrison, Hendry & Leat, 1987, table 2).

A Permo-Carboniferous age has some additional support from petrographic observations. Although the dyke described in this paper has a hypidiomorphic hypocrystalline texture, dolerite dykes of unambiguously Tertiary age in Donegal always have ophitic texture (P. Lyle, personal communication). Thus, although this dyke occurs in an area where many Tertiary dolerite dykes are known (Fig. 1), there is no evidence on which to assign a Tertiary age to it.

2.b. Xenoliths

2.b.1. Ultramafic xenoliths

The most abundant ultramafic xenoliths are of spinel lherzolite which exhibit two texturally distinct varieties: an inequigranular porphyroblastic texture and, more rarely, an equigranular granoblastic texture. These textures are consistent with criteria for undeformed lherzolite (Harte, 1983).

Mineral contents from a number of different individual xenoliths are given in Table 2, and electron probe microanalyses from the separate minerals in one xenolith are presented in Table 3; analyses of clinopyroxene consistently yielded low totals, and the reason for this is not understood.

Table 2. Modal analyses of spinel lherzolite

Slide no.	ol	opx	cpx	sp
S17b	83	14	2	1
2A-5	82	14	1	3
M	82	9	1	8
S17a	81	16	2	1
3	81	17	1	1
SG12	79	18	2	1
13	77	14	6	3
19	76	18	2	4
2B-1	70	23	5	2

Olivine is the most abundant mineral. In the porphyroblastic xenoliths it forms large anhedral crystals up to 4 mm in size, set in a finer recrystallized matrix (grain size approximately 1 mm) with characteristic 120° dihedral angles. In the granoblastic xenoliths the olivines rarely show deformation twinning, and are 2.5–3.0 mm in size.

Colourless orthopyroxene shows strain-induced twinning and occasionally lamellar twinning. Chrome diopside is very pale brownish-green in colour. Spinel, generally with a deep reddish-brown colour, exhibits two different habits: euhedral interstitial, and 'holly leaf' morphology (Pike & Schwarzman 1976). Occasional subhedral crystals form inclusions within olivine hosts.

Serpentinization may be pervasive along grain boundaries, and orthopyroxene is occasionally altered to fine-grained phyllosilicate. There is also evidence of interaction of the xenoliths with the host basalt, in general restricted to the margins of the xenoliths: (a) alteration of chrome-spinel to magnetite; (b) magmatic corrosion of the xenoliths producing irregular boundaries, and necking of individual olivine crystals; (c) disaggregation of xenoliths to xenocrysts, so that some xenoliths grade outwards through decreasing numbers of individual xenocrysts into uncontaminated basalt.

Disaggregation of lherzolite xenoliths has given rise to xenocrystic olivine, pyroxene and spinel in the host dyke.

2.b.2. Basic igneous xenoliths

A small number of millimetre-sized fragments consist of plagioclase, augite and magnetite, with ophitic texture and variable degrees of serpentinization and sericitization.

2.b.3. Silica-rich igneous xenoliths

A single coarse-grained granitoid xenolith, 10 mm in size, has been recovered. It consists of orthoclase (with occasional incipient cross-hatch twinning), altered plagioclase and quartz, together with intensely altered reddish-brown biotite.

2.b.4. Metamorphic and sedimentary xenoliths

A small number of other xenoliths have been recovered, up to 10 mm in size, which can be matched with Carboniferous and Dalradian lithologies outcropping elsewhere in the area.

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Table 3. Electron probe analyses of lherzolite phases

	Olivine (n = 6)		Opx (n = 3)		Cpx (n = 5)		Spinel (n = 11)	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
SiO_2	41.56	0.66	56.39	0.09	52.20	0.30	n.d.	—
TiO_2	n.d.	—	n.d.	—	n.d.	—	n.d.	—
Al_2O_3	n.d.	—	2.56	0.08	4.52	0.54	50.05	0.41
Cr_2O_3	n.d.	—	0.46	0.03	0.99	0.26	17.45	0.42
FeO	9.13	0.18	5.71	0.04	2.64	0.15	12.33	0.18
MnO	0.07	0.07	0.09	0.07	n.d.	—	0.11	0.11
NiO	0.30	0.06	n.d.	—	n.d.	—	0.26	0.04
MgO	50.30	0.85	34.33	0.08	15.57	0.63	20.63	0.33
CaO	n.d.	—	0.40	0.02	21.10	0.08	n.d.	—
Total	101.36		99.94		97.02		100.83	

Cation proportions

	Olivine	Opx	Cpx	Spinel
Anions	4	6	6	4
Si^{4+}	1.0016	1.9448	1.9383	0
Ti^{4+}	0	0	0	0
Al^{3+}	0	0.1040	0.1977	1.5676
Cr^{3+}	0	0.0124	0.0290	0.3667
Fe^{3+}	0	0.0222	0	0.1060
Fe^{2+}	0.1840	0.1425	0.0819	0.1680
Mn^{2+}	0.0015	0.0027	0	0.0090
Ni^{2+}	0.0059	0	0	0.0058
Mg^{2+}	1.8064	1.7641	0.8616	0.8172
Ca^{2+}	0	0.0071	0.8392	0
Cation sum	2.9994	4.0074	3.9478	3.0403

Fe^{3+} calculated using method of Droop (1987). Analyses determined on energy-dispersive electron-microprobe, Department of Earth Sciences, University of Cambridge. n.d.–not detected; s.d.–standard deviation.

2.c. Xenocrysts

2.c.1. Ultramafic

Abundant xenocrysts of olivine, with lesser pyroxene and spinel, are described in section 2.b.1 above.

2.c.2. Other xenocrysts

Plagioclase forms occasional xenocrysts from 0.3 to 13 mm in size. The shapes vary considerably: many are oval and well-rounded, while others are rectangular and wedge-shaped. There is no clear correlation between size and degree of rounding. In some case offset twinning gives evidence of fracturing and subsequent annealing. Occasional sericitization is seen.

3. Discussion

Preliminary calculations based on the mineral chemical data (Table 3) indicate equilibration temperatures broadly comparable with those of numerous similar studies, but there are as yet insufficient data on which to base a discussion of equilibration temperatures, and this paper is primarily descriptive in intent.

While no ultramafic xenoliths have been discovered in Tertiary dolerites in Ireland, a Permo-Carboniferous age for the dyke (see section 2.a) invites comparisons with xenolith suites elsewhere in Ireland and the Midland Valley of Scotland as described by Upton, Aspen & Hunter (1984). Although a wide variety of assemblages is known from these other localities, thus providing a partial vertical profile through crust and upper mantle, spinel lherzolite and spinel harzburgite are the most common. This discovery is the third in Ireland, in which the predominance of spinel lherzolite xenoliths provides a population markedly different from those of Inishowen (Murthy, 1958) or central Ireland (Strogen, 1974). Further study of this xenolith suite will yield further information on the constitution of the sub-Carboniferous crust and upper mantle, and invites the possibility of further such discoveries in Ireland.

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S. GALLAGHER & R. ELSDON
Department of Geology,
University College,
Belfield,
Dublin 4,
Ireland