It is tempting to speculate on the possible origin of such a structure, but in view of the complexity of the history of carbonaceous chondrites it is probably also of little value. What may be worth remembering is that the mineralogy has similarities to that of certain achondrite fragments recorded in Leoville by Keil, Huss, and Wiik (1969), and the zoning is reminiscent of gehlenite–spinel zones found round calcium-rich achondrite fragments in Vigarano (Michel-Lévy, 1968).

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Chemical composition of the upper mantle

HARRIS, Reay, and White (1967) attempted to establish a quantitative chemical composition of the upper mantle, using published analyses of olivine nodules from basalts, garnet-peridotite nodules from kimberlites, and samples of tectonically emplaced ultramafic masses. Independent estimates of undepleted mantle composition derived from each group of rocks were shown to approach a common value. The number of reliable analyses available to Harris *et al.* was insufficient for making any definite conclusion regarding the possible heterogeneity of the upper mantle. The present contribution is an interim report on an analytical programme attempting to make good this deficiency. It is the direct continuation of the earlier authors' work.

One hundred and fifty spinel-lherzolite xenoliths from the basaltic volcanics of five widely spaced localities in the Massif Central, France, forty from the basaltic maar volcano, Dreiser Weiher, in the Eifel, Germany (Frechen, 1963), and fifteen peridotite xenoliths from the Bultfontein kimberlite pipe, South Africa, have been chemically analysed. The South African samples were made available by Dr. J. B. Dawson, University of St. Andrews, to whom we are most grateful. Each sample has been analysed for SiO_2, Al_2O_3, Cr_2O_3, total iron, NiO, MnO, MgO, and CaO by X-ray

fluorescence using a fusion method. Ten xenoliths, used as standards for the X-ray analyses, were first analysed in duplicate by Mr. F. Buckley (also of Leeds) and R. H., using gravimetric, volumetric, atomic absorption, polarographic, and spectro-photometric techniques. D. K. P. determined Na_2O by neutron activation, and K_2O by an X-ray fluorescence trace element technique, as did R. H. for TiO_2. FeO was determined by dichromate titration and H_2O (total) was determined for some French and all Bultfontein pipe samples.

TABLE I

	I	2	3	4	5	6	7	8	9
SiO_2	44·5	44·7	44·4	44·1	45·0	46·0	43·8	44·2	45·16
TiO_2	0·07	0·02	0·04	0·03	0·07	0·04	0·02	0·1	0·71
Al_2O_3	2·69	2·00	1·66	1·75	3·01	1·70	1·45	2·7	3·54
Cr_2O_3	0·43	0·47	0·47	0·45	0·41	0·43	0·45	0·30	0·43
Fe_2O_3	1·46	1·98	1·41	1·49	1·28	2·40	1·61	1·1	0·46
FeO	6·71	6·02	7·50	6·74	6·70	4·20	6·75	7·3	8·04
NiO	0·26	0·27	0·27	0·29	0·25	0·28	0·29	0·20	0·20
MnO	0·11	0·11	0·13	0·12	0·11	0·10	0·12	0·15	0·14
MgO	40·9	42·1	42·3	43·3	39·7	43·3	44·0	41·3	37·47
CaO	2·61	2·18	1·64	1·53	3·15	1·26	1·38	2·4	3·08
Na_2O	0·22	0·10	0·11	0·15	0·24	0·14	0·15	0·25	0·57
K_2O	0·01	0·04	0·04	0·03	0·04	0·20	0·03	0·015	0·13

All analyses calculated to 100 % water-free.

1. Mean of analyses of 42 spinel-lherzolite xenoliths (41 for Na_2O) from quarry in scoria on west side of road N.88, 8 km south-south-west of Le Puy, near Tarreyres, Haute-Loire.

2. Mean of analyses of 43 spinel-lherzolite xenoliths (41 for Na_2O) from plug at Montboissier, Puy-de-Dôme.

3. Mean of analyses of 27 spinel-lherzolite xenoliths from Puy Beaunit, west of Riom, Puy-de-Dôme.

4. Mean of analyses of 18 spinel-lherzolite xenoliths (15 for Na_2O) from quarry at road-side, 4 km north-north-west of Rentèires village, Puy-de-Dôme. The quarry is in the scoria of the Volcan de Zanière.

5. Mean of analyses of 20 spinel-lherzolite xenoliths (19 for Na_2O) from the basalte de Rocher du Lion, Monistrol d'Allier, Haute-Loire (Vilminot, 1965).

6. Mean of analyses of 15 peridotite xenoliths from the Bultfontein kimberlite pipe, South Africa.

7. Mean of analyses of 40 spinel-lherzolite xenoliths from the Dreiser Weiher, Eifel, Germany.

8. Estimate of upper mantle composition (Harris *et al.*, 1967, table 2, no. 3).

9. Ringwood's 'pyrolite' (1966).

Analyses of the average compositions of the xenoliths of each locality have been calculated on a water-free basis to 100 % and appear in table I. Each analysis used in the calculations has a total in the range 97–102·5 %, but most lie in the narrower range of 98–101 %.

From table I it is evident that Al_2O_3, CaO, Na_2O, K_2O, and TiO_2 are the oxides whose average concentrations are most variable, a feature noted by Harris *et al.* (1967) (p. 6359). Dr. J. M. Rooke, of this Department, has used all 150 Al_2O_3 contents from the French xenoliths for a variance test and has shown that there is a highly significant variation in the concentration of this oxide amongst groups of samples from different localities. It has been assumed that all variances are homogeneous; more rigorous treatment for all the data will shortly be completed. In addition, electron microprobe

analyses of clinopyroxenes from Tarreyres xenoliths (A. Chambers, pers. comm.) indicate that these are richer in Al_2O_3 and Na_2O than clinopyroxenes of the other French localities, suggesting that the Tarreyres specimens were equilibrated under greater pressures and are less depleted in their fusible constituents. In the past, the view that ultramafic inclusions in basalts are fragments of the upper mantle received considerable criticism (O'Hara and Mercy, 1963; O'Hara, 1967). However, recent trace element and isotope studies (Leggo and Hutchison, 1968; Kleeman, Green, and Lovering, 1969; Cooper and Green, 1969) suggest that the inclusions are not cognate with their basaltic hosts and *are* derived from the upper mantle. The host rocks of each French locality are fairly uniform in composition, being undersaturated alkalic basalts, and were probably derived from a similar depth region in the upper mantle. The variations in mean compositions of the xenoliths indicate that the upper mantle beneath the Massif Central is geographically variable in composition.

The mean composition of forty spinel-lherzolite xenoliths of the Dreiser Weiher indicates that the underlying mantle is strongly depleted in fusible constituents. Three garnet-lherzolite xenoliths from the Bultfontein pipe have been donated by Dr. J. B. Dawson for work elsewhere, so the fifteen specimens analysed in this study may not be a representative sample and are probably biased in favour of a more depleted, harzburgitic composition. However, the average does indicate that peridotitic xenoliths in kimberlite may have low contents of fusible oxides, except for K_2O, which was probably introduced from the host (Allsopp, Nicolaysen, and Hahn-Weinheimer, 1969).

At this stage it may be concluded that the upper mantle beneath the Massif Central is heterogeneous and that the ultramafic xenoliths brought up by each volcano represent underlying mantle over a limited area. It therefore seems inadvisable to draw general conclusions on mantle composition from the study of samples from a single continental occurrence. The compositions of numerous xenoliths from two French localities approach that of pyrolite (Ringwood, 1966), except that their alkali contents are lower by a factor of two or three.

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Myrmekitic and non-myrmekitic plagioclase compositions in gneisses from Broken Hill, New South Wales

LITTLE correlation appears to exist between the composition of 'primary' plagioclase and the plagioclase of myrmekite in igneous rocks. This difference in composition is especially noticeable in granodiorites and adamellites. In such rocks the 'primary' plagioclase is well-zoned and can range from core labradorite through to marginal oligoclase. The plagioclase in associated myrmekite, however, is usually more sodic and is essentially fixed in composition or changes only slightly from oligoclase to marginal calcic albite (commonly with a corresponding decrease in allied quartz content). Despite recent differences in views on myrmekite genesis (e.g. Hubbard, 1969; Ransom and Phillips, 1969; Shelley, 1969) it appears that few petrologists would dispute this fairly obvious composition contrast. The situation with metamorphic rocks is, however, not as well defined and detailed comparisons between the composition of plagioclase in myrmekite and non-myrmekitic plagioclase are not easily found.

Gneisses from Broken Hill (mainly plagioclase–potash-feldspar–quartz–biotite–garnet rocks) contain plagioclase as unzoned non-myrmekitic xenoblastic crystals and as small xenoblastic myrmekitic grains associated with potash feldspar. Commonly the myrmekite appears to grow out from the larger non-myrmekitic plagioclase into the potash feldspar. In a somewhat different development in Potosi gneiss (table I, anals. 1 and 2) it forms a dense mat of lobate patches that completely surround minor amounts of crudely lenticular potash feldspar. Fine muscovite is commonly associated with such intergrowths.