an abnormally low altitude. This supports Duncan's[1] "dumping" theory, as does the observation[1,3] that the phenomenon is sporadic.

The observation[2] that minimum and maximum h_mF2 are more consistent in UT and LMT respectively suggests that more than one mechanism is responsible. It is tempting to speculate that the observed phenomena are caused by a combination of vertical drifts due to atmospheric winds and dumping of particles by a "geomagnetic tide", as suggested by Duncan[1]. A comprehensive study of all available data is, however, needed to test these ideas more fully.

I thank Dr R. A. Duncan for providing Fig. 2 and for discussions.

R. A. CHALLINOR

Upper Atmosphere Section,
CSIRO,
Camden, NSW.

Received December 30, 1968.

[1] Duncan, R. A., *J. Geophys. Res.*, **67**, 1823 (1962).
[2] Piggott, W. R., and Shapley, A. H., *Antarctic Res., Geophys. Monogr. No. 7*, 111 (1962).
[3] Hill, G. E., *J. Atmos. Sci.*, **20**, 492 (1963).
[4] Wilkes, M. V., *Oscillations of the Earth's Atmosphere*, 11 (Cambridge Univ. Press, 1949).
[5] King, J. W., Kohl, H., Preece, D. M., and Seabrook, C., *J. Atmos. Terr. Phys.*, **30**, 11 (1968).
[6] Challinor, R. A., *Planet. Space Sci.*, **16**, 557 (1968).
[7] Challinor, R. A., *Planet. Space Sci.* (in the press).
[8] Geisler, J. E., *J. Atmos. Terr. Phys.*, **29**, 1469 (1967).
[9] Kohl, H., and King, J. W., *J. Atmos. Terr. Phys.*, **29**, 1045 (1967).

Ringwoodite, Natural $(Mg,Fe)_2SiO_4$ Spinel in the Tenham Meteorite

We have observed numerous rounded purple isotropic grains up to 100 microns in diameter in thin sections of two stones from the Tenham meteorite shower[1] (British Museum B.M.1935,792 and Australian Museum DR 8298). The grains occur chiefly within black veins cutting across the stones, but the same material also replaces olivine within 10–20 microns of certain thicker veins and at the margins of some large chondritic fragments within the veins. Our investigations show that the purple mineral is the high pressure spinel polymorph of olivine, and for this first authentic natural occurrence we propose the name ringwoodite, in honour of the experimental studies[2] by Professor A. E. Ringwood, Australian National University. The name covers the entire range of $(Mg,Fe)_2SiO_4$ spinels, and has been approved by the Commission on New Minerals and Mineral Names, International Mineralogical Association.

Table 1. ELECTRON PROBE MICROANALYSES (J. M. HUNNEX), TENHAM METEORITE, B.M.1935,792

	Ringwoodite		Olivine
	Purple 1	Bluish-grey 2	3
SiO_2	38·9	38·7	38·3
FeO	23·4	23·2	23·2
MgO	37·0	38·8	38·6
CaO	Nil	Nil	Nil
Total	99·3	100·7	100·1

Column 1 of Table 1 lists an electron probe microanalysis (average of several determinations showing no significant variation) of purple ringwoodite from the veins. The analysis is identical within the analytical precision to that of unaltered olivine away from the veins (Table 1, column 3), and recalculates to the orthosilicate formula $(Mg_{0\cdot74}Fe_{0\cdot26})_2SiO_4$. The X-ray diffraction pattern (Table 2, column 2) resembles that of synthetic $MgAl_2O_4$ spinel (Table 2, column 1) with rather different intensities and several weak lines, notably (111), missing. This pattern, obtained with an 11·46 cm diameter camera on a single uncrushed analysed grain, also showed weak lines at $d = 2\cdot57$, 1·54, 1·60, 1·29 and 2·35 Å (in decreasing order of intensity) arising from garnet present in black vein material still adhering to the grain. The ringwoodite diffraction lines were smooth and showed no preferred orientation, showing that the grain was finely polycrystalline. The cell dimension ($a_0 = 8\cdot113 \pm 0\cdot003$ Å) and the refractive index ($n = 1\cdot768 \pm 0\cdot003$) of the purple ringwoodite are close to those observed[2,3] for synthetic $(Mg,Fe)_2SiO_4$ spinel with the observed Mg,Fe content (see Fig. 1). The density calculated for the purple grains is 3·90 g cm^{-3}, some 12 per cent greater than that of olivine of the same chemical composition[4] (3·48).

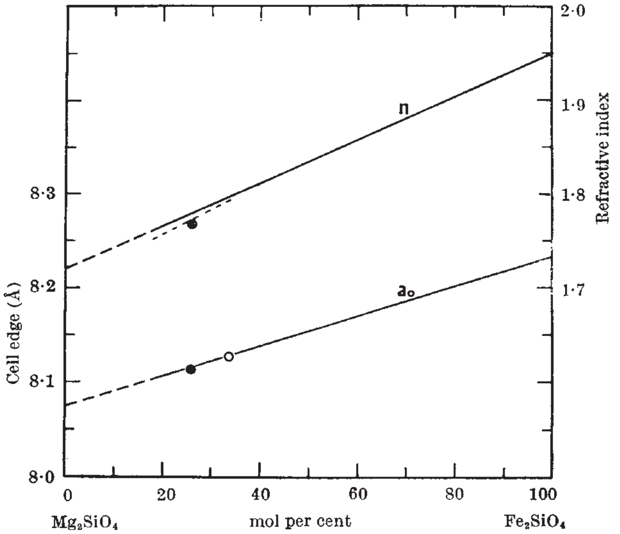

Fig. 1. Variation in refractive index (n) and cell dimension (a_0) with composition in synthetic $(Mg,Fe)_2SiO_4$ spinels[2,3]. For n the solid line is calculated from the Gladstone–Dale rule; the dashed line below is the best fit to the measurements. Full circles are for purple ringwoodite from Tenham; the open circle is for the bluish-grey ringwoodite. Dashed lines below 20 per cent Fe_2SiO_4 denote the region where $\beta(Mg,Fe)_2SiO_4$ is the stable high pressure polymorph.

A second form of ringwoodite occurs in Tenham as bluish-grey pseudomorphs after olivine within about 200 microns of one of the veins. Microprobe analyses (Table 1, column 2) are almost identical with those of nearby purple ringwoodite and olivine, and the X-ray diffraction pattern (Table 2, column 3) obtained as before from an uncrushed fragment showed smooth lines due to a spinel-

Table 2. X-RAY POWDER DATA FOR SYNTHETIC $MgAl_2O_4$ SPINEL[8] AND FOR RINGWOODITE. FILTERED CuK_α RADIATION

	Spinel ($MgAl_2O_4$) 1		Ringwoodite Vein 2	Chondrule 3	
hkl	*d* (Å)	I/I_0	*d* (Å)	*d* (Å)	I/I_0*
111	4·67	4	—	—	—
220	2·858	40	2·872†	2·871	20
311	2·436	100	2·447	2·451	100
222	2·333	3	—	—	—
400	2·021	58	2·628	2·031	40
422	1·649	10	1·656†	—	1
511	1·555	45	1·560	1·563	20
440	1·429	58	1·434	1·437	60
531	1·366	3	—	—	—
620	1·278	2	—	—	—
533	1·232	9	1·237	1·240	2
622	1·218	1	—	—	—
444	1·166	7	1·172	1·173	1
711	1·131	2	—	—	—
642	1·080	4	—	—	—
731	1·0518	12	1·0559	1·0563	10
800	1·0100	5	1·0137	1·0158	5
822	0·9522	3	—	—	—
751	0·9330	10	0·9348	0·9388	2
840	0·9034	6	0·9067	0·9104	1
911	0·8869	< 1	—	—	—
664	0·8613	< 1	—	—	—
931	0·8469	10	0·8498	—	1
844	0·8247	20	0·8283	0·8294	10
a_0 (Å)	8·080		8·113	8·127	

* Visual estimates.

† Lines possibly affected by strong lines of admixed garnet.

type phase only. The cell dimension ($a_0=8\cdot127\pm0\cdot003$ Å) suggests a somewhat higher iron content, $(\mathrm{Mg}_{0\cdot66}\mathrm{Fe}_{0\cdot34})_2\mathrm{SiO}_4$ (see Fig. 1), and we believe that this form of ringwoodite is finely dispersed in an amorphous, more magnesian, silicate glass.

We have also observed in the Australian Museum specimen large isotropic grains grading from colourless cores to purple rims; these may also be ringwoodite.

In thin section, about 10 microns thick, the black vein material in Tenham appears as deep brown isotropic material, apparently microcrystalline, through which are dispersed threads and tiny spherical droplets (diameter 2 microns) of an extremely fine metal–troilite intergrowth. X-ray powder photographs of uncrushed fragments show that the material is dominantly a microcrystalline garnet-type phase, cell dimension $a_0=11\cdot507\pm0\cdot003$ Å, with weak extra lines varying somewhat from sample to sample, which might in part be accounted for by traces of kamacite, taenite, troilite, ringwoodite and possibly chromite. So far, we have been unable to resolve the components in the vein material by electron microprobe; spot analyses showed that the vein material is a magnesium iron silicate with compositions usually equivalent to either the olivine or the pyroxene in the main body of the meteorite. In view of its cell dimension, the garnet may be a high pressure polymorph[3] of the orthopyroxene (Fs_{22}) which elsewhere forms a major constituent of the Tenham meteorite.

Mason *et al.*[5] reported a purple isotropic mineral with the composition of olivine in veins in the Coorara meteorite which, like Tenham, is an olivine–hypersthene chondrite. We suggest that this material may also contain ringwoodite. The garnet-type X-ray pattern ($a_0=11\cdot51$ Å) obtained could easily obscure the ringwoodite pattern, for the latter contains only three strong lines, each of which coincides with a fairly strong garnet line.

In Tenham, the sodic feldspar (An_{10-12}) has been almost entirely converted to glassy maskelynite, which is a widely accepted indicator of shock[6,7]. Ringwoodite is thought to be produced by the transformation of olivine by high shock pressures in the veins. Further details of the occurrence of ringwoodite in Tenham, and its interpretation in terms of shock phenomena, will be given by one of us (R. A. B.) later.

R. A. BINNS

Department of Geology,
University of New England,
Armidale, New South Wales.

R. J. DAVIS
S. J. B. REED

Department of Mineralogy,
British Museum (Natural History),
London SW7.

Received January 13, 1969.

[1] Spencer, L. J., *Mineralog. Mag.*, **24**, 437 (1937).
[2] Ringwood, A. E., and Major, A., *Earth Planet. Sci. Lett.*, **1**, 241 (1966).
[3] Ringwood, A. E., *Phase Transformations in the Mantle*, Dept Geophys. Geochem., Austral. Nat. Univ., Canberra, Publ. 666 (1968).
[4] Deer, W. A., Howie, R. A., and Zussman, J., *Rock Forming Minerals*, **1**, 22 (Longmans, London, 1962).
[5] Mason, B., Nelen, J., and White, J. S., *Science*, **160**, 66 (1968).
[6] Milton, D. J., and De Carli, P. S., *Science*, **140**, 670 (1963).
[7] Binns, R. A., *Nature*, **213**, 1111 (1967).
[8] Swanson, H. E., and Fuyat, R. K., *US Nat. Bur. Stand. Circ.*, **2**, 36 (1953).

Continuous Spectrum of Taurus *A* at 1·2 mm Wavelength

WE have measured the radiation from the region of the Crab nebula (Taurus *A*) in a waveband centred at 1·2 mm (250 GHz) in the far infrared. Our equipment was an indium antimonide detector of the Rollin[1] type cooled by liquid helium at the cassegrain focus of the 98 inch Isaac Newton telescope of the Royal Greenwich Observatory. The observations were made with the aid of a rapid-scan unit, comprising an oscillating mirror which scanned in declination 13·7′ of arc on the sky either side of its axial point with a period of 1·2 s. The effect of the rapid scanning is to increase the discrimination of the system against ν^{-1} components in both sky background and detector electronic noise[2]. The scans were synchronized, stored digitally and averaged by means of an "enhancetron" digital analyser, which provided a visual display and chart recorder readout.

The optical quality of the telescope was used for a preliminary determination of the pointing accuracy of the infrared system to within 1′ of arc during a brief cloud-free interlude, but the observations themselves were made on the night of November 30–December 1 through cloud, relying on the accuracy of the setting scales and sidereal timing of the telescope, which placed a limit of 2′–3′ of arc on the position of the scan centre of the infrared system. Scans of the source were followed by an equal number of scans 10′ of arc away. Groups of 25, 50 or 100 scans were interleaved so that any effect due to d.c. drift of the detector electronics would be minimized by subtracting electronically the sky scans from those of the source. The results shown in Fig. 1*a* summarize the averaged data of 3,000 scans representing 1 h of integration time across the source, together with 3,000 subtracted scans of sky background. The abscissa is in minutes of arc, and the ordinate in arbitrary units of flux per beam-width per minute of arc. Comparison may be made with Fig. 1*b* showing the result of 500 scans of Jupiter taken on the same night, also at 250 GHz and having the same abscissa and ordinate. The theoretical half-power points for the angular gain function of the telescope are plotted in each case, showing that, as expected, Jupiter behaves essentially as a point source, while the nebula has a finite angular diameter of average value 4′ of arc in declination. This average is for five values of right ascension having a root mean square variation of 1·5′ of arc, because the 3,000 scans were made in five separate runs.

In order to calculate the relative fluxes from Jupiter and Taurus *A* we have assumed circular symmetry for each object. While unlikely to be an accurate description of Taurus *A* which is known optically to have a major axis of 6′ and a minor axis of 4′ of arc[3], this is the most sensible

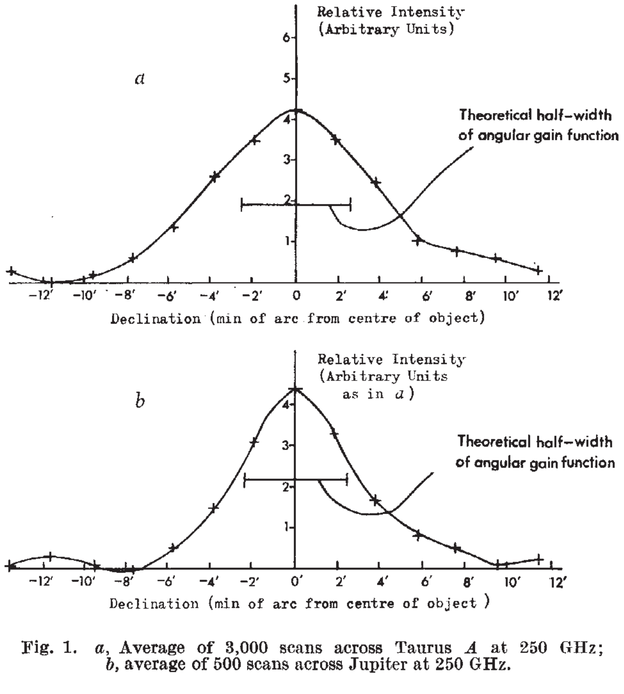

Fig. 1. *a*, Average of 3,000 scans across Taurus *A* at 250 GHz; *b*, average of 500 scans across Jupiter at 250 GHz.