currence of a tillite near the top of the Table Mountain Series in the Cape System of South Africa provides paleoclimatic evidence for the timing of the transition. A possible Lower Devonian age for this tillite is consistent with the polar transition taking place within the Lower Devonian.

The transition that occurs during the mid-Carboniferous (*13*) is represented by two poles (5b, Fig. 1, for both Africa and Australia) occupying positions intermediate between the middle and upper Paleozoic positions. However, Creer (*14*) does not seem to recognize a Carboniferous transition of the same magnitude in the South American data, although this would appear to be a matter of interpretation. It would not be difficult to interpret results from the Piaiu formation (*15*) such that South American pole 5b is replaced by two poles, one lying to the west and one to the east of its position shown in Fig. 1. Such an arrangement would be consistent with the interpretation of African and Australian results (*13*). Finally, the upper Paleozoic poles are all characterized by reverse magnetization, which suggests that they all fall within the Kiaman Magnetic Interval (*16*).

The reconstruction of Fig. 1 is very similar to the one originally proposed by du Toit (*17*), but it has been derived from paleomagnetic results only. The data are now sufficient to make it almost unambiguous, although one possible adjustment might be the narrowing of the gap between Antarctica and Australia when further lower Paleozoic results from Australia become available. In Fig. 2 we have compared our reconstruction with evidence from geological age provinces. The inclusion of Madagascar in this figure to fill the vacant gap between India and Antarctica constitutes the only departure from a recent computer fit of the southern continents (*18*). The paleomagnetic data cannot at present distinguish between these alternatives. The age provinces have been drawn according to zones similarly shown on a different reconstruction by Hurley (*19*). They comprise two main groups: the ancient cratons with an age of at least 2000 million years and their surrounding younger metamorphic belts or geosynclines, whose ages cluster around 450 to 650 million years but reach a maximum of 1100 million years. Recent geochronological information from India shows that the events with ages of 450 to 650 million years, which affected Ceylon, have also affected southernmost India and coastal Andrah Pradesh (*20*) (see Fig. 2). The fit of these geological age provinces across the continental boundaries on our reconstruction is equally as good as, or better than, the fit proposed by Hurley (*19*). We believe, therefore, that these geologic data provide additional support for the paleomagnetically determined reconstruction.

M. W. McELHINNY
G. R. LUCK

Department of Geophysics and Geochemistry, Australian National University, Canberra, A.C.T.

References and Notes

1. M. W. McElhinny, *Earth Planet. Sci. Lett.*, in press.
2. ——— and G. R. Luck, *Geophys. J. Roy. Astron. Soc.*, in press; G. R. Luck, *ibid.*, in press.
3. J. A. Clegg, C. Radhakrishnamurthy, P. W. Sahasrabudhe, *Nature* **181**, 830 (1958); C. Bull, E. Irving, I. Willis, *Geophys. J. Roy. Astron. Soc.* **6**, 320 (1962); K. M. Creer, *ibid.* **7**, 1 (1962).
4. E. Irving, W. A. Robertson, P. M. Stott, *J. Geophys. Res.* **68**, 2313 (1963); D. I. Gough, N. D. Opdyke, M. W. McElhinny, *ibid.* **69**, 2509 (1964).
5. E. Irving, in *Continental Drift—A Symposium* (Univ. of Tasmania, Hobart, 1958); K. W. T. Graham, C. E. Helsley, A. L. Hales, *J. Geophys. Res.* **69**, 3895 (1964).
6. M. W. McElhinny, J. C. Briden, D. L. Jones, A. Brock, *Rev. Geophys.* **6**, 201 (1968).
7. K. M. Creer, *Phil. Trans. Roy. Soc. London A* **258**, 27 (1965); paper presented at the Symposium on Continental Drift, International Union of Geological Sciences and Unesco, Montevideo, October 1967.
8. M. W. McElhinny, paper presented at the Symposium on Continental Drift, International Union of Geological Sciences and Unesco, Montevideo, October 1967.
9. J. C. Briden, *Nature* **215**, 1336 (1967).
10. J. D. A. Zijderveld, *J. Geophys. Res.* **73**, 3773 (1968).
11. S. Beuf, B. Biju-Duval, J. Stevaux, G. Kulbicki, *Rev. Inst. Fr. Petrole Ann. Combust. Liquides* **21**, 363 (1966).
12. B. J. J. Embleton, *Nature* **222**, 1036 (1969).
13. E. Irving, *J. Geophys. Res.* **71**, 6025 (1966); M. W. McElhinny and N. D. Opdyke, *ibid.* **73**, 689 (1968).
14. K. M. Creer, *Nature* **219**, 41 (1968).
15. ———, *Bol. Paranaeuse Geogr.*, p. 93–141 (1964).
16. E. Irving and L. G. Parry, *Geophys. J. Roy. Astron. Soc.* **7**, 395 (1963).
17. A. L. du Toit, *Our Wandering Continents* (Oliver & Boyd, Edinburgh, 1937).
18. A. G. Smith and A. Hallam, *Nature* **225**, 139 (1970).
19. P. M. Hurley, *Sci. Amer.* **218**, 53 (1968).
20. A. R. Crawford, *Nature* **223**, 380 (1969).
21. H. Wensink and C. T. Klootwijk, *Earth Planet Sci. Lett.* **4**, 191 (1968); H. Wensink, *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **5**, 323 (1968).

6 February 1970

■

Pyroxene-Garnet Transformation in Coorara Meteorite

Abstract. *Majorite is a new garnet in a veinlet of the Coorara meteorite. Its chemical composition is compatible with derivation mostly from original pyroxene, not from olivine as originally reported. Silicon is partly in sixfold coordination. Ringwoodite, a spinel of olivine composition, occurs as purple grains set in a matrix of fine-grained garnet. The similar mineralogy and texture of the Coorara and Tenham meteorites suggest a common parent body.*

The mineralogical assemblages in the veinlet of the Coorara meteorite examined by Mason, Nelen, and White (*1*) are extremely complex as a result of high-pressure extraterrestrial transformations followed by extensive alteration, probably terrestrial. The reported discovery of a garnet with olivine composition must be modified, because the composition of the garnet is actually near that of pyroxene and is associated with a spinel of olivine

Table 1. Microprobe analyses. All abundances are given in percent by weight. Analysis for Ni was very uncertain because extensive net veining of a material rich in Fe and Ni caused a secondary fluorescence.

Element	Ringwoodite (%)	Olivine in main body (%)	Majorite (%)	Pyroxene in vein (%)	Pyroxene in main body (%)
Si	17.8	18–19	22–26(24.3*)	26.7	25–26
Ti	0	0	0	0.16	0.2
Al	0	0	0.4–1.6(1.4)	0.00	0.00
Cr	0	0	0.2–0.6(0.45)	0.11	0.1
Fe	18.1–19.9	19.4–22.5	12–14(13.1)	10.2–11.3	10–11
Mn	0.16–0.28	0.2	0	0.4	0.4
Mg	21.7–23.2	18.7–21.5	15–22(16.6)	15.7–17.5	16.5–17.5
Ni	0	0.03 up	0.02–0.05(0.03)	0.07	0.1
Ca	0	0.03	0	0.06	0.6
Na	0	0	0.4–0.6(0.5)	0	0
K	0	0	0	0	0

* Mean of five measurements thought to best represent the composition of specimen checked by x-ray powder diffraction.

Table 2. Atomic formula of garnet calculated to 12 oxygens.

Site	Atom	Assuming divalent Fe		Assuming trivalent Fe	
X	Si	3.00		3.00	
Y	Si	0.78	2.06	0.62	1.84
	Al	0.23		0.22	
	Fe	1.02		0.97	
	Cr	0.03		0.03	
Z	Mg	2.98	3.08	2.86	2.96
	Na	0.10		0.10	

composition. The name *majorite* has been approved for the garnet by the International Mineralogical Association Commission on New Minerals. The name honors Alan Major, who assisted Ringwood (*2*) in high-pressure synthesis of garnet from pyroxene composition.

The spinel has an olivine composition that overlaps the composition of the spinel in the Tenham meteorite (*3*). Binns, Davis, and Reed assigned the name ringwoodite to the spinel phase. The ringwoodite of the Coorara meteorite has a variable composition, which overlaps the composition of the Tenham ringwoodite (Table 1). The Coorara specimen contains 0.2 percent by weight of Mn, whereas no Mn was listed (but might have been overlooked) for the Tenham material. The composition range of the olivine in the main body of the Coorara meteorite overlaps that of the ringwoodite.

The Coorara ringwoodite, like the Tenham ringwoodite, has an eye-catching purple color in thin section and consists of discrete grains, often coarsely interwoven with a pyroxene. The majorite is fine-grained (several micrometers across) and forms a brown-pinkish matrix with goethite and kamacite surrounding the coarse spinel and pyroxene crystals.

A small sliver of the matrix from the veinlet yielded a Debye-Scherrer pattern (*4*) whose lines could be indexed in accordance with the reference patterns for pyrope garnet, goethite, and α iron in the Powder Diffraction File. The extrapolated cell dimension for the majorite was 11.524 ± 0.002 Å consistent with the value 11.51_5 Å obtained by Mason *et al.* (*1*). The line intensities are quite similar to those for pyrope reference card 15-742 of the Powder Diffraction File.

The majorite of the Coorara meteorite is so fine-grained that microprobe analysis was very difficult. The compositions (*5*) reported in Table 1 were obtained from a polished thin section by rejecting some data with a high Fe and low Si content, which were thought to result from overlapped goethite and other Fe-rich minerals. The oxidation state of the Fe is unknown, and the analysis has been calculated to 12 oxygen atoms on the two extremes of all divalent and all trivalent Fe (Table 2). Whatever the assumption, some Si must be in nontetrahedral coordination, almost certainly in octahedral coordination. The major elements Mg, Fe, and Si have concentrations similar to those of the orthopyroxene that occurs as a major constituent of the main body of the meteorite, but the minor elements are quite different. The garnet is brownish, but the color may result from iron oxides rather than being inherent. The garnet of the Tenham meteorite has x-ray and chemical properties (*2*) similar to the properties reported here.

Also in the polished thin section of the vein are rare crystals of an optically isotropic material of orthopyroxene composition. These crystals are probably majorite, but an x-ray validation has not yet been obtained.

The ringwoodite and majorite were undoubtedly formed from olivine, pyroxene, and other minerals in the meteorite as a result of extraterrestrial high-pressure transformations. The overlap of the composition ranges of the ringwoodite and olivine indicates an isochemical transformation. The major elements of the majorite and pyroxene are fairly similar when account is taken of substitution of Si by Al (see Table 2). However the minor element concentrations are quite different. The Na and Al of the majorite probably come from plagioclase. The Cr probably comes in part from chromite. Presumably original pyroxene with lesser amounts of plagioclase, olivine, and chromite were converted into the fine-grained mixture of majorite with lesser amounts of iron-rich phases. Subsequently, terrestrial weathering caused considerable changes in the hydration and oxidation states of the iron.

On the basis of incompatibility of the cell dimension of majorite with the cell dimension expected theoretically for a garnet with an Mg-rich olivine composition, McConnell (*6*) proposed that the garnet has the composition of khoharite, whereas Geller (*7*) suggested that its composition is a mixture of pyroxene and olivine. The new chemical data yield an estimated cell dimension that is consistent with the observed cell dimension.

The great similarity between the chemical and textural data for the Tenham and Coorara meteorites strongly suggests a common extraterrestrial origin. However, Tenham is an observed fall (1879), whereas the weathered condition of Coorara (found in 1967) indicates that it probably fell hundreds or even thousands of years ago.

J. V. SMITH
Department of the Geophysical Sciences, University of Chicago, Chicago, Illinois 60637

BRIAN MASON
Smithsonian Institution, Washington, D.C. 20560

References and Notes

1. B. Mason, J. Nelen, J. S. White, Jr., *Science* **160**, 66 (1968).
2. R. A. Binns, R. J. Davis, S. J. B. Reed, *Nature* **221**, 944 (1969).
3. A. E. Ringwood, *Earth Planet. Sci. Lett.* **2**, 255 (1967).
4. Submitted to Powder Diffraction File, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103. FeK_α, 114.6-mm radius.
5. Analyses at 15 kv, 0.1 μa, approximately 1-μm spot, Applied Research Laboratory microprobe. Standards and correction procedures as in R. A. Howie and J. V. Smith [*J. Geol.* **74**, 443 (1966)], and J. V. Smith (*ibid.*, p. 1).
6. D. McConnell, *Science* **163**, 828 (1969).
7. S. Geller, *ibid.*, p. 829.

8. Supported by NASA contract NAS 9-8086. We thank R. Zechman, Scott Baird, and S. J. Louisnathan for technical help and P. B. Moore for discussion.

4 March 1970

Orientation Order of Dipole Molecules in the Surface of Embryonic Droplets

Abstract. *During the growth of embryonic droplets in an imperfect vapor the surface polar molecules pass from a disordered orientation state to an ordered orientation state, the transition size being on the order of 100 molecules. This transition poses an interesting model problem in the study of order-disorder transitions in the thermodynamics of small systems.*

Until 1962 the classical nucleation theory for water condensation, as given by Becker and Döring (*1*), had been regarded as well founded and substantially verified by experiment. In 1962 Lothe and Pound (*2*) pointed out that, according to this treatment, the embryonic droplets are considered to be at rest in the vapor whereas, in reality, they form a macromolecular gas so that their translation and rotation must be