dairying practices introduce variation in the I^{131} in milk, with the same level of pasture contamination (*9*), but the possibility of their explaining the higher Midwest concentrations of I^{131} in milk, except from St. Louis, Missouri (*9*), is remote. Nor would any nonmeteorological factor explain the pattern of Sr^{90} fallout.

Meteorological phenomena other than high-reaching thunderstorms suggest themselves. Many radioiodine episodes occurred entirely in dry weather (*2*). Another thunderstorm scavenging mechanism has been proposed (*10*). The tropopause can fold and extrude a thin layer of stratospheric air, less than 1 km in thickness, into the troposphere below (*11*); in the course of the extrusion, stratospheric air is brought to the lower troposphere or even to the ground in a matter of 1 day; part of the descending current reascends, and this air is most likely to cause scavenging since it helps to initiate thunderstorms.

Unfortunately no climatology of extrusions, and thunderstorms which penetrate them, exists (*12*), although there is reason to think that the Midwest in May may be most vulnerable. In May of 1965 and 1966, cyclones were favorably situated to allow the extrusion process to operate over the Midwest. There are no data on radioactivity to confirm the reality of high concentrations of radioactivity below 10 km. But in May 1962 the extrusion mechanism is not implicated. Thus, although the concentration of I^{131} at Argonne, Illinois (*3*), during 1962 was highest on 10 May in thunderstorm rain, the radiosonde ascents from Peoria, Illinois, on that day show no signs of the temperature inversion or of dry air that are normally indicative of the extruded layer in the troposphere. Although not confirmed, scavenging by thunderstorms of radioactivity from extruded layers cannot be discounted as the explanation of the Midwest-in-May maximum.

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13. Supported by the AEC. Much of the work was done while I was an exchange scientist with the British Meteorological Office, Bracknell, Berkshire. I thank G. Cotton, Environmental Science Services Administration, for assistance in analysis of the Sr^{90} statistics.

26 February 1968

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Olivine-Garnet Transformation in a Meteorite

Abstract. *Garnet has been identified for the first time as a meteorite mineral in the Coorara chondrite from Western Australia. It replaces olivine grains in a 1-millimeter veinlet traversing the body of the meteorite. The associated olivine has abnormally low birefringence, which suggests a highly shocked condition. Microprobe analyses do not distinguish the garnet from the associated olivine, which has the composition* $(Mg_{.75}Fe_{.25})_2\ SiO_4$*; the garnet may have the composition* $Mg_3Fe_2Si_3O_{12}$ *but be unresolvable from the accompanying olivine, or alternatively is nonstoichiometric. Transformation of olivine to garnet under high pressure could have significant implications for the phase composition of the Earth's mantle.*

We received from W. H. Cleverly of the Kalgoorlie School of Mines a small piece of the Coorara meteorite for examination. This meteorite, a much weathered stone, was recently found on the Nullarbor Plain in Western Australia, about 70 miles (112 km) northeast of Rawlinna. While G. Moreland of this institution was making a thin section of the meteorite he noted a purple mineral that was unlike anything he had observed in his long experience in making such sections. X-ray diffraction showed that this purple mineral is a garnet.

The Coorara stone was not seen to fall, but it is certainly a meteorite. Although so weathered that the nickel-iron and almost all the troilite (FeS) originally present are now altered to limonite, it has the typical mineralogy of a chondritic meteorite (olivine, pyroxene, and a little plagioclase), and chondritic structure is present but not prominent.

Examination of three different thin sections has shown that the purple mineral occurs only in a veinlet 1 mm thick. This veinlet is prominent in the body of the meteorite because of its high content of limonite that has a dark brown color in contrast to the pale brown of the rest of the stone. The veinlet contains numerous grains of olivine and pyroxene that have the same composition (determined by electron microprobe) as the olivine and pyroxene in the body of the meteorite. The purple mineral replaces the olivine, but not the pyroxene. Examination of thin sections showed that the purple mineral is isotropic and has a higher refractive index than the enclosing olivine. This olivine has abnormally low birefringence, a feature we have previously observed in olivine in highly shocked meteorites such as Weatherford (*1*).

One grain of the purple mineral, about 0.2 mm across and enclosed in limonite, was carefully cut out from a thin section and mounted in an x-ray powder diffraction camera. The resulting photograph showed a pattern of lines corresponding to that of a garnet with $a = 11.51_5$ Å (calculated from the back-reflections 14.4.0 and 14.4.2). The strongest lines of goethite ($HFeO_2$) and of kamacite (α-Fe,Ni) were also present, but there were no lines of olivine or pyroxene.

Ten different grains containing the purple mineral were analyzed with the electron microprobe and were found to have the following composition: FeO, 23.5 to 25.0 percent; MgO, 36.9 to 39.5 percent; and SiO_2, 37.1 to 39.6 percent (the totals in each analysis were close to 100 percent). Minor constituents detected were Mn ($\sim$ 0.1 percent) and Cr ($<$ 0.1 percent, 0.33 percent in one spot); Al was sought but not found. These analyses correspond to the formula $(Mg_{.75}Fe_{.25})_2SiO_4$, the same composition as the olivine in the body of the meteorite. It is difficult to reconcile this composition with that of a garnet. The general formula of a garnet is $R_3{}^{2+}R_2{}^{3+}Si_3O_{12}$; thus a magnesium-iron garnet should be $Mg_3Fe_2Si_3O_{12}$, with a composition MgO 26.2, Fe_2O_3 34.7, and SiO_2 39.1 percent. To derive this directly from olivine would require a reaction of this kind:

$$3(\mathrm{Mg,Fe})_2\mathrm{SiO}_4 = \mathrm{Mg}_3\mathrm{Fe}_2\mathrm{Si}_3\mathrm{O}_{12} + \mathrm{Fe}$$

that is, a simultaneous oxidation of two atoms of iron to the ferric state and reduction of one atom to the metal. Moreover, the proportions of Mg to Fe in the olivine are 3 : 1, not 1 : 1 as required in the above equation. A balanced equation for these proportions would be more complex, for example

$$6(\mathrm{Mg}_{.75}\mathrm{Fe}_{.25})_2\mathrm{SiO}_4 = \mathrm{Mg}_3\mathrm{Fe}_2\mathrm{Si}_3\mathrm{O}_{12} + \mathrm{Fe} + 3\mathrm{Mg}_2\mathrm{SiO}_4$$

thus involving the concomitant formation of magnesium-rich olivine. Probably the garnet is so finely dispersed throughout the olivine that it is beyond the resolving power of the microprobe beam, and the above analyses do not give its true composition. Otherwise we must consider the possibility of a nonstoichiometric composition, maybe a "stuffed" garnet with a total of six 6- and 8-coordinated cations for 12 oxygen ions instead of five as in the normal garnet structure.

Did the garnet form in the meteorite extraterrestrially or after its arrival on Earth? We believe the following evidence supports an extraterrestrial origin. Significantly, the garnet is confined to a veinlet that resembles shock-produced veinlets in other meteorites. Impact on Earth of a small meteorite like Coorara would not produce such shock effects. Terrestrial weathering is unlikely to convert olivine to garnet; terrestrial alteration of olivine in igneous rocks is of common occurrence, but it has never been reported to result in the formation of garnet. Garnet is usually the product of metamorphic recrystallization of rocks under considerable pressures and is a notably dense phase—compare $\mathrm{Mg}_2\mathrm{SiO}_4$ (olivine), sp. gr. 3.21; $\mathrm{Mg}_2\mathrm{SiO}_4$ (spinel), sp. gr. 3.53; and $\mathrm{Mg}_3\mathrm{Al}_2\mathrm{Si}_3\mathrm{O}_{12}$ (garnet), sp. gr. 3.56.

When we first observed this isotropic mineral in the Coorara meteorite, our immediate reaction was that we had found the spinel form of $(\mathrm{Mg,Fe})_2\mathrm{SiO}_4$. The existence of this form has been predicted on crystallochemical grounds for some years; it has recently been made in the laboratory by Ringwood and Major (*2*). The conversion of olivine with the composition $(\mathrm{Mg}_{.75}\mathrm{Fe}_{.25})_2\mathrm{SiO}_4$ to the spinel form takes place at about 170 kb at 900°C. This transformation is believed to occur in the Earth's mantle at depths of about 500 km. The possibility of olivine transforming into garnet has never been suggested, but this transformation would have geophysical results similar to those predicted for an olivine-spinel inversion in the upper mantle.

It seems remarkable that this conversion of olivine into garnet in a stony meteorite has not been observed previously. Coorara is not an unusual meteorite; hundreds of essentially similar ones are present in the collections of this and other institutions. Many of these have been sectioned, and had any of these sections contained this striking purple mineral it would certainly have been noticed. Evidently some rare, possibly unique, circumstances were involved in its formation. What these circumstances were, apart from the probability of high pressure and temperature induced by extreme shock, we have yet to discover.

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24 January 1968

Carbon Monoxide and Air Pollution from Automobile Emissions in New York City

Abstract. *Local business-day traffic determines the diurnal carbon monoxide concentrations at individual sites in Manhattan. Concentrations during the day can be predicted from readings taken in early morning.*

The Department of Air Pollution Control of the City of New York has embarked upon an intensive program to control carbon monoxide. The program is based upon the measurement of carbon monoxide emissions and the behavior of the gas in the atmosphere at different locations under different conditions. The Department estimated the daily emissions of pollutants from automobiles for each square mile in the city. Estimated totals of these emissions for the entire city were:

Carbon monoxide	4140 ton/day
Hydrocarbons	560 ton/day
Oxides of nitrogen	106 ton/day

The estimates indicated that midtown and lower Manhattan were main sources of automobile exhaust gases. Steps were taken to determine how local traffic conditions influence the atmospheric concentrations of automobile exhaust gases measured at a given location.

Equipment to monitor continually carbon monoxide concentrations was installed near street level at five locations in Manhattan. The largest amount of valid data was obtained at 110 East 45 Street from 6 January through 17 May 1967, and from 30 July through 14 September. The sampling probe was set approximately 15 feet above the pavement and 5 feet into the street from the curb. A continuous flow of air was analyzed and recorded 24 hours per day, 7 days per week. The average hourly concentrations exceeded 15 parts per million from 9:00 a.m. to 7:00 p.m. New York State recommended that carbon monoxide concentrations of 15 parts per million for 8 consecutive hours should not be exceeded more than 15 percent of the time.

The apparent correlation between the business day and measured atmospheric carbon monoxide concentrations spurred further investigation, the results of which are shown in Fig. 1. They show simultaneous hourly traffic counts and hourly average concentrations of carbon monoxide for 4 April 1967. The traffic volumes for each hour are the totals for all traffic moving on Park Avenue past 45th Street itself. The shapes of the curves for traffic count and carbon monoxide are markedly similar, indicating that local concentrations of atmospheric carbon monoxide are strongly influenced by local traffic conditions.

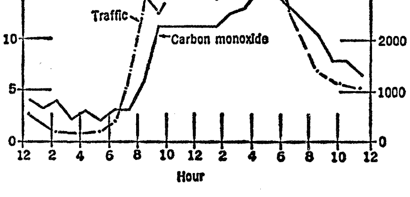

Fig. 1. Hourly average carbon monoxide concentration of and traffic count at East 45 Street; *ppm*, parts per million.