# OXYGEN ISOTOPES IN SEVERAL YAMATO METEORITES

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***Abstract:*** Oxygen isotopic compositions ($^{18}O/^{16}O$ and $^{17}O/^{16}O$) of five Yamato meteorites have revealed that Yamato-7303(m), -74190, -74191, and -7308(l), -74013 can be classified as L ordinary chondrites and differentiated meteorites, respectively. The former three meteorites may have been derived from one parent body, and the latter two meteorites are from another parent body in the solar system.

## 1. Introduction

A new powerful weapon called "three-isotope plot for $^{18}O/^{16}O$ vs. $^{17}O/^{16}O$" has been introduced into cosmochemistry by CLAYTON *et al.* (1973), and now, is rewriting the origin and evolution of solar system.

An important feature of the three-isotope plot for oxygen makes possible the discrimination between chemical fractionation processes and nuclear reaction processes which are both superimposed on given planetary materials. Thus, the technique has clarified: (1) the existence of pre-solar materials with a separate history of nucleosynthesis in anhydrous minerals in carbonaceous chondrites (CLAYTON *et al.*, 1973, 1977), and (2) the existence of several groups of meteoritic and planetary bodies which cannot be related to one another by chemical fractionation processes (CLAYTON *et al.*, 1974, 1976a, b).

The new evidence implies the existence of an isotopically heterogeneous early solar system. To visualize the heterogeneous solar system, we need much more information on oxygen isotopic compositions of various kinds of planetary materials. The present paper presents $^{18}O/^{16}O$ and $^{17}O/^{16}O$ values on five Yamato meteorites, Yamato-7308(l), -7303(m), -74013, -74190 and -74191. These meteorite samples were collected by the 14th and 15th Japanese Antarctic Research Expedition (JARE-14 and -15) and one of the authors (K. Y.) on the bare ice field near the Yamato Mountains in Antarctica.

## 2. Experimental Procedures

Oxygen was extracted from the powdered whole rock samples by the bromine pentafluoride procedure (CLAYTON and MAYEDA, 1963). Mass spectrometric analyses were done, using $O_2$ as the sample gas, on a 15 cm, 60° sector, double-collecting mass spectrometer. The data are reported in $\delta$-notation, as permil deviations relative to the SMOW standard.

## 3. Results and Discussion

Oxygen isotopic compositions of meteorites are given in Table 1. The data are plotted on $^{18}O/^{16}O$ vs. $^{17}O/^{16}O$ diagram in Fig. 1, along with the previously

*Table 1. Oxygen isotopic compositions of Yamato meteorites.*

| Meteorite | Class | $\delta O^{18}$ | $\delta O^{17}$ |
|---|---|---|---|
| Yamato-7308 (l) | Howardite | +3.17 | +1.33 |
| Yamato-7303 (m) | L5 Chondrite | +4.63 | +3.65 |
| Yamato-74013 | Diogenite | +3.07 | +1.27 |
| Yamato-74190 | L5 Chondrite | +4.42 | +3.45 |
| Yamato-74191 | L3 Chondrite | +5.22 | +3.44 |

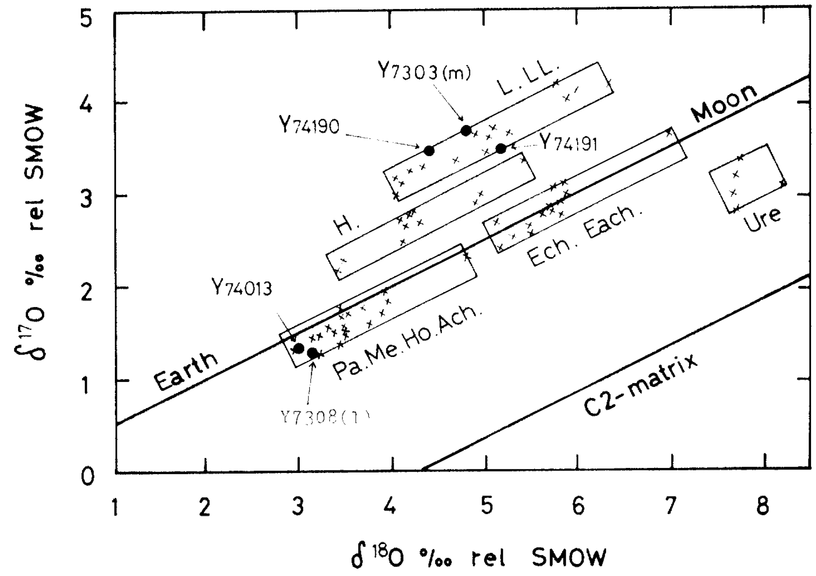

*Fig. 1. Three-isotope plot for Yamato meteorites. The terrestrial mass-fractionation line, the C2-matrix line and points (X) derived from minerals separated from individual meteorites are taken from CLAYTON et al. (1976). Abbreviations: Pa=Pallasites; Me=Mesosiderites; Ho=Howardites; Ech=Enstatite chondrites; Each=Enstatite achondrites; Ure=Ureilites.*

published data on various kinds of meteorites (CLAYTON *et al.*, 1976).

At present, meteorites and planets can be classified into at least six groups on $^{18}O/^{16}O$ vs. $^{17}O/^{16}O$ diagram (CLAYTON *et al.*, 1976a, b; CLAYTON and MAYEDA, 1977a): (1) the terrestrial group, consisting of the earth, moon, differentiated meteorites such as achondrites and stony irons, enstatite chondrites and enstatite achondrites, and matrices of Al Rais and Renazzo meteorites; (2) H ordinary chondrite group, consisting of H ordinary chondrites, Colomera and Weekeroo Station meteorites, Shergotty and LaFayette meteorites, and Cl carbonaceous chondrites; (3) L and LL chondrite group; (4) the ureilite group; (5) anhydrous minerals of C2, C3, C4 carbonaceous chondrites, including Eagle Station and Itzawisis meteorites; (6) hydrous matrix minerals of C2 carbonaceous chondrites, including Bencubbin, Kakangari, and Weatherford meteorites.

Meteorites and planetary bodies of one group cannot be derived by fractionation or differentiation from the source materials of any other group. Planetary materials apparently represent samples of different regions of an initially heterogeneous solar nebula. The heterogeneity could be established by a rapid injection of $O^{16}$-rich gas into proto solar nebula, as would result from a nearby supernova explosion (CAMERON and TRURAN, 1977). Condensation and accretion of planetary materials might take place on a time scale smaller than that for complete gaseous mixing in the nebula (CLAYTON and MAYEDA, 1977 b).

As shown in Fig. 1, Yamato-7303(m), -74190 and -74191 meteorites fall in the L ordinary chondrite group. The oxygen isotope classification is in good agreement with the classification based on chemical and petrological evidence (YAGI *et al.*, 1977; YANAI *et al.*, 1977). Yamato-7308(l) and -74013 meteorites fall in the differentiated meteorite group which consists of pallasites, mesosiderites, howardites and achondrites. Once again, both oxygen isotope and petrological-classification (TAKEDA *et al.*, 1976, 1977; MIYAMOTO *et al.*, 1977) agree well. Thus, weathering effects on the Yamato meteorites in the natural refrigerator of Antarctica are negligibly small.

The L ordinary chondrite group lies above the differentiated meteorite group in the $^{18}O/^{16}O$ vs. $^{17}O/^{16}O$ diagram. As previously pointed out by CLAYTON *et al.* (1976), the derivation of one of the two groups from the other is impossible by any combination of chemical processes, since the products of such processes would lie on the same fractionation line of slope 1/2 as the source materials. The two groups are derived from separate parent bodies. In comparison with the differentiated meteorite group, L ordinary chondrite group contain less of the $^{16}O$-rich component, implying either formation in an $^{16}O$-poor region or more complete evaporation and recondensation diluted by "normal" component in the same region of solar system.

The points of the differentiated meteorites and enstatite chondrites and enstatite achondrites fall on the terrestrial fractionation line, as shown in Fig. 1. On this line, the differentiated meteorites cluster around relatively low $O^{18}$ values, typically 3.0–3.5‰, while enstatite chondrites and enstatite achondrites cluster around high $O^{18}$ values, about 5.0–5.5‰, The differentiated meteorites may lie slightly below the terrestrial line as well. Formation of the clusters may imply the existence of at least two separate parent bodies for the differentiated meteorites, and the enstatite chondrites and enstatite achondrites, respectively. Thus, basaltic achondrites, hypersthene achondrites, mesosiderites, and pallasites are derived from a common parent body of which the precursor is quite different from any chondritic meteorites.

If these variations along the mass fractionation line are the result of different temperatures of accretion or equilibration with the nearby nebula gas, then two temperature sequences are conceivable: (1) enstatite chondrites and enstatite achondrites>the differentiated meteorites, assuming the accretion to have taken place above 800 K (CLAYTON *et al.*, 1976), (2) the differentiated meteorites> enstatite chondrites and enstatite achondrites, assuming the accretion to have taken place below 800 K. The temperature corresponds to $CO \rightarrow H_2O$ transition of oxygen bearing gaseous species in a solar nebula (ONUMA *et al.*, 1972).

If we employ the latter interpretation, a parent body of the differentiated meteorites was derived from a source material which was relatively enriched in Ca, Al-rich early condensates and a parent body of enstatite chondrites and enstatite achondrites is from a source material enriched in relatively late condensates from a common gaseous nebula. In connection with this interpretation, it is interesting to note that enstatite chondrites are depleted in the Ca, Al-rich early condensates as compared to carbonaceous chondrites of a representative solar system material (LARIMER and ANDERS, 1970).

## Acknowledgments

This research was supported in part by National Science Foundation grant EAR-74-19038.

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*(Received June 21, 1977)*