OXYGEN AND SILICON ISOTOPES IN INCLUSIONS AND CHONDRULES FROM VIGARANO; R.N. Clayton,[1,2,3] T.K. Mayeda,[1] G. J. MacPherson,[4] and L. Grossman.[1,3] 1. Enrico Fermi Institute, 2. Department of Chemistry, 3. Department of the Geophysical Sciences, all at University of Chicago, Chicago, IL 60637; 4. Department of Mineral Sciences, National Museum of Natural History, Washington, D.C. 20560.

Most of the studies of isotopic anomalies in carbonaceous chondrites have been done on Allende, due primarily to the ready availability of samples. The most commonly observed pattern of oxygen isotopic compositions of calcium-aluminum-rich inclusions (CAI) in Allende is an ^{16}O mixing line which is defined both by bulk comopsitions of the CAI's and by separated minerals from individual CAI's. The mixing line has been interpreted as resulting from a gas-solid isotope exchange process involving ^{16}O-rich solids and a nebular gas with isotopic composition close to terrestrial oxygen (1). One question to be considered is whether this exchange process was part of the alteration reaction which led to the formation of secondary minerals (garnet, feldspathoids, etc.) in Allende CAI's. A test of this proposition can be made by analysis of CAI's from Vigarano, in which the formation of secondary minerals is very minor (2).

Allende also contains a small proportion of CAI's with exceptional isotopic compositions in several elements, the so-called FUN inclusions (1, 3, 4). Until now, these had not been observed in any other meteorite.

Oxygen and silicon isotopic compositions of several CAI's, chondrules, and clasts are given in Table 1. With one exception, the CAI's fall on the oxygen isotope mixing line determined by Allende CAI's. Although no isotopic analyses of separated minerals have yet been done, the fact that three of the analyses (1623-2, 1623-8, and 1623-14) have compositions intermediate between the ^{16}O-rich and ^{16}O-poor ends of the Allende line implies that these inclusions have undergone the same sort of gas-solid exchange as is seen in Allende. Hence this exchange appears to be unrelated to the formation of secondary minerals.

One inclusion (1623-5) has the oxygen and silicon isotopic characteristics of a FUN inclusion. The oxygen lies far off the ^{16}O-mixing line in the ^{18}O-rich, ^{17}O-poor direction. The magnitude of the displacement is similar to that in Allende inclusions C1 and TE (4). The silicon is strongly mass fractionated by an amount second only to Allende inclusion C1. The inclusion is similar in mineralogy and texture to Allende inclusion CG 14 (4), consisting of forsterite and spinel poikilitically enclosed within clinopyroxene. CG 14 was found to have FUN characteristics for oxygen, magnesium, and silicon, but not for heavier elements.

Another exceptional inclusion is 1623-3, which is described in detail by Davis et al. (5). Although its mineralogy is dominated by spinel and hibonite, it is not enriched in ^{16}O, as are all of the known spinel-rich samples from Allende, Leoville, and Murchison.

Sample V1c is a forsterite-rich inclusion or chondrule which is unusual in its oxygen isotopic composition in that it falls near the ^{16}O-end of the Allende mixing line. In both oxygen and silicon isotopic compositions it resembles closely the Allende inclusion, AL 6S3 (6). Most other olivine-rich chondrules are much less enriched in ^{16}O.

Sample 1623-13 is a 4.5 mm diameter barred olivine chondrule. Its oxygen isotopic composition lies above the Allende mixing line, as has also been observed for barred olivine chondrules in Allende (7). Its silicon isotopes are unfractionated relative to the mean solar composition.

TABLE 1

Vigarano Inclusions, Chondrules, and Clasts

Sample No.	Description	$\delta^{17}O$ (‰)	$\delta^{18}O$ (‰)	$\delta^{30}Si$ (‰)
1623-2	Type A CAI	-17.1	-13.2	+2.2
1623-3	Fine-grained CAI	-5.0	-1.3	——
1623-5	Forsterite-rich inclusion	-23.0	-8.3	+20.6
1623-8	Type B2 CAI	-21.4	-17.1	+4.9
1623-12	Dark clast	+5.7	+12.5	——
1623-13	Barred olivine chondrule	-0.5	+2.4	-0.3
1623-14	Fine-grained CAI	-13.9	-9.1	——
V1c	Forsterite-rich inclusion	-41.0	-38.2	+1.9

Dark clast 1623-12 has an oxygen isotopic composition near that of the matrix of Murchison and other C2 chondrites (8). Nothing similar to this has been seen in Allende, where dark clasts have been found to have isotopic compositions in the same range as porphyritic chondrules.

This relatively small sampling of the Vigarano inclusions has produced a remarkable array of materials: CAI's which span the whole Allende mixing line, a FUN inclusion, a dark inclusion with a composition close to C2 matrix, a spinel-rich inclusion without ^{16}O enrichment, and an interesting olivine chondrule. Further petrographic and trace-element studies of these samples are under way.

References

(1) Clayton R.N. and Mayeda T.K. (1977) J. Geophys. Res. 4, 295-298.
(2) MacPherson G.J. (1985) Meteoritics 20, 703-704.
(3) Wasserburg G.J., Lee T., and Papanastassiou D.A. (1977) J. Geophys. Res. 4, 299-302.
(4) Clayton R.N., MacPherson G.J., Hutcheon I.D., Davis A.M., Grossman L., Mayeda T.K., Molini-Velsko C.A., Allen J.M., and El Goresy A. (1984) Geochim. Cosmochim. Acta 48, 535-548.
(5) Davis A.M., MacPherson G.J., Hinton R.M., and Laughlin J.R. (1987) L.P.S.C. XVIII.
(6) Clayton R.N., Onuma N., Grossman L., and Mayeda T.K. (1977) Earth Planet. Sci. Lett. 34, 209-224.
(7) Clayton R.N., Onuma N., Ikeda Y., Mayeda T.K., Hutcheon I.D., Olsen E., and Molini-Velsko C. (1983) in Chondrules and Their Origins, E.A. King, ed., pp. 37-43. Lunar and Planetary Institute, Houston.
(8) Clayton R.N. and Mayeda T.K. (1984) Earth Planet. Sci. Lett. 67, 151-161.