OXYGEN ISOTOPE STUDY TO EXPLORE THE EXTENT OF AQUEOUS ALTERATION IN CHONDRULES FROM ALLENDE CV3 CHONDRITE

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Introduction: The oxygen isotopes in carbonaceous chondrites are very intriguing and have lead to debates on mass dependent and mass independent fractionation of oxygen isotopes [1,2] as well as the primary and secondary signatures owing to the nebular and asteroidal processes [1,3]. These debates are the result of the fact that there is an observation of lines with different slopes on the three isotope plot of oxygen such as a slope 1, slope ½ and other intermediate slopes which reflect the distinct oxygen isotope ratios of various components of these chondrites [1,4,5,6, 7, 8, 9]. Oxygen isotope compositions of anhydrous minerals in CV chondrites fall along a line of slope~1 [10,11]. The arrays for the CI, CM, and CR groups also show shallower slopes on three O-isotope plot and reflect the fact that these chondrites have undergone aqueous alteration, probably on asteroidal bodies, during which oxygen isotope fractionation occurred [12,13,14].

Chondrules in carbonaceous chondrites covers >15vol% and the majority of these are sub-millimeter sized, igneous spheres, consisting predominantly of ferromagnesian silicates (olivines, pyroxenes and a feldspathic glass). The environment in which chondrules are formed is a manner of considerable debate with little consensus. A high precision oxygen isotope study of specific types of chondrules can help to understand the processes involved in their formation. In the present study we have focused on Allende chondrules and have attempted to compare the oxygen isotope behaviour of chondrules to the anhydrous and hydrous mineral/material data from Allende to constraint the conditions of alteration processes imprinted within them.

Analytical techniques: Different types of chondrules from Allende CV3 carbonaceous chondrites as porphyrytic olivines, porphyritic olivine pyroxene, porphyritic pyroxenes and barred olivines were selected and analyzed for chemistry using a wavelength dispersive X-ray spectrometer (WDS), JEOL 733-super-probe at 15kV acceleration voltage and 10nA beam current.

The oxygen isotope analyses of 31 different chondrules were done using CO_2 laser fluorination-mass spectrometry system. The sample assembly has a nickel holder which contains 1x1.5 mm sized holes. Individual chondrules were loaded into the chamber, pretreated under 100 mbar BrF_5 and then irradiated under 300 mbar BrF5 atmosphere until the laser reaction was complete. A single irradiation took few minutes. No sample scattering was observed. Throughout the course of Allende chondrule analyses, some reference materials (NBS-28 quartz, San Carlos olivine, UWG-2 garnet) were also analyzed with precision and accuracy of ±0.1‰ for both $\delta^{17}O$ and $\delta^{18}O$ data. More details of system calibration and method of analyses are given in [15,16].

Oxygen Isotope Compositions: The different chondrule types studied in Allende meteorites have a wide range in oxygen isotopes which is reflected in their delta values with $\delta^{17}O$ = -8.07 to -1.68‰ and $\delta^{18}O$ = -4.79 to 2.57‰. A collective slope of the line drawn through the oxygen isotope data of different chondrules is ~0.8.

The data from the various chondrules is plotted along with the anhydrous mineral data [8] as well as the hydrous mineral data from the carbonates and the matrix from Allende chondrite [17,1] in Fig.1. The chondrules O-isotope data is falling below the terrestrial fractionation line (TFL with slope 0.5), Anhydrous mineral line (AAML with slope 1) and the hydrous mineral/material line (HML with slope 0.5).

The trend shown by the chondrule data on the three isotope plot of oxygen obviously could not be the result of a mass dependant fractionation which would draw a slope 0.5 line as well as the mass independent fractionation drawing a slope 1 line on the plot (Fig.1). To explain this trend we would look into the well established fact of aqueous alteration in carbonaceous chondrites which

effect and alter the oxygen isotope compositions in a specific manner.

The first evidence for aqueous alteration in carbonaceous chondrites was given by Clayton and Mayeda (1984) on the basis of oxygen isotopes studies done for the CI and CM chondrites. These chondrites, such as Orgueil and Murchison, contain hydrous silicates which might form at low temperature as a result of mass dependent oxygen isotope fractionation [11]. The aqueous alteration was also reported for the CR chondrites on the basis of petrology, geochemistry and oxygen isotopes [12] and presence of secondary mineralization like magnetite, phyllosilicates, ferrous olivine etc. in these chondrites was noted and the oxygen isotopic composition of the CR chondrite components (chondrules, matrix, dark inclusions, etc.) was inferred to form a mixing line with the slope of ~0.7 on the three isotope plot of oxygen. This CR mixing line connects predominantly anhydrous silicates at the lower left with hydrous matrix and dark inclusions at the upper right. Chondrules and whole rocks occupy intermediate positions. The slope of 0.7 is distinctly different from a closed system fractionation line which should have a slope of ~0.5 and therefore is a product of mixing between at least two oxygen reservoirs; ^{16}O poor hydrous component and ^{16}O rich anhydrous component.

The secondary mineralization and phases in most of the Allende chondrules covers almost 25 vol % and magnetite, sodalite, nepheline and iron-rich olivines phases are observed in Allende by various researchers [18,19,20,3]. The oxygen isotope data from hydrous phases of chondrules in Allende [8] and some of the chondrules from Allende itself have shown to have a slope 0.5 on the three isotope plot [7].

The data obtained in this study hints towards the fact that aqueous alteration is present at varying degrees and there could be areas in parent body or size or type of certain chondrules that are affected by such alteration to varying degrees. As 31 different chondrules are analyzed and their oxygen isotope data show the mixing behaviour between the anhydrous and the hydrous phases or the primary and the secondary phases, it explains the fact that the majority of chondrules from Allende retains the primary signatures and have been masked or diverted from their mainstream trend by the presence/growth of secondary mineralization as a result of aqueous alteration in them. We are looking more deeply into this fact to elaborate the study using the size and type of different chondrules from Allende.

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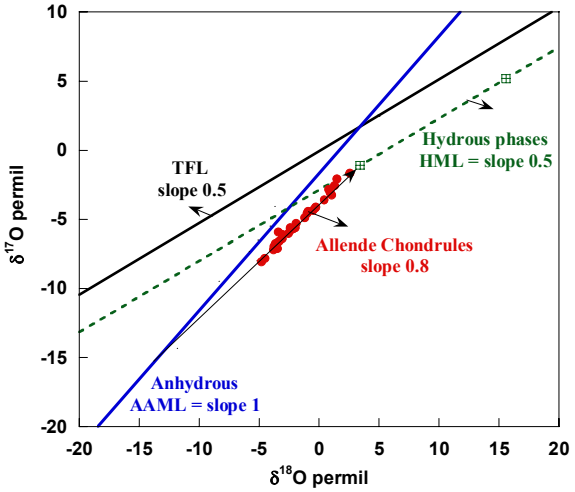

Fig. 1. Oxygen isotope data of various chondrules (filled circles) making a slope 0.8 line on three isotope plot. The error bars are within the filled circles. The data falls below the terrestrial fractionation (TFL) and anhydrous mineral line.

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