

**VERY LOW OXYGEN-ISOTOPIC RATIOS IN ALLAN HILLS 84001 CARBONATES: A POSSIBLE METEORIC COMPONENT?** G. Holland, I. C. Lyon, J. M. Saxton, and G. Turner, Department of Earth Sciences, University of Manchester, Manchester, M13 9PL, UK (gholland@fs1.ge.man.ac.uk).

**Introduction:** We have studied chemical and isotopic zoning in two small (2–8 mg) grains of sample ALH 84001,287. These contain carbonate rich areas up to 200  $\mu\text{m}$  in diameter often intimately associated with feldspar and fragments of rosettes  $\sim 70 \mu\text{m}$  across [1,2] similar to those we and others have studied previously [3,4].

**Experimental:** Chemical analyses of carbonates were acquired using the Manchester electron microprobe [1,2]. Isotopic data were acquired using the Manchester VG Isolab 54 ion microprobe [3] with a spatial resolution of  $\sim 10 \mu\text{m}$ .

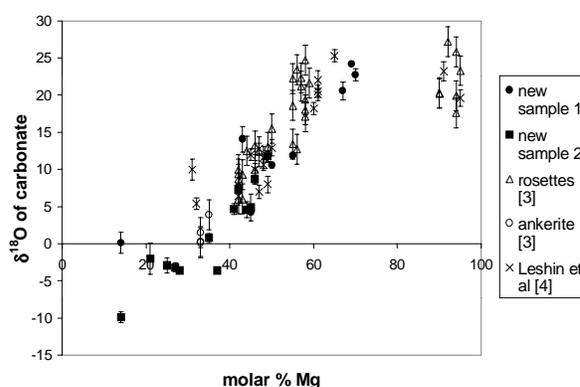
**Results:** Electron probe microanalyses reveal Mg-rich inner core carbonates surrounded by Ca-rich carbonates which increase in Mg content towards pyroxene [1,2]. Ion probe analyses shows the rare Ca-rich regions have very low  $\delta^{18}\text{O}$  values of  $-4\text{‰} \pm 2$  (one spot  $-10\text{‰} \pm 2$ ) zoning to  $14\text{‰} \pm 2$  adjacent to pyroxene. The inner Mg-rich regions have a  $\delta^{18}\text{O}$  of  $\sim 22\text{‰}$ .

**Discussion:** Two models appear petrographically feasible in explaining the observed chemical zoning: remobilisation of existing carbonate and deposition of a later generation of carbonate.

A first scenario considers that the Ca-rich carbonate may be carbonate remobilised by the shock event that fragmented the rosettes. Ca-rich carbonate and feldspar would then have formed together from a carbonate-silicate melt. However, this model cannot account for the low  $\delta^{18}\text{O}$  values of the Ca-rich carbonate. The average isotopic composition of ALH 84001 carbonate is  $\sim 19\text{‰}$  [5]. Remobilisation of this carbonate and no isotopic exchange with silicate cannot produce the observed zoning from  $-4\text{‰}$  to  $+14\text{‰}$  by Rayleigh fractionation in a closed system. If temperatures were sufficiently high during the shock event to equilibrate the remobilised carbonate with the host silicate (pyroxene of  $4.6\text{‰}$  [6]), high temperature formation of carbonate would yield a lower limit of  $\sim 7\text{‰}$ . This cannot explain the negative  $\delta^{18}\text{O}$  values.

The second scenario postulates that the very low  $\delta^{18}\text{O}$  carbonates were precipitated from a later pulse of fluid, possibly induced by the shock event that fractured the rosettes. In this case the carbonate would replace maskelynite. The isotopic heterogeneity between the inner Mg-rich region of  $22\text{‰}$  and the Ca-rich region of  $\sim 0\text{‰}$  only  $10 \mu\text{m}$  apart (the other sample contains  $-4\text{‰}$  carbonate) implies this was not high temperature deposition. If the isotopic composition of the source remains fixed, the linear increase in  $\delta^{18}\text{O}$

from  $-4\text{‰}$  to  $+14\text{‰}$  requires a gradual decrease in temperature. For example, assume a cold formation temperature as implied by the isotopic heterogeneity. If the highest  $\delta^{18}\text{O}$  carbonate formed at the lowest possible temperature ( $0^\circ\text{C}$  for a water rich fluid) then the lowest  $\delta^{18}\text{O}$  carbonate (Ca-rich cores) formed at  $75^\circ\text{C}$ . The  $\delta^{18}\text{O}$  of the source fluid required at these temperatures is  $-25\text{‰}$ . This fluid is significantly lower than  $-2.4\text{‰}$  water from planetary outgassing estimates [7]. A meteoric component could satisfy the requirement for a low  $\delta^{18}\text{O}$  source fluid.



**Fig. 1.** carbonate isotopic zoning with molar % Mg. Note the inner Mg cores at  $22\text{‰}$  (solid circles upper right) adjacent to Ca rich area (solid circle lower left). Note also the linear trend to negative  $\delta^{18}\text{O}$  with increasing Ca (squares) extending the trend beyond previous rosettes [3] (triangles) and Leshin [4] (crosses). Finally note anomalously low ankerite from our previous work [3] (hollow circles) which correlates well with the new data.

Work continues to extend the chemical composition range of the standards. This may cause minor revision of the  $\delta^{18}\text{O}$  values but does not alter the discussion.

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**References:** [1] Holland G. et al. (1999) *MAPS*, 34, A55. [2] Holland G. et al. (1999) *5th Intl. Conf. Mars*, Abstract #6100. [3] Saxton J. M. et al. (1998) *EPSL*, 160, 811–822. [4] Leshin L. A. et al. (1997) *GCA*, 62, 3–13. [5] Romanek C. S. et al. (1994) *Nature*, 372, 655–657. [6] Shearer C. K. et al. (1999) *MAPS*, 34, 331–339. [7] Clayton R. N. and Mayeda T. K. (1988) *GCA*, 52, 925–927.