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LIMITED SUBSOLIDUS DIFFUSION IN TYPE B1 CAI; EVIDENCE FROM Ti DISTRIBUTION IN SPINEL; **G.P. Meeker and J.E. Quick**, U.S. Geological Survey, MS 903 Denver Federal Center, Denver CO, 80225 and **Julie M. Paque**, SETI Institute NASA-ARC, MS 244-11 Moffett Field, CA 94035-1000

Most models of calcium aluminum-rich inclusions (CAI) have focused on early stages of formation by equilibrium crystallization of a homogeneous liquid. Less is known about the subsolidus cooling history of CAI. Chemical and isotopic heterogeneities on a scale of tens to hundreds of micrometers [e.g. MacPherson et al. (1989) and Podosek, et al. (1991)] suggest fairly rapid cooling with a minimum of subsolidus diffusion. However, transmission electron microscopy indicates that solid state diffusion may have been an important process at a smaller scale (Barber et al., 1984). If so, chemical evidence for diffusion could provide constraints on cooling times and temperatures. With this in mind, we have begun an investigation of the Ti distribution in spinels from two type B1 CAI from Allende to determined if post-crystallization diffusion was a significant process.

Titanium is an abundant element in type B1 CAI. Most of the Ti in these objects resides in zoned fassaitic pyroxene where concentrations of Ti, expressed as TiO_2, at the cores can be >15 weight percent. Numerous studies indicate that a significant portion of the Ti in the fassaitic pyroxene is in the +3 oxidation state. The only other major phase in type B inclusions that contains Ti in amounts greater than 1000 ppm is spinel. The Ti content of CAI spinel is generally between 0.1 and 0.9 weight percent.

The type B1 CAIs, 3529Z and 5241 have been described by Podosek et al. (1991) and by El Goresy et al. (1985) and MacPherson et al. (1989). We have analyzed spinels in these inclusions using the electron microprobe. These spinels are generally euhedral, range in size from <10 to 50 µm and are poikilitically enclosed by millimeter-sized pyroxene, melilite, and anorthite. Analyses were obtained from both the mantles and cores of the inclusions. Compositions of pyroxene in the vicinity of individual spinel grains were obtained by analyzing at least two points on opposite sides of the spinel and averaging the compositions. The pyroxene analyses were obtained within 15 µm of the spinel-pyroxene interface. No compositional gradients were observed within single spinel crystals.

Ti concentrations in spinels included within pyroxene, melilite, and anorthite are presented in Figure 1. Data include analyses from Meeker et al. (1983). Spinels included within pyroxene show a wide range in Ti concentration that correlates with the Ti concentration of the surrounding pyroxene. These data contrast with analyses from spinels within melilite, and anorthite which have low concentrations of Ti. In 3529Z, the highest concentration of Ti observed in spinel enclosed by anorthite and melilite is 0.22 weight percent TiO_2. A similar situation exists in 5241, although in this inclusion the spinels have an average Ti concentration of 0.25 weight percent TiO_2, which is approximately 25 percent higher than observed in 3529Z. Figure 1 suggests that spinels in the mantle of 5241 have a higher Ti concentration than the spinels in the core. Some of the mantle spinels from 5241 are in contact with small pyroxene blebs containing high (~12 wt.% TiO_2) concentrations of Ti.

Also shown in Figure 1 are spinel compositions from experimental run products produced by Stolper and Paque (1986). These data are for spinels enclosed within pyroxene, melilite, and anorthite. The maximum Ti concentration observed in these spinels is 0.22 weight percent TiO_2. These experiments were quenched at temperatures above 990°C so that no significant subsolidus equilibration occurred.

It is noteworthy that the Ti concentration of spinels in the experimental study are similar to spinels in melilite and anorthite in 3529Z and 5241, but strikingly different from the spinels enclosed by pyroxene. This observation suggests that the concentration of Ti in CAI spinel enclosed within pyroxene is the result of partial subsolidus equilibration rather than primary crystallization from a liquid. Spinels enclosed within melilite and anorthite, which are Ti-free, retain their original composition because they have no opportunity to exchange Ti with the enclosing phase. In contrast, spinels enclosed within pyroxene gain Ti from their host after incorporation. It is possible that the subsolidus cooling history may be constrained by the steep concentration gradients preserved in zoned pyroxene, and by at least partial equilibration of spinel.

REFERENCES: 1] MacPherson, G.J., Crozaz G. and Lundberg L.L (1989) GCA 53, 2413. 2] Podosek, F.A., Zinner E.K., MacPherson G.J., Lundberg L.L., Brannon J.C. and Fahey, A.J., (1991) GCA 55, 1083. 3] Barber D.J., Martin P.M., and Hutcheon I.D. (1984) GCA 48, 769. 4] El Goresy A.H., Armstrong J.T., and Wasserburg G.J., (1985) GCA 49, 2433. 5] Meeker G.P., Wasserburg G.J., and Armstrong J.T., (1983) GCA 47, 707. 6] Stolper E., and Paque J.M., (1986) GCA 50, 1785.

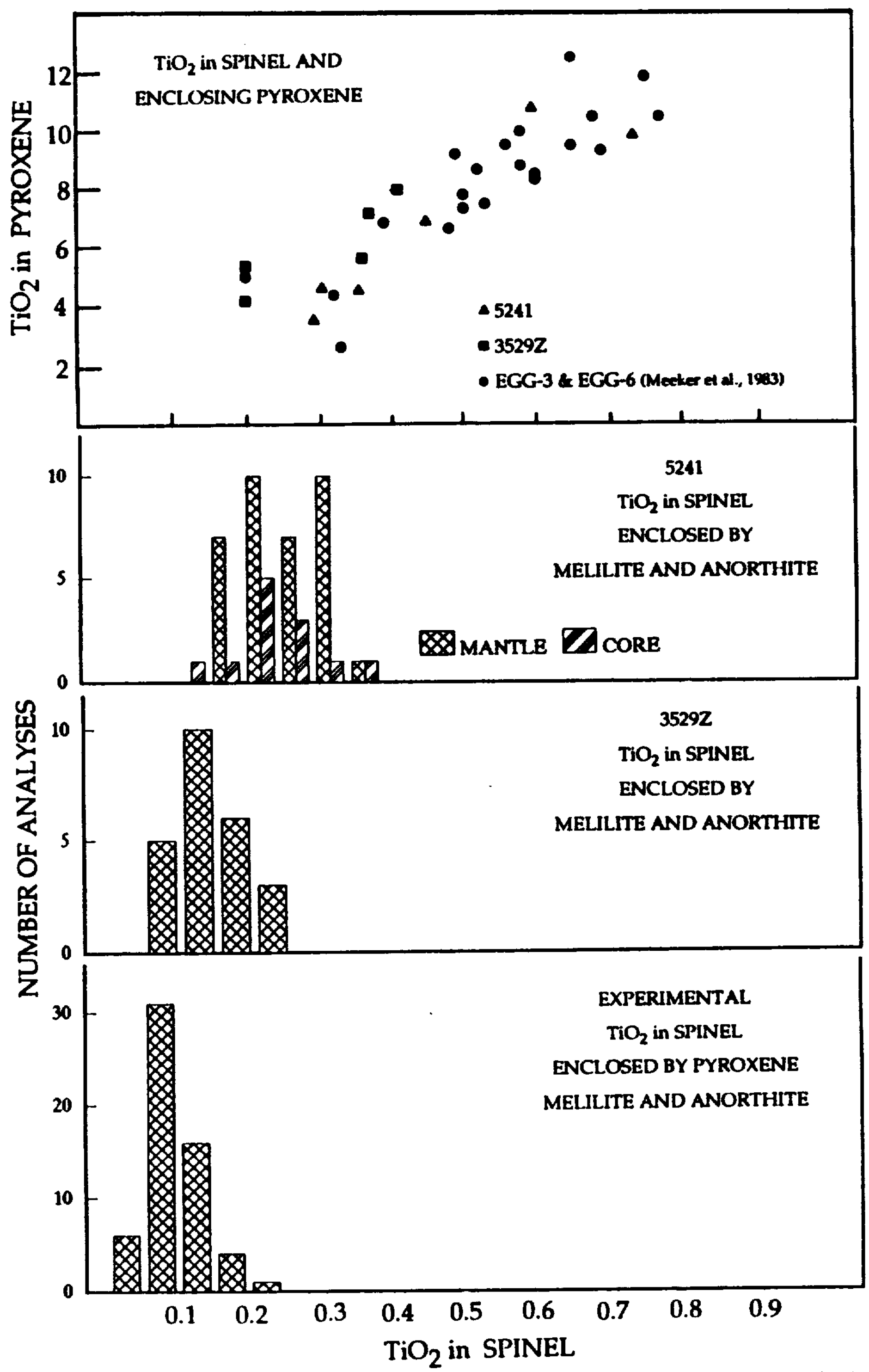

Figure 1. Ti concentrations expressed as weight percent TiO_2 in spinel of CAIs and in spinel produced by crystallization experiments. Data for spinels enclosed by pyroxene (top) plotted against Ti concentration of coexisting pyroxene. Histograms show Ti concentrations in spinel enclosed by melilite and anorthite and in spinel from experimental runs.