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Formation of an unusual compact Type A inclusion from Allende

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Type A Ca-, Al-rich inclusions (CAIs) consist predominantly of melilite that enclose fine grains of spinel, perovskite, and Al, Ti-bearing pyroxene (termed as fassaite). Type A inclusions are subdivided into irregularly shaped fluffy and rounded compact subtypes. Compact type A inclusions (CTAs) have more magnesian melililte displaying complex zoning relative to fluffy type A inclusions (MacPherson 2003).
An unusual CTA from Allende, ON01, was studied to investigate its origin and to understand the formation history of compact type A inclusions. A polished thin section was used for the petrography with an optical and a scanning electron microscope (SEM). Backscattered electron images, X-ray maps, and quantitative analyses were obtained with a JEOL JSM-7000F SEM equipped with energy-dispersive X-ray analysis system (EDS).
The ON01 is a large (5.5 x 6.5 mm), round-shaped and nearly monomineralic melililte inclusion surrounded by 100-150 micron-thick Wark-Lovering (W-L) rim. Melilite crystals range from small (up to ~0.4mm), stubby grains to laths or blocky grains (up to 1.2 mm long). Stubby grains generally occur just inside the W-L rim, in contrast, interior part displays interlocking textures of large laths and blocky grains. Some melilite grains exhibit optical zoning with birefringence of white to blue color under cross-polarized light. Birefringence colors are strongly connected with akermanite content that increases from white to blue. Spinel grains are enclosed within melilites and mostly distributed in the inner core of the inclusion, ranging from ~1 micron up to ~50 micron across. Tiny perovskite grains commonly are present between and adjacent to spinel grains. Fassaite grains generally occur as very fine blebs within melilite crystal.
X-ray maps and quantitative analyses with SEM-EDS show that ON01 inclusion consists of three distinctive regions, nearly gehlenitic mantle, spinel-poor outer core and spinel-rich inner core. The gehlenitic mantle is enclosed by W-L rim, completely encloses the magnesian core, and contains hibonite grains. Melilite grains in spinel-rich inner core are more aluminous (median Ak 25), and lower akermanite contents appear along grain boundaries. Melilite grains of spinel-poor outer core are relatively magnesian (median Ak 36), and exhibit normal zoning with high akermanite contents along grain boundaries. There are dusty melilite grains showing more Ak-rich patchy zones. Akermanite contents around spinel grains are commonly lower than those of host melilite crystal. Sector zoned fassaite (0.1 x 0.3 mm) in the spinel-poor core is surrounded by highly Ak-rich melilite (Ak 70-75). Melilite blebs are enclosed in perovskite occurring between melilite grains, and show high akermanite contents (Ak 60-65). The melilite blebs only exist in spinel-poor outer core.
There are many evidences to indicate that ON01 inclusion was crystallized from melts like other CTAs described in (Simon et al. 1999): rounded shape of inclusion, melilite grains oriented toward rim, spinel-poor outer core and spinel-rich inner core, and perovskite between melilite grains. Occurrences of highly Ak-rich melilite can be indicative of late-stage crystallization. The melting can be explained by partial melting of precursor CAI. The observations of high akermanite contents along grain boundaries in the spinel-poor outer core, aluminous rim surrounding spinel framboids, dusty melilite grains, and tiny fassaite, perovskite grains adjacent to spinel grains support the idea. The gehlenitic mantle and hibonite grains may be due to the vaporization of

moderately volatile elements like Mg and Si during the melting (Beckett & Stolper 1994). Therefore, the formation history of ON01 inclusion may be as follows: formation of proto-CAI, partial melting event, gehlenitic mantle formation, and W-L rim formation.
For the further understandings of ON01 inclusion, oxygen isotopic compositions will be measured using a secondary ion microprobe.