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WHY IGNEOUS WOLLASTONITE IS SO RARE IN CAIs

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Introduction: Primary wollastonite (wo) thought to have crystallized from a liquid is quite rare in CAIs, having been reported in only two igneous inclusions, White Angel and KT-1 [1, 2]. Both of these CAIs exhibit significant mass fractionations in multiple elements and KT-1 is a FUN inclusion, so it is highly desirable to place as many constraints as possible on their formation. Since phase diagrams previously developed for CAIs do not involve wo [3], we use literature data on wo-saturated and wo-free phase diagrams in the system CaO-MgO-Al_2O_3-SiO_2 (CMAS) to establish a basic framework for describing crystallization of wo-bearing CAIs.

White Angel: White Angel from the Leoville CV3 chondrite is a melilite(mel)-rich (type A) CAI with ~12 vol% wo, 3% perovskite (pv), and no interior spinel (sp) [1]. The bulk composition is close to the ternary Åkermanite(Åk)-Gehlenite(Ge)-Wollastonite(Wo) so the phase diagram of [4] can be applied directly except for late stage crystallization. From the bulk composition [1], mel (~$Åk_1$) is the liquidus phase with fractional crystallization leading to progressively more Åk-rich mel. The onset of wo crystallization leads to a reversal in Åk. There are no data on how the addition of pv affects the phase relations but, assuming fractionation curves for mel are not strongly affected, the onset of pv crystallization will lead to a second reversal in Åk. This order of crystallization and a double reversal in melilite zoning are consistent with observations of [1] in the White Angel.

KT-1: KT-1 from the CV chondrite NWA 779 is a type B inclusion but with sp mostly restricted to a central band across the section. A fine-grained assemblage of wo + anorthite(an) + mel + diopside(di) occurs interstitial to coarse melilite grains but only in sp-free portions of the inclusion. We used literature data to construct a wo-saturated liquidus phase diagram with liquids projected from Wo onto the plane Åk-Ge-SiO_2. Compositions of one wo-bearing region, determined by defocused beam analyses, plot above the wo-saturation surface (i.e., wo is the liquidus phase) with a predicted fractional crystallization sequence of wo → an → mel → di, consistent with the observed phase assemblage of the wo-bearing regions in KT-1.

Rarity of Igneous Wollastonite in CAIs: A key observation for both White Angel and KT-1 is that sp and wo do not occur together. In White Angel, there is no interior sp. KT-1 has lots of sp but not in the wo-bearing regions. Based on phase relations in CMAS, this is not fortuitous. Sp- and wo-saturated liquidus phase fields are always separated by wo-, sp-free fields leading to mel + di + an + liquid(liq), which has a thermal minimum. As long as the CMAS phase relations are applicable, wo-saturated residual liquids cannot evolve to sp + liq and sp-saturated liquids cannot evolve to wo saturation. Since most igneous CAIs have sp on or near the liquidus, it is igneous wo that is rare. Where present, igneous wo likely implies unusual bulk (White Angel) or local melt (KT-1) compositions relative to "normal" CAIs.

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CONCISE ATLAS OF THE SOLAR SYSTEM (11): COMPARISON OF THE PETROGRAPHIC TEXTURES AND EVOLUTIONARY PROCESSES IN THE PARENT BODIES

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The number of the meteorites, representing a size range of PBs from asteroids through Moon to Mars are gradually increasing. In our new textbook and educational program we collected the most important rock types with their characteristic textures, arranged them in igneous units of their suggested geological settings in the PB. We used petrographic microscopic studies and the samples of several collections of: NASA Lunar Sample Set, NIPR Antarctic Meteorite Set, Hungarian meteorites, NASA meteorite educational set, Eötvös University Mineralogy database of planetary analog rocks samples. The 5 chapters of the textbook:

1. Meteorites of the Chondritic Metamorphous Evolution. First part of the chondritic PB evolution. PB heated up by short living radionuclides: results in onion-layered body (higher T in core regions, lower T at the margins of the body). Chondritic groups (initial condition) and types (T grades), the textural sequence of thermal metamorphism are represented in this section.

2. Meteorites of the Evolved, Differentiated Asteroidal Parent Body. Second part of the chondritic PB evolution: textures after the lost chondritic characteristics, textures of rocks by partial melting, migration and differentiation inside the parent chondritic body. After transitional stages of acapulcoite, lodranite, ureilitic, and mesosideritic stages: layers of differentiation appear. Two segregating materials: first the metallic/sulfide melts appear and migrate in depths, forming core (first collecting in blocks), second a low-melting point silicate (basaltic) melts migrate toward surface. Basaltic achondrites are observable on the evolved asteroidal body Vesta and on its asteroidal fragments.

3. Samples and Meteorites of the Moon. Basaltic sequence and anorthosites, breccias and soil samples all represent the interplay of inner and outer processes. Volcanic flow bodies with texturally layered igneous masses can be reconstructed from cooling rate. Example series: 74220 (orange spherule ~1000 °C/min), variolitic clast of 68501 (hundreds C/day), 12002 porphyritic tx. (large olivine grains, 20–2000 °C/h); intergranular clast in 14305 breccia (k. 100 °C/week); subophitic clast in 72275,128 breccia; 70017 poikilitic tx. (sector zoned cpx), 12005 poikilitic tx. (zoned pyroxene oikocrysts, olivine chadacrysts). Lunar meteorites reveal new types compared to Apollo samples.

4. Meteorites of the Mars. Of the ~50 distinct meteorites shergottite and nakhlite samples are shown by gradually deeper textural characteristics, modifications with depth in cumulate texture, impacts modifications, phase changes, melt pockets and veins, alteration in layered igneous masses.

5. Planetary Analog Rocks on Earth. Both larger units and "individual" examples represent rich set of textural types. Several of them: 1) Theo-flow in Canada for nakhlites, 2) basalt and peridotite inclusions for shergottites (basaltic and lherzolitic), 3) Disco-island basalts with iron nuggets inclusions to some carbon-reduced meteoritic textures, 4) komatiites and boninites with high Mg content igneous rocks.