# AMPHIBOLE-RICH R CHONDRITE LAP 04840 – FROM AN ICY ASTEROID OR MAIN-BELT COMET?

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The R5 chondrite meteorite LAP 04840 contains a unique assemblage of metamorphic minerals, including OH-rich amphibole, biotite and apatite [1]. Chemical reactions among these and other minerals (olivine, orthopyroxene, albite, magnetite) give equilibration T≈650°C and $P(H_2O) \approx$ 25-50 MPa [1]. On Earth this 'low' partial pressure of water would imply shallow depths, or significantly reduced activity of water [e.g., $P(H_2O)<P(total)$].

However, even this low water pressure is problematic for an asteroid. In an asteroid of 250 km radius, typical density of 2.5 $g/cm^3$, pressures >25 MPa would be developed at >3 km depth. A typical asteroid parental to meteorites, ~75 km radius [2], would develop that pressure at >20 km. These depths are minima, because the calculations assume $P(H_2O)$ = Ptotal, and P(total) = P(lithostatic), i.e. asteroids are impermeable. Most asteroids are likely to be permeable (e.g., rubble piles), and most interior pores are not at P(lithostatic) but connect to deep space at P = 0 MPa.

LAP 04840 poses the problem of how to maintain significant fluid pressure inside an asteroid – how to seal the asteroid and isolate interior fluid from deep space. Self-compaction of chondritic components or regolith is insignificant at asteroidal gravities [3]. Lava emplaced on or near an asteroid's surface (e.g., [4]) can reduce permeability. However, lava flows contract and fracture as they cool and thus will not eliminate permeability. Sheets of impact melt also contract and fracture (e.g., [5]). Impact shock can compact rock and regolith locally, but causes extensive fracturing nearby and thus enhances permeability overall.

Another hypothesis, given that LAP 04840 is water-rich and was hot, is that its parent asteroid was sealed with water ice (like in [6]). The heat of radioactivity or differentiation could generate water vapor by sublimination of original ice and by mineral dehydration reactions [1]. This water vapor would diffuse and flow outward, and be cold-trapped as ice in regolith near the asteroid's surface. Ice at the very surface would sublime away, leaving dry regolith. This mechanism (as proposed for Mars [7]) can yield an impermeable layer of ice-filled regolith, with significant tensile strength [7,8]. If the layer of icy regolith were broken, it would re-seal as water vapor flowed through the break and froze.

This idea, impermeable ice-filled regolith, can explain the high water pressure recorded in LAP 04840 in the setting of a large asteroid. It could have acted in other large asteroids like Ceres [6,9], and possibly also in main-belt comets [10-12].

**References:** [1] McCanta M.C. et al. 2008. *Geochimica et Cosmochimica Acta* 72:5757-5780. [2] McSween et al. 2002. 559-571 in *Meteorites and the Early Solar System II.* University of Arizona Press. [3] Zolotov M.Yu. 2009. *Icarus* 204:183-193. [4] Mayne R.G. et al. 2009. *Geochimica et Cosmochimica Acta* 73:794-819. [5] Spray J.G. et al. 2009. *Planetary Space Science* 58:538-551. [6] DuFresne E.R. & Anders E. 1962. *Geochimica et Cosmochim. Acta* 26:1085-1114. [7] Clifford S. 1993. *Journal of Geophysical Research* 98:10973-11016. [8] Mellon M.T. 1997. *Journal of Geophysical Research* 102:25617-25628. [9] Castillo-Rogez J.C. & McCord T.B. 2009. *Icarus* 205:443-459. [10] Hsieh H.H. & Jewitt D. 2006. *Science* 312: 561–563. [11] Campins H. et al. 2010. *Nature* 464:1320-1321. [12] Rivkin A.S. & Emery J.P. 2010. *Nature* 464:1322-1323.