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The hunt for liquid water in meteorites

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Hydrothermal alteration is one of the fundamental processes by which several planetary bodies within our Solar System have been modified. The abundance of transient liquid water throughout the Solar System is increasingly recognised as playing a vital and active role in shaping the evolution of planetary surfaces. In particular, the process of hydrothermal alteration affects mineral composition on a microscopic level, simultaneously altering pre-existing minerals and allowing new mineral species to nucleate. This research reports new findings of fluid inclusions and their composition from one achondrite meteorite (Allan Hills A77256) and eight chondrite meteorites (Allan Hills 84029, Bells, Lonewolf Nunataks 94101 & 94102, Mighei, Santa Cruz, Sutter's Mill, Sayama). We show that the presence of fluid inclusions within these meteorites is much more common than previously recognised, spanning much of the diversity of chondritic meteorite classes.

The first discovery of extraterrestrial liquid water was within halite crystals of the Zag and Monahans (1998) ordinary chondrites in 1999. Recent studies concerning extraterrestrial water and its evolution throughout the Solar System have attempted to gather inferences on the hydrothermal histories of parent asteroid bodies by utilising different proxies, including (but not limited to) magnetite grains, hydrous minerals, and degree of thermal metamorphism. These studies have highlighted a lack of direct water samples used within research and the need to determine whether further extraterrestrial liquid water fluid inclusions exist. Aside from those within the Zag and Monahans (1998) chondrites, additional claims of fluid inclusions within other meteorites have been previously reported. Until now, none have been independently confirmed or analysed further to determine whether or not they host liquid water.

Here we show that both petrographically primary and secondary in all our nine meteorites are hosted in olivine. Due to the formational nature of olivine, we predict that all petrographically primary fluid inclusions will fail to host liquid water. In contrast, petrographically secondary fluid inclusions may prove to be more plausible candidates. These inclusions are much more likely to possess liquid water as they were likely formed by subsequent and late periods of localised hydrothermal alteration, resulting in the serpentinisation of the host olivine crystals. Despite their

predominance within our samples, in many cases, the analysis of secondary fluid inclusions is impeded by their sub-micron sizes and technological limitations of the instruments to operate at such a minuscule specimen size (< 1μm).

This research utilises a combination of SEM-EDS and Raman spectroscopy to target and determine the composition of the trapped fluids within suitable inclusions (diameter > 1μm). Spectra from initial Raman analyses conducted on selected fluid inclusions within olivine crystals of the Bells and Santa Cruz carbonaceous chondrites are presented. The majority of spectra from twenty-eight analysed fluid inclusions showed the fingerprint wavelength peak for olivine between 820-850 cm^{-1} alongside an unanticipated discovery of several cosmic diamonds embedded deep within certain olivine grains at a wavelength peak of 1320-1360 cm^{-1}. This research highlights that numerous factors can affect the probability of a fluid inclusion hosting liquid water.