The formation of the angritic crust

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Angrites are a small group of basaltic meteorites which record the early stages of planetary formation and differentiation [1]. They are comprised of two main textural subgroups reflecting different cooling and metamorphic histories: fine-grained 'quenched' angrites (e.g., D'Orbigny), and coarse-grained 'plutonic' angrites (e.g., Angra dos Reis) [1]. The recently recovered angrite Northwest Africa (NWA) 6291 is suggested to be paired with NWA 2999; both have larger modal abundances of metal and spinel compared to other angrites [2, 3]. NWA 6291 contains fine- (FG) and coarser-grained (CG) lithologies comprised of pyroxene, anorthite, olivine, and spinel.

We measured trace element abundances and the $^{238}U/^{235}U$ ratio in a whole-rock (WR) sample of NWA 6291 (WR1, washed in 0.05M HCl). We processed 7 acid-washed WR powders prepared from the FG and CG lithologies and 3 pyroxene separates from the CG lithology of NWA 6291 for Pb isotopic analysis. The weak leachates (L_{1-3}) and all Pb column matrices of subsequent leachates (L_{4-8}) and residues (R) were recombined respectively for U separation and isotopic analysis. Analytical details are provided in [4,5]. The REE pattern is LREE-depleted (La/Yb_N=0.6), with HREE abundances at ~4×CI. The Th/U is ~3.5. The $^{238}U/^{235}U$ =137.754 for WR1, =137.785 for the recombined L_{1-3}, and =137.744 for the recombined L_{4-8} and R (±0.026, 2SD); these values are similar to those for other angrites [6].

The Pb-Pb internal isochron age of NWA 6291 (calculated using its measured $^{238}U/^{235}U$) is 4560.1 ±1.1 Ma (MSWD=2), identical to that of NWA 2999 [7] using $^{238}U/^{235}U$ =137.75. The incompatible element depletion in both these angrites relative to other quenched and plutonic angrites is attributed to lack of phosphate. Their similarities confirm their pairing and suggest a new angritic subgroup, while their ages indicate that crust formation on the angrite parent body began ~5 Ma after CAI formation, and continued for a period of ~6 Ma thereafter [4,7,8].

[1] Mittlefehldt *et al.* (2002) *MAPS* **37**, 345-369. [2] Gellissen *et al.* (2007) *LPSC* **38**, A#1612. [3] Connolly *et al.* (2006) *MAPS* **41**, 1383-1418. [4] Bouvier & Wadhwa (2010) *Nature Geosc.* **3**, 637-641. [5] Bouvier *et al.* (2011) *LPSC* **42**, A#2747. [6] Brennecka & Wadhwa (this conference). [7] Amelin & Irving (2007) *Work. Chron. Met. & Early Solar Syst.*, A#4061. [8] Amelin (2008) *GCA* **72**, 221-232.

Interaction of small organic molecules with the calcite surface

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Calcite ($CaCO_3$) is one of the most abundant salts in the Earth's crust. Its surface behaviour in the presence of liquids and gases controls its dissolution, precipitation, adsorption and desorption. To help understand these complicated phenomena, a fundamental understanding of surface/gas interaction is required.

In this work, we investigated the molecular interaction of small organic molecules with the {10.4} surface of calcite. X-ray photoelectron spectroscopy (XPS), a surface sensitive technique that allows quantitative and qualitative investigation of surfaces, and simulations using molecular dynamics (MD) and density functional theory (DFT) were applied to determine the geometry, coverage and bond strength of ethane, ethanol, t-butanol, carbon dioxide, acetic acid and glucose molecules on calcite.

A series of pristine calcite {10.4} surfaces, prepared by cleavage in vacuum, were examined with XPS while gases were leaked into the experimental chamber. We used the high resolution carbon 1s signal, which has significant energy shifts, to observe coverage of the organic molecules. We also measured the temperature of desorption for each species to estimate its bonding strength.

The results show that CO_2 molecules form the weakest bond with calcite, with a desorption temperature of –130 °C. Glucose forms the strongest bond among the molecules studied and does not desorb even at 560 °C. We also observed that all the molecules formed a compact layer on the surface, except ethane, which does not adsorb at all in our experimental conditions, exhibiting no affinity with calcite. The MD and DFT calculations parallel the experimental results, indicating that CO_2, alcohols and acetic acid form a well ordered monolayer on calcite.

We are using the information about the bonding of simple molecules on calcite to interpret interaction of more complex organic molecules, such as those that play a role in biomineralisation, adsorbing from solution and inhibiting calcite growth and recrystallisation.