METHANE RETENTION BY ROCKS FOLLOWING SIMULATED METEORITE IMPACTS: IMPLICATIONS FOR MARS. S. McMahon[1], J. Parnell[2], M. Burchell[3] and N. J. F. Blamey[4] [1]School of Geosciences, University of Aberdeen, Aberdeen AB24 3UE, UK. sean.mcmahon@abdn.ac.uk, [2]School of Geosciences, University of Aberdeen, Aberdeen AB24 3UE, UK. [3]School for Physical Sciences, Ingram Building, University of Kent, Canterbury, Kent CT2 7NH, UK. [4]Department of Earth & Environmental Science, New Mexico Tech, 801 Leroy Place, Socorro, NM 87801, USA.

Introduction: Since the first observations of methane in the Martian atmosphere [1, 2], numerous mechanisms for replenishment and removal have been proposed, including biological, geological, atmospheric and exogenous processes. Although the direct contribution to the atmosphere from comets and micrometeorites has been previously considered [3, 4], the impregnation of Martian surface rocks by methane released or generated during impacts has not.

Over geological time, organic-rich impactors may supply methane and other hydrocarbons to an extensive reservoir in pores, impact-generated vesicles or sealed microfractures around craters, which are abundant on the surface of Mars and other planets and moons. As a first step in evaluating the significance of this reservoir, a high-velocity impact was simulated in the laboratory and methane-retention in the crater quantified by crushing and mass spectrometry.

Method: *Light-gas gun.* A 1.5-mm cube of organic-rich Devonian siltstone from the Orcadian basin of North-East Scotland was loaded into a two-stage light-gas gun at the University of Kent [5–7]. Under a pressure of 10–100 Pa, this projectile was launched at 5.05 kms^{-1} into a block of Triassic 'Beestone' sandstone from Cumbria, England, with low native organic content. Speed was calculated from the passage of the projectile through two laser curtains.

Sampling strategy. The cratered sandstone block was sawn apart to obtain match-head-sized pieces representing; *(a)* an unaffected corner of the block (post-impact) as a control; *(b)* the interior wall of the crater; *(c)* the centre of the crater, and; *(d)* the ejecta, including fragments of both the projectile and the target. The original positions of samples *(b)* and *(c)* are shown in Fig. 1. To remove superficial organic matter, samples were washed in H_2O_2 for ~10 minutes or until the cessation of effervescence.

CFS mass spectrometry. Volatiles were analysed by the crush-fast scan method [8–10]. Samples were analyzed by incremental cold-crush fast scan method under a vacuum (approx. 10^{-8} Torr) using Pfeiffer Prisma quadrupole mass spectrometers operating in fast-scan, peak-hopping mode. Two to six bursts of volatiles (up to ~2×10^{-11} l) were released per sample and analyzed for CH_4, CO_2 and several other species. Calibration was checked against commercial standard gas mixtures, atmospheric capillary tubes and three fluid-inclusion standards as described by [11]. Instrumental blanks are also analysed routinely.

The amount of each species was calculated by proprietary software, but crushing does not liberate all the entrapped gas from samples, so data are reported as ratios of molar percentages rather than bulk quantities. Here, methane is reported as CH_4/CO_2.

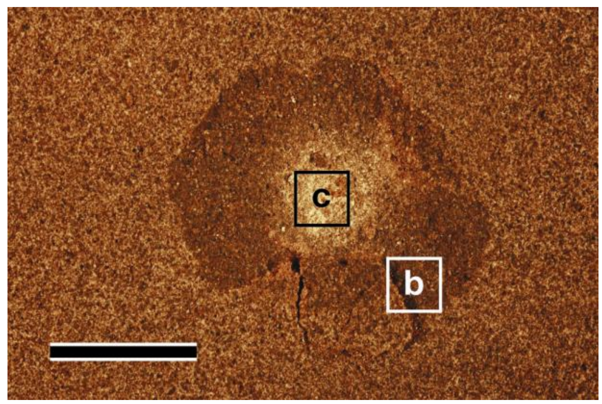

Figure 1. Impact crater and sample positions. The scale-bar represents 1 cm.

Results: The mean CH_4/CO_2 ratios, weighted by burst size, are shown in Fig. 2.

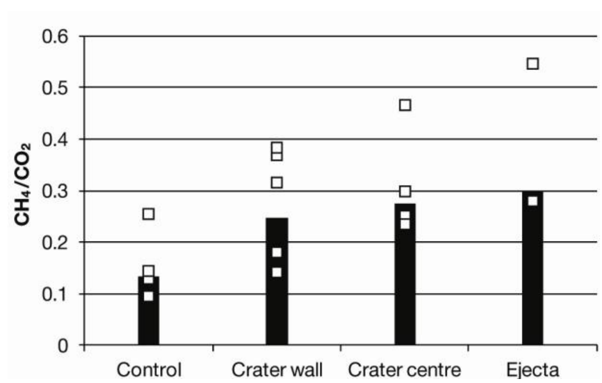

Figure 2. CH_4/CO_2 in individual bursts of fluid (squares) liberated by crushing, and means weighted by burst size (bars).

The sandstone in the crater is somewhat enriched in methane compared to the control. The ejecta, containing fragments of the projectile and the target, is only slightly more methane-rich than the sandstone in the crater.

Discussion: These results demonstrate that target rocks can acquire a small amount of methane from organic-rich impactors. In this case, immersion of the samples in a strong oxidant (H_2O_2) failed to remove the methane, suggesting that it was retained internally by intergranular cavities or sealed microfractures. Similar textural features are known to preserve fluid inclusions over geological time in many rock types, although fluids derived directly from extraterrestrial impactors have yet to be identified in inclusions on Earth.

The abundance of carbonaceous chondrites, which are rich in carbonate and diverse organic phases, suggests that many impactors may be carbonaceous. They may also be able to deliver many organic compounds other than methane to planetary crusts. The siltstone used in this experiment has previously been shown to preserve complex biomarkers during impact events, as both target and projectile [7].

Future work. More work is needed to demonstrate reproducibility and establish how the methane is produced, released and retained. Applicability to Mars requires that similar results are obtained in basalt and andesite. If impactor-derived methane can be remobilized in significant quantities by later aqueous or aeolian weathering processes, at least some of the methane reported in the Martian atmosphere today may be a relic of ancient impact events..

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