

MODELLING SECONDARY MINERAL FORMATION WITHIN A MARTIAN IMPACT-GENERATED HYDROTHERMAL SYSTEM. N. K. Ramkissoon, S. P. Schwenzer, V. K. Pearson and K. Olsson-Francis, Faculty of Science, Technology, Engineering and Mathematics, The Open University, Milton Keynes, MK7 6AA (Corresponding author: nisha.ramkissoon@open.ac.uk).

Introduction: Impacts are a ubiquitous process, playing an important role in the evolution of planetary crusts, particularly in the Solar System's early history during the Late Heavy Bombardment (LHB), which ended approximately 3.7 to 3.8 Gy [1]. On Mars, it is thought that impact rates began to decline soon after the end of this period and at the start of the Hesperian epoch (~3.7 Gy) [2]. Impacts can generate hydrothermal systems that can play a key role in crustal evolution, through water-rock interactions. These interactions lead to the modification of bedrock through the formation of secondary alteration minerals [3, 4]. The detection of such minerals and geochemical signatures in martian impact craters [5-8] suggests that this process has contributed to the evolution of the martian crust.

Today, and for much Mars' history, conditions have not been conducive to liquid water [2]. However, computer models of crater cooling rates show temperatures above 0 °C can persist within craters for thousands to millions of years [9, 10], even if the crust is frozen [11]. This would indicate that beneath impact craters temperatures would be sufficient for water to exist for an extended period of time, potentially extending the mineral alteration and liquid water phase beyond the Noachian-Hesperian boundary. This suggests that impact-generated hydrothermal systems could have developed within lithologies different from the initial basaltic protolith. These include sulfate and Fe³⁺-rich deposits, which formed as a result of a shift in climatic conditions towards the end of the Noachian epoch; this environment was colder, acidic and more oxidizing [2]. Therefore, to ensure we fully understand the evolution of the martian crust, we need to determine the effect impact-generated hydrothermal systems can have if developed within a variety of lithologies.

We present results from thermochemical modelling that explores the formation of secondary mineral assemblages that can arise in an impact-generated hydrothermal system within sulfate and Fe³⁺-rich lithologies.

Models: CHIM-XPT [12, 13] was used to model the water-rock interactions that occur at pressure and temperatures found within a 100 km diameter impact crater [9]. The model assumes that reactants completely dissolve within a fixed quantity of solvent, and uses mass balance and mass action equations to determine the minerals precipitated, as well as the resultant fluid chemistry. Reactant materials can be incrementally added to the solvent, which represents different water-

rock ratios (W/R), and thus different water-rock interactions.

We used the chemistry of three newly developed simulants [14] as the reactant, which represent the chemistries of a sulfur-rich (OUSR-1), a haematite-rich (OUHR-1) and a global regolith (OUCM-1; Table 1). Solvent chemistries were derived from initially titrating individual reactants with pure water at 25 °C and 1 bar. The models were repeated, this time using the fluid chemistry at W/R 1000 from the first run as the starting solvent chemistry. The process resulted in an evolved fluid chemistry based on the composition of the individual simulants, which is more realistic to what would be found on Mars.

Simulant chemistries were used so future laboratory work (described in [15]) can be compared to verify models and examine the chemical evolution of these aqueous environments over longer timescales.

Table 1. Chemistry of simulants used in thermochemical models.

	OUCM-1	OUSR-1	OUHR-1
Na₂O	2.91	1.25	1.96
MgO	6.76	4.06	7.36
Al₂O₃	10.80	4.05	7.47
SiO₂	41.87	16.50	38.17
P₂O₅	0.72	2.48	0.58
SO₃	5.65	37.50	8.40
K₂O	2.14	1.00	1.38
CaO	7.82	7.03	6.21
TiO₂	0.81	0.39	0.53
Cr₂O₃	0.12	0.05	0.11
MnO	0.21	0.08	0.18
FeO	17.43	22.68	15.04
Fe₂O₃	2.77	2.92	12.61
Total	100.00	100.00	100.00

Results: Models were run to represent depths between 10 m and 1 km (1 bar and 1000 bar, respectively) and at temperatures of 5, 150 and 300 °C. Fig. 1 shows the alteration minerals precipitated at W/R of 100, 1000 and 10000 for each of the three simulant chemistries. Overall, there is some variation in minerals precipitated for all three chemistries. OUSR-1 shows the most dissimilarity with the other two simulants. OUHR-1 and OUCM-1 produce similar mineral assemblages, but with differences in precipitated mineral abundances.

Interestingly, SiO_2 is the dominant mineral precipitated (29 wt% or greater) for all three chemistries at W/R of 10000 at 5 °C, which is not seen at 150 or 300 °C. At 5 °C, OUHR-1 produces more clay minerals than OUCM-1, which produces a larger proportion of chlorites at all three W/R. At 150 °C chlorites are the dominate minerals precipitated for OUCM-1 and OUHR-1 for a W/R of 10000 and 1000, at W/R 100 amphibole is the primary mineral precipitated for these two chemistries. At higher temperatures (300 °C), and at W/R of 10000 and 1000, mineral assemblages for OUCM-1 and OUHR-1 are dominated by epidote, magnetite and serpentine. However, at a W/R of 100 there is a decrease in the proportion of magnetite formed and an increase in chlorite. Pyrite is the dominant mineral precipitated for OUSR-1 under all three physical conditions and W/R, with the exception of W/R of 10000 at 5 and 300 °C, which resulted in SiO_2 and anhydrite, respectively, being the dominant minerals.

Previous work using martian meteorite chemistries as the reactant material, at comparable temperatures of 150 and 300 °C and a comparable W/R of 1000, showed secondary mineral formation is dominated by the formation of haematite (at both 150 and 300 °C) and clays (at 150 °C) [16]. However this is not seen here. This indicates that the starting chemistry plays an important role in the formation of secondary mineral assemblages and would result in different minerals being identified within craters.

Summary: Thermochemical modelling shows there is a distinctive change in resultant mineral assemblages with an increase in temperature and pressure for OUCM-1 and OUHR-1, which cannot be said for OUSR-1. OUSR-1 shows the least amount of variation in the dominant types in minerals precipitated under all three conditions. Sulfur-bearing minerals, particularly pyrite, dominates minerals assemblages, which is presumably because of the high concentration of S and Fe found within the OUSR-1 chemistry.

These results show there is a clear distinction in secondary mineral assemblages between sulfur-rich regolith and contemporary or Fe^{3+} -rich regolith chemistries formed within impact generated hydrothermal systems.

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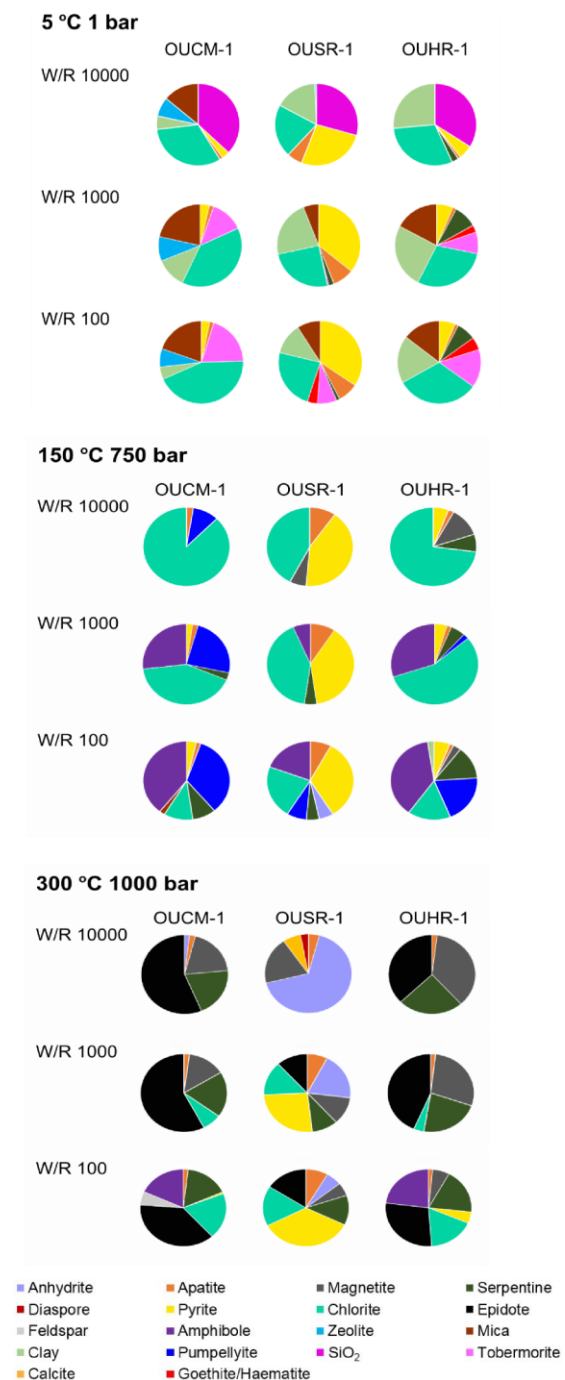


Fig. 1 Secondary mineral assemblages determined from thermochemical models.