PERMEABILITY DATA FOR IMPACT BRECCIAS. J. Parnell[1], C.W. Taylor[1], S. Thackrey[1], G.R. Osinski[2], P. Lee[3]. [1]Dept. of Geology & Petroleum Geology, University of Aberdeen, Aberdeen AB24 3UE, U.K., J.Parnell@abdn.ac.uk), [3]University of Western Ontario, Canada, [2]Mars Institute, U.S.A..

Introduction: Permeability is a fundamental characteristic of rocks and sediments that controls fluid flow and the rate at which it occurs. In a planetary context, such as on Mars, it is of interest for a range of reasons, including studies of fluid seepage at the surface, penetration of oxidants beneath the surface, diagenesis of sediments, and fluid movement driven by heating (magmatism, impacts).

Several workers have incorporated permeability into models for the circulation of hydrothermal fluids within impact craters [1,2,3,4]. In most cases, the permeability values used have been estimates, or ranges of values to test model sensitivity to this parameter. Some workers have made a tacit assumption that the permeability of impact breccias is likely to be high. However, a single data base of values for suevites in the Chicxulub crater is in the range 0.001 mD to 1 mD (10^{-18} to 10^{-15} m^2) [5]. A useful frame of reference for interpreting these values is that permeabilities of 1 mD and 0.1 mD are the minimums required for production from oil and gas reservoirs respectively [6]. In fact most oil reservoirs that do not require stimulation to produce their oil have permeabilities above 100 mD. Values of less than 1 mD are therefore low, and not likely to support the flow of water. On the contrary they make good seals to fluid circulation. Rocks of this type would only support hydrothermal circulation, or any process involving discernable flow rates, in zones of higher permeability created by fracture networks.

This study reports permeability measurements in suevites from the Haughton Impact Structure. The objectives were to:

(i) Record a data base of values for the suevites and other rocks in the Haughton Structure.

(ii) Compare the permeabilities against those used in models and in the Chicxulub crater. The comparison is extended by measuring values in suevites from the Ries (Germany) and Rochechouart (France) craters.

(iii) Consider the implications for fluid flow through impact breccias.

Haughton Impact Structure: The ~39 Ma, 23 km diameter Haughton impact structure [7] is located on Devon Island in the Canadian High Arctic. The target rocks comprise a thick Lower Palaeozoic sedimentary succession, dominated by carbonates. The crater is filled with carbonate-rich impact breccias [8], which contain silicate/carbonate/sulphate melt, and clasts of carbonate and Precambrian crystalline basement. Subsequent to impact, the crater was filled with Miocene lake sediments.

Fig. 1. Core plugs from Haughton impact breccias. Core diameter one inch.

Methodology: The permeability of one-inch diameter core plugs (Fig. 1) was measured using a nitrogen gas permeameter. Nitrogen gas is injected at a controlled constant pressure through the plug in a Hassler sleeve holder. Pressure is then applied to the rubber sleeve (400 psi) to seal it to the plug to stop leakage of gas around the sample. The pressure difference between the two ends of the plug and the flow rate are recorded, and the permeability is then calculated from these data using a form of Darcy's Law. The output gas pressure is atmospheric. The input pressure can be varied over the range 1 to 60 psi. Flow rate was measured with an orifice tube manometer for high flow rates, and a travelling meniscus oil meter for low flow rates. The values reported are corrected for the Klinkenberg Effect (an overestimation where pore sizes are smaller than mean free path of nitrogen atoms) using a graphical treatment of permeabilities measured at more than one input gas pressure. System performance is checked against standards with known permeability for several permeability ranges.

Data: Seven core plugs were made from Haughton impact breccias with sufficient coherence to yield reliable permeability values, of:
0.05mD, 0.11mD, 0.14mD, 0.16mD, 0.17mD, 0.25mD, 0.81mD.
Two core plugs were obtained from impact breccias in each of the two other craters, yielding values of:
Ries: 1.60mD, 2.71mD
Rochechouart: 1.06mD, 1.09mD
Data from other Haughton structure rock types allows these values to be put in context:
Bedrock dolomite: <0.01mD, 7.29mD, 9.95mD
Dolomite clasts in impact breccia: 5 values 0.01mD or less
Shocked basement clasts in impact breccia: 10.50mD, 27.93mD, 252.49mD
Low-shocked basement clasts in impact breccia: 0.06mD, 1.60mD
Crater-fill lake sandstones: 0.22mD, 0.22mD, 0.23mD, 0.36mD

Discussion: The values for the Haughton suevites are all less than 1mD, comparable with those reported for the Chicxulub crater [5], and a single value of 0.1 mD for the Chesapeake Bay crater [2]. The data measured here for the Ries and Rocheouart craters are also close to 1 mD. These data are all from geologically young craters, and permeability may be lower in older craters. The data from young craters will be closest to the permeabilities pertaining at the time of impact-induced hydrothermal activity. The Haughton breccias have a matrix rich in carbonate and sulphate, so their low permeability is not surprising. However, the similar data from other craters show that low permeabilities are the norm in impact breccias, and indicates that as a general rule they are more likely to act as fluid barriers than to support fluid flow. Permeability values for suevites assumed in models tend to be higher, for example 100mD [3], and 1 to 100 mD [1]. In an assessment of how flow behaviour is sensitive to permeability, values of 0.1mD and 1mD are regarded as representing low and moderate permeabilities [2].

The low permeabilities have consequences for the behaviour of hydrothermal fluids generated immediately after impact. The measured values are not conducive to convective flow, but rather to the transfer of heat by conduction. Heat transfer by conduction is much slower than by convection, implying that the heat is dissipated over a longer period and therefore elevated temperatures are maintained for longer [2]. This has astrobiological implications, as the time available for microbial colonization of warm waters is greater, although concomitantly the circulation of fluids that allows microbial ingress and cycling of nutrients would be less. However, the low matrix permeability (as measured in the samples) could give rise to overpressuring of fluids, which in turn could trigger fracturing and the development of high fracture permeability. This response could then *enhance* convective flow. The low matrix permeabilities would also focus flow along existing fracture systems developed at the time of impact, particularly circum-crater fault networks. Consequently most evidence of hydrothermal activity is expected at the faulted periphery of impact craters, as is found around the Haughton structure [9,10].

The data from other rock types in the Haughton impact structure show that the whole structure is a low permeability system. It also highlights the enhanced permeability of shocked basement clasts in the impact breccias, which also exhibit very high porosities, consistent with their potential for microbial colonization [11,12].

Conclusions: The eleven new measurements of permeability in the impact breccias from three craters, combined with the limited data previously available, indicates that fluid flow through impact deposits will be dominated by fracture systems rather than through matrix permeability. The colonization of craters by microbial life is therefore most likely in fracture networks, emphasizing the importance of impact-related hydrothermal systems [13] as a target in the search for life on Mars.

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