EFFECT OF TARGET LITHOLOGY ON IMPACT MELTING. G. R. Osinski[1], R. A. F. Grieve[2], and J. G. Spray[3], [1]Canadian Space Agency, 6767 Route de l'Aeroport, St-Hubert, QC J3Y 8Y9, Canada (osinski@lycos.com), [2]Earth Sciences Sector, Natural Resources Canada, Ottawa, ON K1A OE8, Canada, [3]Planetary and Space Science Centre, Dept. of Geology, University of New Brunswick, 2 Bailey Drive, Fredericton, NB E3B 5A3, Canada.

Introduction: Impact melting is a characteristic feature of hypervelocity impact events on Earth and other planetary bodies. One of the outstanding questions in impact cratering studies is the effect of target properties on impact (or shock) melting and the relative importance and role of impact melting versus decomposition for impacts into sedimentary-bearing target rocks. The aim of this paper is to provide an up-to-date assessment of the effect of target lithology on impact melting, based on studies carried out at several terrestrial impact structures and a review of the existing literature (based on a more detailed review of impact melting, currently *in press* [1]).

Physics of impact melt generation: Numerical modeling of the impact cratering process, together with theoretical calculations and shock experiments, have revealed insights into the generation of impact melt:

1) Shock melting occurs upon decompression [2]. Energy deposited in the target during shock compression remains as heat following decompression; if the shock is strong enough and sufficient heat remains, the released material may be left as a melt or vapor [2].

2) The effect of porosity is such that a large amount of compression and shock heating occurs in porous target rocks [3-5]. The presence of high porosities significantly increases the amount of pressure–volume work in the target rocks resulting from the shock wave, which results in greater amounts of post-shock waste heat, raising temperatures, and generating more melt that non-porous targets. However, the crushing of pore space reduces the overall shock pressures in the target, possibly reducing overall melt volumes.

3) The volumes of target material shocked to pressures sufficient for melting are not significantly different in sedimentary or crystalline rocks [6].

4) Calculations indicate that both wet and dry sedimentary rocks yield greater volumes of melt on impact than crystalline targets [6].

Observed impact melt volumes: Impact melt occurs in two main forms in impactites within impact structures [7, 8]: (i) as coherent impact melt sheets or discrete bodies of impact melt rocks within impact breccias, and (ii) as discrete clasts within impact melt-bearing breccias (impact melt breccias and "suevites").

It is widely reported that the volume of impact melt recognized in predominantly sedimentary and in mixed (sedimentary–crystalline) targets is on the order of two magnitudes less that for crystalline targets in comparably sized impact structures (e.g., the widely cited compilation by Grieve and Cintala [7]. However, when the results of more recent studies are considered, it becomes clear that the volume of impact melt appears to be similar for impacts into different target lithologies (Fig. 1) (e.g., the estimated original melt volume at the 23 km diameter Haughton impact structure (predominantly sedimentary target) of ~22.5 km^3 [9]). This is in accordance with past theoretical calculations [6] and more recent numerical modeling [5] (see above).

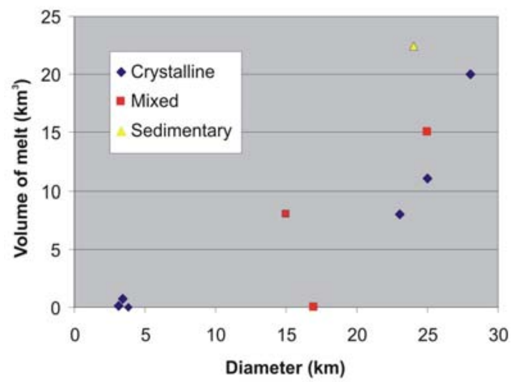

Figure 1. Plot of estimated initial impact melt volume for several terrestrial impact structures up to 28 km in diameter formed in different target lithologies.

It is, however, apparent from Figure 1 that little accurate data is available on melt volumes for terrestrial impact structures and that these estimates are dependant on diameter estimates that may or may not be accurate. Further studies are, therefore, required to refine these melt and diameter estimates.

Recognition of impact melt products: For impacts into predominantly crystalline target rocks, coherent impact melt rocks or 'sheets' are formed. These rocks often display classic igneous features (e.g., columnar jointing) and textures (e.g., glassy or fine-grained crystalline groundmass) (e.g., Fig. 2a). Thus, there has been no questioning of the impact melt origin of these lithologies. In contrast, for impacts into sedimentary-rich target rocks, it has been generally accepted that impact melt rocks are not generated [8], in contradiction of theoretical predictions (see above).

It is suggested that this inconsistency is due to the challenges in recognizing impact melt products derived from sedimentary-rich target rocks, rather than different processes and products during impacts into different target lithologies. For example, at the Haughton structure, distinctive pale gray crater-fill deposits form a discontinuous 54 km^2 layer in the central area of the structure (Fig. 2b). Contrary to previous workers who interpreted these impactites as clastic matrix breccias, or as fragmental breccias [10, 11], recent field, optical and analytical SEM studies reveal that these impactites can be classified as impact melt breccias or clast-rich impact melt rocks according to the terminology of Stöffler and Grieve [12]. Thus, although the products of meteorite impact into volatile-rich target rocks may appear very different from those developed in crystalline targets, it is suggested that these different lithologies are genetically equivalent.

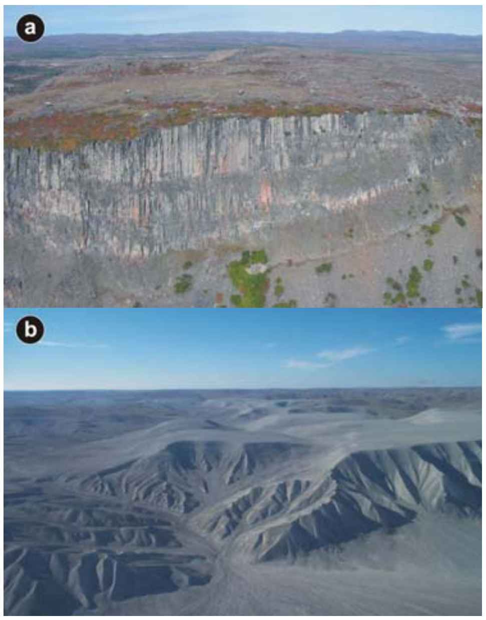

Figure 2. (a) Oblique aerial view of the ~80 m high cliffs of impact melt rock at the Discovery Hill locality, Mistastin impact structure, Labrador. Photograph courtesy of Derek Wilton. (b) Field photograph of the crater-fill impact melt breccias at the Haughton impact structure. The vertical distance to the highest point is 35 m.

Clast content of melt-bearing impactites. One apparent difference between melt-bearing impactites found in craters in different target rocks is the higher clast content of impactites in sedimentary versus crystalline target rocks. For example, the clast content of crater-fill impact melt breccias at Haughton (sedimentary target) is up to ~40–50 vol%, which is higher than in the comparably-sized Mistastin structure (crystalline target) (~20–30 vol% [13]). However, it has been suggested [9] that this can be explained by the effect of mixing 'wet' sediments or carbonates into a melt as opposed to dry crystalline rocks: the enthalpies of H_2O-bearing and carbonate systems are so high that a much smaller proportion of admixed sedimentary rocks than of anhydrous crystalline rock is required to quench the melt to subsolidus temperatures [6]. Thus, all other conditions being equal, a lower percentage of sedimentary rocks will be assimilated than crystalline rocks, before a melt is quenched, resulting in higher final clast contents for melts derived from impacts into sedimentary as opposed to crystalline targets.

Melting versus decomposition: The phase relations of $CaCO_3$ suggest that limited decomposition from $CaCO_3$ melt may be possible following decompression [14], although evidence for this has not yet been observed in naturally shocked rocks. For impact into limestones, this absence of evidence may be due, in part, to the recombination of CO_2 and CaO during fast back-reactions [15]. However, studies of naturally shocked rocks also suggest that decomposition is a post-impact contact metamorphic process, which also occurs in igneous rocks [1], governed by the post-impact temperature of the melt–clast mixture (i.e., rapid quenching and/or low post-shock temperatures will inhibit carbonate decomposition).

Summary: Synthesizing observations from terrestrial impact structures with experimental results, computer simulations, and phase relations, it is clear that previous assumptions about the response of sedimentary rocks during impact events are inaccurate. Impact melting appears to be the dominant response of hypervelocity impact into sedimentary rocks. Limited decomposition from the melt phase may be possible following decompression if the melt remains at high temperatures long enough for this to occur. The apparent 'anomaly' between the volumes of impact melt generated in sedimentary versus crystalline targets in comparably sized impact structures, therefore, appears to be due to a misinterpretation of the characteristics of impact melts derived from sedimentary rocks.

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