ULTRAMETAMORPHISM OF IMPURE CARBONATES BENEATH THE MANICOUGAN IMPACT MELT SHEET: EVIDENCE FOR SUPERHEATING. John G. Spray, Planetary and Space Science Centre, Department of Geology, University of New Brunswick, Fredericton, NB, E3B 5A3, Canada. E-mail: jgs@unb.ca.

Introduction: Impact melt sheets generated by the hypervelocity collision of comets or asteroids with planetary bodies are widely held to be superheated at the time of formation [e.g., 1]. However, little direct evidence of ultrahigh-temperature effects in either melt sheets or footwalls has been documented. This is because minerals tend to record the lowest PT conditions under which they equilibrated. Impure carbonates exposed directly beneath the impact melt sheet at Manicouagan have retained some of their high-temperature parageneses and these is used to place constraints on the lower bound of the melt sheet's temperature of formation.

Geological setting: The ~100 km diameter Manicouagan impact structure of Quebec is one of the larger craters known on Earth. It is late Triassic in age (214 Ma [2]) and is essentially undeformed [3, 4]. The targets are predominantly Precambrian gneisses, charnockites, amphibolites and anorthositic rocks of the ~1 Ga Grenville Province. In addition there are sparse outcrops of Middle Ordovician sedimentary rocks. These form local outliers of siltstone, shale and limestone, with dolomitic limestone being dominant [3]. The sedimentary rocks lie unconformably on the Precambrian basement. During field investigations during a summer season when the Manicouagan reservoir was particularly low, the contact between Ordovician siliceous dolomite and the overlying impact melt sheet was exposed at the shoreline. Sampling took place on a small ~0.25 km^2 island, which lies to the east of what is now referred to as Memory Bay (formerly Memory River prior to hydro-flooding), which is an inlet penetrating the central main island of the reservoir. The impure carbonates have undergone extreme metamorphism due to direct juxtaposition with the impact melt sheet (of andesitic bulk composition). The unusual mineralogy provides new constraints on the temperature of the melt sheet.

Texture: The metamorphosed impure carbonate is fine grained (mostly <0.1 mm, but in places up to 1 mm in grain size). It has a hornfelsed texture and shows local areas (~10-20% by volume) of melting in the form of veins that are up to a few mm wide. Some of the veins show fluidal (flow) textures, implying a degree of mobilization. The melt veins comprise material derived from the carbonate protolith, not extraneous lithologies or mineralogies (i.e., in situ partial melting is implied with restricted transport).

Mineralogy: The mineralogy of the metacarbonates is complex. There is a high-temperature (HT) prograde assemblage and a retrogressive low-temperature (LT) overprint, with the latter involving H_2O infiltration. The HT assemblage comprises diopside + labradorite + periclase + brownmillerite + spurrite + perovskite + mayenite. Remnant larnite is also present. The lower grade paragenesis comprises muscovite + calcite + brucite + afwillite, which has partly replaced the HT assemblage.

Pressure-Temperature Constraints: Mineral stability fields indicate that the impure carbonate attained at least 900 ˚C under low pressure conditions (~100 bars). This is corroborated by the partial melting of the rock, which is considered to occur at a similar temperature. This is akin to the calcining temperature used in furnaces to produce Portland cements, which can possess similar refractory HT mineral assemblages.

Implications: Attaining at least 900 ˚C requires juxtaposed melt temperatures of ~1800 ˚C if the heat is transferred solely by conduction. The field setting indicates that the carbonate outcrop is in situ as part of one of the largest Ordovician sedimentary rock outcrops in the region (as documented pre-flooding [3, 4]). This precludes the HT assemblage being derived by convective heating (i.e., as a block suspended and moving within the impact melt), wherein the contact temperature can approach that of the melt. Melt sheet temperatures of at least 1800 ˚C are compatible with conservative estimates of 1800-2000 ˚C as used for modeling (e.g., in the case of Sudbury [1, 5]).

References: [1] Zeig M. J. and Marsh B. D. (2005) *Bull. Geol. Soc. Am.*, 117, 1427-1450. [2] Hodych J. P. and Dunning G. R. (1992) *Geology*, 20, 51-54. [3] Currie K. L. (1969). Geol. Survey Canada, Dept. Energy, Mines & Resources, Bull. 198, 153 p. [4] Murtaugh J. G. (1976) Quebec. Dept. Nat. Resources, Open File Report DPV-432, 180 p. [5] Ivanov B.A. and Deutsch A. (1999). Geol. Soc. Am. Spec. Pub. 339, 389-397.