MODIFICATION-STAGE TECTONICS PRIOR TO MELT SHEET EMPLACEMENT: CONSTRAINTS FROM THE MANICOUAGAN IMPACT STRUCTURE. Jessie J. Brown, Lucy M. Thompson and John G. Spray, Planetary and Space Science Centre, University of New Brunswick, 2 Bailey Drive, Fredericton, New Brunswick E3B 5A3, Canada <jessie.brown@unb.ca>

Introduction: The Manicouagan impact structure, formed at 214 Ma, comprises a target dominated by Precambrian metamorphic rocks, including various gneisses and anorthosite assembled during the 1 Ga Grenville orogeny [1]. In addition, a veneer (<200 m thick) of Middle Ordovician carbonates and shales was present at the time of impact [2]. This sedimentary rock cover provides a valuable marker horizon with which to calibrate transient cavity evolution during the excavation- to modification-stage transition of the impact process. The cover sequence was regionally eroded and largely erased from the Canadian Shield following impact, leaving only down-dropped units preserved within the impact structure itself. The limestone-shale assembly now occurs as blocks (with multi-metre dimensions), and as smaller fragments (cm- to m-size) in three settings: (1) the main body of impact melt, especially at its base and periphery; (2) in basal suevites, which are located between melt sheet and underlying footwall, and (3) within the footwall assemblage as deep as at least 300 m beneath the melt sheet. The latter association is revealed through field studies and the logging of drill core. These deep occurrences of sedimentary rocks are of particular interest because they must have been transported to their buried positions prior to emplacement of the overlying impact melt sheet, which most probably took place within minutes of melt formation. Rapid tectonics are required to achieve this. We propose that the mechanism to achieve burial involves widening and shallowing processes associated with progressive rim failure and crater collapse.

Field context: Field operations around the west flank of the Manicouagan structure based at the edge of the main island (at a radial distance of approximately 27 km from the crater's centre) reveal a footwall section dominated by gneisses underlying impact melt. The gneisses are typically fractured. They are not incoherent, but rather shattered like 3D puzzle pieces. Faulting is also evident, most of which is high-angle, with sub-metre displacement. More massive gneiss zones also occur. Intercalated with the Precambrian gneisses are Ordovician limestone blocks. The presence of the limestone in the field area is clear evidence that the rocks observed must have been emplaced by the collapse of the rim of the transient crater, and cannot represent rocks of the original basement.

In most cases the contact between the gneiss and limestone units is defined by an intervening breccia comprising gneiss and limestone fragments combined, occasionally with an associated friction melt (pseudotachylyte). It is not clear whether the limestone is still related to its original underlying gneiss, or whether gneiss and limestone decoupled during collapse. Both may be possible. Either way, there appears to be some coherence to the sedimentary rock-gneiss relationship: the footwall is not a jumble of random blocks.

Drill core constraints: Multiple mineral exploration drill holes produced in the 1990s and 2000s generated ~18 km of core, 10 km of which is currently held by the Planetary and Space Science Centre at UNB. In the western section of the island, logs of core that complement field mapping, namely holes 0504, 0505, 0507 and 0607, reveal that limestone is interleaved with gneiss to depths of at least 300 m below the melt sheet. Apparent limestone thicknesses in these drill holes range from 18 to 128 m.

Borehole logs also provide more information on the nature of the sedimentary rock-gneiss relationship. In boreholes 0507 and 0607 limestone occurs twice, with gneiss between the two occurences. The majority of contacts observed between gneiss and limestone are brecciated. This observed association is best explained by assuming the geology represents large, coherent blocks, which originated in the transient crater rim and reached their current location by falling, or sliding, from the oversteepened edge. With this model, it is possible to estimate a linear dimension for these coherent blocks by measuring the distance between the tops of the limestone occurrences in the holes in which they are repeated. From this simple estimation, we suggest that blocks falling from the rim may have been between 50 and 200 m in linear section.

Discussion: The interleaving of limestone with gneiss to depths of at least 300 m below the impact melt sheet indicates that the original surface sequence of limestone-on-gneiss has been (1) tectonically repeated via imbrication or folding of the surface stratigraphy as it collapsed into the widening transient cavity; (2) limestone became decoupled from its immediate footwall gneiss and was more randomly incorporated during collapse, or (3) the cavity margins behaved incoherently and collapsed randomly into the growing crater. The nature of the limestone-gneiss relations does not support a rubble association, but rather an interleaving of more coherent, larger blocks, with movement between lithologies being accommodated by frictional melting, comminution and/or brecciation. However, our interpretation of these processes may be scale dependent, with our view being compromised by outcrop restrictions and the limited lateral information provided by drill core.

It is well established that the modification stage continues after impact melt emplacement [3], e.g., with crater-margin slumping into the melt sheet and associated terrace formation. This work shows that considerable cavity collapse can initiate very early in the cratering process prior to melt sheet emplacement. This must occur during the late excavation to initial modification stages. Moreover, the rocks in the oversteepened rim must begin to move almost immediately in order to attain the very high speeds necessary to emplace surface rocks at significant depths beneath the melt sheet before the highly-mobile, superheated liquid comes to rest.

References: [1] Spray, J. G. et al. (2010) *Planet. Space Sci.* 58, 538-551. [2] Nowlan, G.S. and Barnes, C. R. (1987) *Bull. Geol. Surv. Can*. 367, 47 p. [3] French, B. M. (1998) *Traces of Catastrophe*, LPI Contrib. 954, 120 p.