THE MANICOUAGAN IMPACT STRUCTURE, CANADA: A REVIEW. John G. Spray, Planetary and Space Sience Centre, University of New Brunswick, Fredericton, NB E3B 5A3, Canada. Email: jgs@unb.ca

Résumé La structure d'impact du Trias tardif de Manicouagan est un cratère complexe bien conservé et non déformé possédant un soulèvement central anorthositique et une feuille de fusion d'impact d'environ 55 km de diamètre formé à 215 ± 1 Ma. Manicouagan fournit un analogue terrestre précieux pour les structures d'impact développées sur d'autres corps planétaires, en particulier la Lune et Mars, qui sont tous deux au centre de diverses initiatives d'exploration en cours et futures. Cette présentation résumera les aspects saillants de la structure en termes de processus de choc, d'excavation et d'effondrement.

Introduction: The late Triassic Manicouagan impact structure is a well-preserved, undeformed complex crater possessing an anorthositic central uplift and a ~55 km diameter impact melt sheet (Fig. 1). It occurs in the province of Quebec, Canada, and was formed at 215 ± 1 Ma [1]. The target rocks comprise a complex polymetamorphosed and polydeformed assembly of predominantly amphibolite facies grade (locally granulite facies) that constitute the Proterozoic Manicouagan Imbricate Zone [2]. Manicouagan provides a valuable terrestrial analogue for impact structures developed on other planetary bodies, especially the Moon and Mars, both of which are the focus of various ongoing and future exploration initiatives. The occurrence of shocked meta-anorthosite as part of the central uplift is especially relevant to lunar studies. The scientific value of Manicouagan was enhanced by the production, between 1994 and 2006, of ~18 km of drill core from 38 holes by the mineral exploration industry. Drilling was initiated based on the possibility of Manicouagan being a second, if smaller, Sudbury structure, with the potential for the development of economic Ni-Cu sulfides and associated PGEs. To date, no comparable economic deposits have been discovered. Three of the drill holes are in excess of 1.5 km deep, with the deepest attaining 1.8 km. Combined with surface exposures, the drill core provides an invaluable third dimension to the structure, with Manicouagan representing one of the most drilled structures in the world.

Research Initiatives: The Planetary and Space Science Centre (PASSC) at the University of New Brunswick has been actively working on Manicouagan since 2006. Funded by the Canadian Space Agency and other national and provincial grants, 10 km of the largely abandoned core was acquired by PASSC, including the deeper holes. The relatively remote location of the structure renders field work expensive (e.g., requiring helicopter support), but several PhDs and multiple undergraduate field assistants have benefited from being trained and carrying out research on this excellent example of a terrestrial impact structure. Our collective work has revealed that (1) Manicouagan is smaller than originally thought, with an apparent collapsed rim-to-rim diameter of 80 ± 5 km. This is based on revised geophysical and field constraints [3]; (2) the central uplift shows the development of shock veins containing HP-HT polymorphs [4], including stishovite, tissintite and stoefflerite (see the abstract of Hopkins and Spray this conference). In situ shock veins are only known to occur in three terrestrial impact structures so far: Vredefort, Manicouagan and Steen River (although ex situ vein systems have been described from breccias in the Ries and Xiuyan structures). As such, in situ shock veins provide important spatial context for shock vein systems that are developed in meteorites, where the latter reveal limited constraints on their source spallation location [5]; (3) the impact melt sheet at Manicouagan has a flat surface (eroded), but clearly has a more complex footwall structure. Many drill holes reveal that the melt sheet is <200-400 m thick, as reported in the earlier literature and undifferentiated. However, it is clear that the melt sheet is up to 1.0 km thick (or more) in places. These thicker sections are differentiated [6]. This makes Manicouagan one of

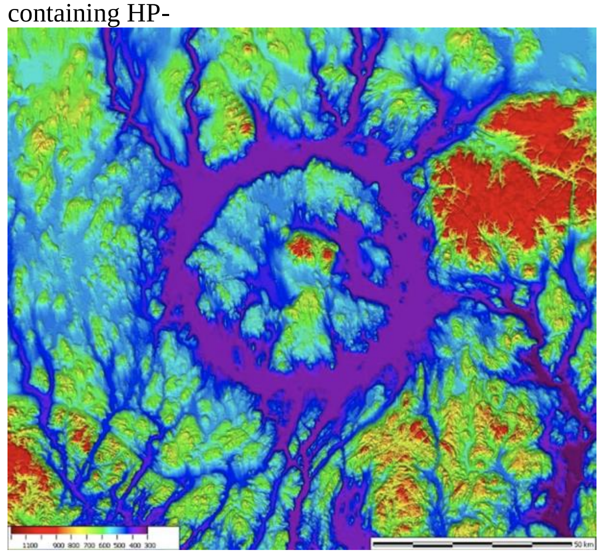

Figure 1. Colour-coded relief map of the Manicouagan impact structure and surrounding terrain computed from NASA Shuttle Radar Topographic Mission (SRTM) data. Height given bottom left in metres. Scale bar (bottom right) is 50 km long. High elevation areas include the central uplift (off centre of island) and the Mount Groulx gabbros to the northeast.

only three currently known structures on Earth that show differentiation (Sudbury, Morokweng and Manicouagan). Differentiation is dependent on melt thickness, with thicknesses >600 m allowing for fractionation [e.g., 7]. The important insight here is that the footwall to the impact melt sheet at Manicouagan is highly variable in morphometry. This most probably arose via faulting, with faults being activated to form horst-graben structures prior to melt sheet solidification. The ~1.0 km thick impact melt sections have undergone differentiation to yield a lower monzodiorite, a transitional quartz monzodiorite and an upper-quartz monzonite sequence; (4) Planetary comparisons: local differentiation calls into question the previous citing of Manicouagan as an exemplar of a relatively large crater possessing an undifferentiated melt sheet. This was used as a rationale for assigning different composition lunar impact melts (including clast-bearing impact melts) to distincts cratering events. The predominantly anorthositic central uplift at Manicouagan is comparable to certain lunar highlands material, with morphometric analogies to the King, Tycho, Pythagoras, Jackson, and Copernicus impact structures, which have similar diameters and uplift structure.

Conclusions: Manicouagan is a well-preserved, largely intact and undeformed impact structure. Excellent exposure around the reservoir edges and inland on the main island along fault scarps and topographic peaks allow for surface mapping and sampling. Exposures include a basal suevite unit located located between the impact melt sheet and footwall gneisses, which is especially well developed east of the main island [8]. Surface access is complemented by 10 km of curated drill core providing the third dimension in select areas. It is one of only three terrestrial impact structures currently known to possess melt sheets showing differentiation.

References:

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