DETERMINING SOURCE OF EJECTA USING HEAVY MINERAL PROVENANCE TECHNIQUES; A MANICOUAGAN DISTAL EJECTA CASE STUDY. S. Thackrey[1], G. Walkden[1], S. Kelley[2], R. Parrish[3], M. Horstwood[3], A. Indares[4], J.Still[1], J. Spray[5], [1]Dept. of Geology, University of Aberdeen UK. [2]Dept. of Earth Sciences, Open University, UK. [3]NIGL, BGS, UK. [4] Dept. of Earth Sciences, Memorial University, Canada. [5]Planetary and Space Science Centre, University of New Brunswick, Canada.

Introduction: Due to the nature of impact ejecta on Earth, preserved deposits are very rare and are typically altered by diagenetic processes [1-3]. Rare earth element (REE) analysis correlation is a common and well-accepted technique for ejecta provenance studies [4-8]. However, isotopic REE properties of impactites are altered during diagenesis [9,10]. It is therefore difficult to implement an accurate provenance study on diagenetically altered tektites/impact melts. An alternative correlation technique is suggested here for establishing the source of ejecta that utilises already well-documented applications of heavy minerals for provenance studies [11].

Defining the problem: The distal Wickwar ejecta deposit detailed in [1], contains tektites that have been devitrified to disordered illitic clay. Although reference in [1] was made to Manicouagan in terms of a possible source, no definitive analysis could prove this hypothesis. With the lack of preserved "clean" melts, an isotopic REE analysis study would not yield any credible source. It was therefore necessary to develop a new approach to ejecta correlation studies so that this link could be assessed.

An alternative approach: A vast majority of rocks on Earth will exhibit a heavy mineral suit to some degree. The target rocks at Manicouagan are largely composed of Grenville province basement with a thin cover of middle Ordovician sediments [12]. The target rocks are exceptionally rich in heavy minerals, typically garnet, zircon, biotite, olivine and rutile. During an impact, ballistic ejecta is sourced from the excavation of the crater that incorporates material from a vast volume of the target rocks that have experienced varying degrees of shock. Impact ejecta will therefore exhibit some of the characteristic properties of the target geology. In the Wickwar ejecta deposit, a significant enrichment of various heavy minerals is observed (garnet in particular) compared to its confining sediments. Previous studies using zircons have been successful in correlating ejecta source [13] using U-Pb dating. By utilising these radiogenic dating techniques and also mineral geochemistry analysis it has been possible to establish an unequivocal link between the Wickwar ejecta deposit and the Manicouagan impact crater.

Sample preparation: The ejecta layer is preserved in a series of carbonate muds that facilitate easy extraction of silicates through HCl dissolution. The residues of both the ejecta and its confining sediments were subjected to bromoform density separation in order to extract the heavy mineral assemblages.

Analysis and results: Garnet was selected as the best candidate to conduct a geochemical correlation study, largely due to the volume of garnets observed in the layer and also the garnet-rich nature of the Manicouagan target rocks. Using electron-microprobe analysis, garnets from the ejecta layer were compared to garnets from the Manicouagan target, including surrounding "rim" target rocks, the central uplift and anorthosite clasts from the impact melt. Figure 1 shows a strong geochemical correlation between Manicouagan and the ejecta layer. Garnet geochemistry from the ejecta layer correlate well with the target rocks and clasts from the impact melt, and differ from the background sediment garnets. The central uplift does not correlate well, which is to be expected, as the material from this part of the crater would not be incorporated into the ejecta curtain responsible for the distal ejecta. Furthermore, the central uplift geology would have been formed from lithologies deeper in the crust at time of impact, therefore providing the variation in geochemical signature.

Biotite, zircon and rutile were analysed using radiogenic LA-ICP-MS dating techniques. Shocked biotites extracted from the ejecta layer yield a spectrum of ages (circa 300Ma to circa 1500Ma), although dominated by Grenvillian ages, similar to the Manicouagan target lithology cooling ages. U-Pb data for the zircons below the ejecta layer are generally more concordant than zircons from the ejecta layer but zircons alone do not clearly distinguish the two since Grenvillian zircons are common to both. Rutile however, is mainly early Palaeozoic (~420-430 Ma) whereas they are considerably older in the ejecta layer and may be consistent in part with a mainly Grenvillian source.

Discussion: Silicate minerals are always preserved in ejecta deposits and are relatively stable in a range of diagenetic P-T conditions.

From the high resolution analysis completed in this study, it is evident that heavy minerals can be readily utilised as a correlation/provenance technique for establishing the source of ejecta. As with any provenance study, its application is only limited by the preservation of the source. However, heavy mineral assemblage characteristics can give insights into the types of geology that formed the target rocks.

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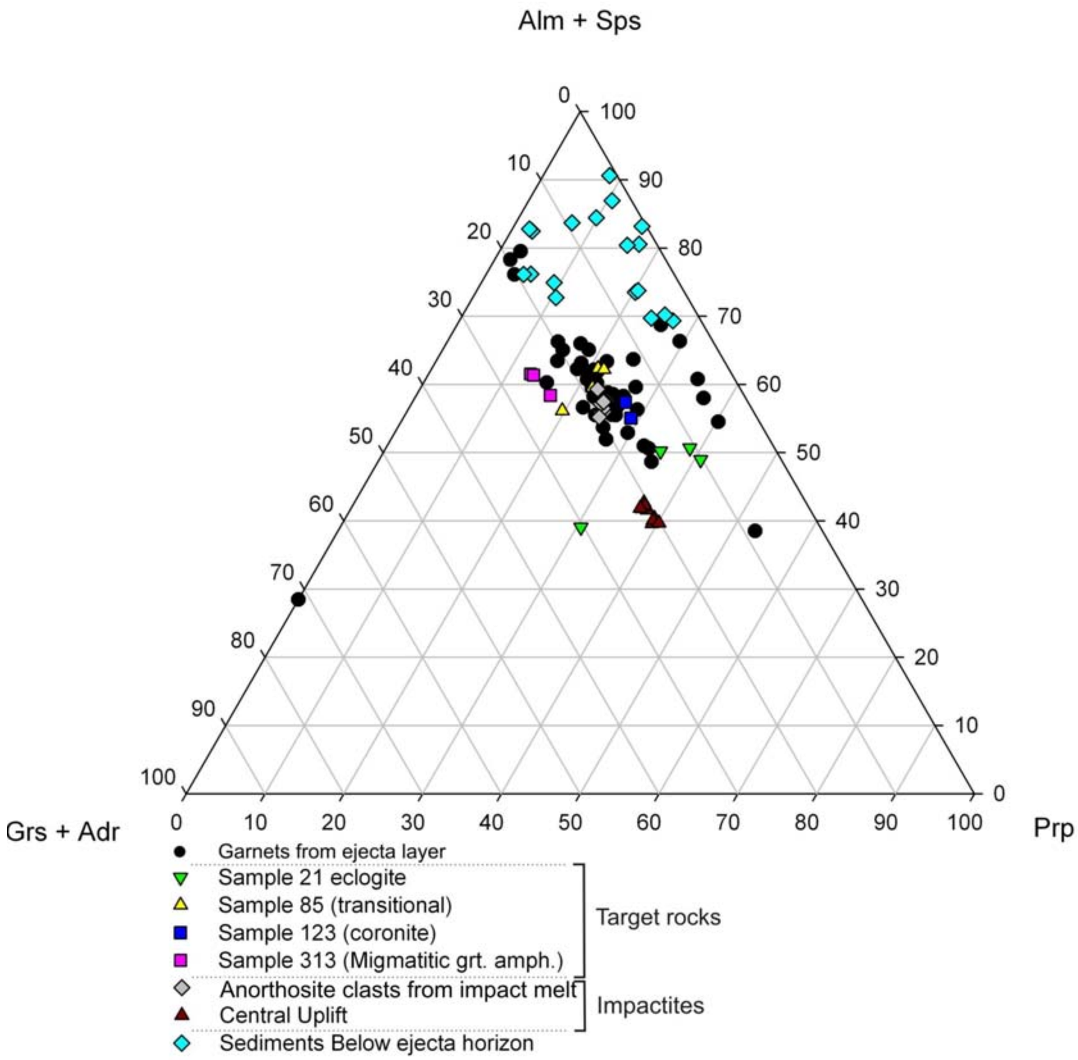

Fig 1. Ternary plot comparing garnet geochemistries from the Wickwar ejecta layer with garnets from the target rocks, impact melt, and central uplift of Manicouagan, and the background garnets of the sedimentary sequence immediately below the ejecta layer. **Note** that some of the background garnets are mixed into the ejecta. This is as a result of the nature of the deposition of the ejecta. n=130.

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