STRUCTURAL AND GEOCHRONOLOGIC CONSTRAINTS ON THE TIMING OF THE CHARLEVOIX IMPACT, QUEBEC, CANADA. J. Whitehead[1], S. Kelley[2], S.C. Sherlock[2], R. A. F. Grieve[3], J. G. Spray[1], and C. A. Trepmann[1]. [1]Planetary and Space Science Centre, Department of Geology, University of New Brunswick, 2 Bailey Drive, Fredericton, New Brunswick, E3B 5A3, Canada, jwhitehe@unb.ca, [2]Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, UK., [3]Earth Sciences Sector, Natural Resources Canada, Ottawa, ON, K1A OE4, Canada.

Introduction: Accurate determinations of the ages of impact structures are required if associations between impacts and extinction events are to be tested. In addition, the extistence of multiple and potentially related impacts can only be inferred if accurate ages exist for the candidate impacts.

Although the 54 km-diameter Charlevoix impact structure in Quebec, Canada (47°32' N, 70°17' W) is the 13th largest confirmed impact structure on Earth [1] its age is poorly constrained.A potential association between an impact event and the Devonian Frasnian/Famennian extinction has been made [2], and Charlevoix is a natural candidate. However, the established Devonian K-Ar ages for Charlevoix are inconsistent with the outcrop pattern of the structure. Here we present the preliminary results of a new Ar-Ar dating study of impact melt rocks and pseudotachylytes from the structure.

Existing Age Constraints: Precambrian anorthosites, charnockites and granitic gneisses in the target rock are overlain by the Ordovician Black River, Trenton and Utica Groups – constraining the impact event to Ordovician or post-Ordovician times.

The north-western limit of Appalachian thrusting, Logan's line, truncates the southeastern margin of the crater in the St Lawrence River. This fault clearly accommodates post-impact movement juxtaposing the impact structure with unshocked rocks to the immediate southeast on the Isle aux Coudres. If this post-impact thrusting is a result of Taconic to Salinic orogenesis (Ordovician to upper Silurian), then the impact occurred during the Ordovician or early Silurian, not the Devonian.

The existing K-Ar ages for impact melt rocks (342 and 372 Ma) and pseudotachylyte (335 Ma) from the structure [3] were determined prior to the 1977 publication of a standardised set of decay constants by Steiger and Jäger [4]. Despite this, the recalculated ages (327, 356 and 321 Ma, respectively) are seldom presented in the literature – and no longer are contemporaneous with the Frasnian-Famennian extinction.

The quoting of uncorrected ages is not restricted to the Charlevoix impact – here we present the recalculated ages of six other craters whose ages were determined prior to 1977 (Table 1).

Table 1

Structure	Reported Age (Ma)*	Method	Lithology	Recalc. age (Ma)**
Aouelloul, Mauritania	3.1 ± 0.3	K-Ar	glassy impact melt	3.0 ± 0.3
Brent, Canada	≥ 414 ± 20 450 ± 9	K-Ar Ar-Ar	impact melt impact melt	≥ 396 ± 20 431 ± 9
Charlevoix, Canada	342 † 372 † 335 †	K-Ar K-Ar K-Ar	impact melt impact melt pseudotachylyte	327 356 321
Ilyinets, Ukraine	395 ± 5	K-Ar	impact melt	378 ± 5
Steen River, Canada	95 ± 7	K-Ar & Rb-Sr	pyroclastic whole rock	91 ± 7
Tenoumer, Mauritania	2.5 ± 0.5	K-Ar	impact melt	2.4 ± 0.5
Wanapitei, Canada	37.8 ± 1.6 36.0 ± 1.6	K-Ar K-Ar Ar-Ar	glass whole rock †† impact melt	36.2 ± 1.6 37.2 ± 1.2

* Ages calculated using pre-1977 decay constants.
** Ages recalculated using decay constants of Steiger and Jäger, 1977
† no errors reported
†† glass is undevitrified and whole rock is partially devitrified

The age of impact events are typically best determined by the isotopic ages of impact melt rocks. At Charlevoix, the two melt rock ages, which were obtained by two separate labs, differ by 31 Ma [3]. Owing to the range of these ages, the timing of the impact has been variously quoted as an average of these two ages [5] or as the younger age, on the basis that the younger sample may have experienced a partial resetting of the isotopic system, possibly as a result of subsequent tectonic activity or devitrification of groundmass glasses.

The degree of partial resetting of ages by post-impact heating or disturbance by St Lawrence faulting and fluid flow is unknown, though the impact melt rocks and pseudotachylytes are both highly susceptible to resetting owing to their fine grain sizes.

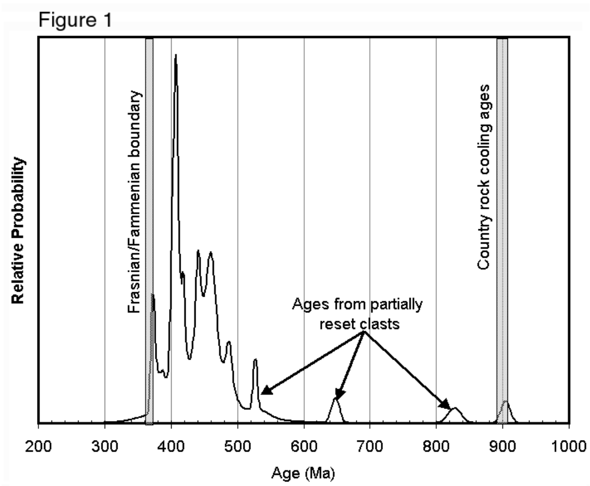
Sample Descriptions: Samples dated at the Open University, UK include three *in situ,* and two potentially glacially displaced impact melt rocks, and one pseudotachylyte from the central uplift.

Three of the impact rock samples possess a cryptocrystalline groundmass of quartz, andesine, albite and orthoclase, ilmenite and titanite surrounding acicular crystallites of augite, ranging from 0.2 to 14 mm long, with widths typically <20 µm.

One impact melt rock collected from glacial till possesses a coarser groundmass grain size than the in-situ samples with crystals of 10-400 um in diameter. Groundmass phases include quartz, titanite, alkali feldspar (10-20 µm) and secondary clinochlore. The sample also contains lechatelierite glass with flow texture and shocked, toasted quartz [6].

The pseudotachylyte sample was taken from a vein within central peak anorthosites and has a uniform grain size of 1-5 µm, and contains clasts of anorthosite. X-ray compositional maps indicate that the K is distributed evenly throughout the matrix.

New Age Data: The samples were analysed by melting spots ~ 100 µm in diameter using a focused laser, a technique which highlights age variations within the sample. Approximately 60 laser spots were



analysed, yielding individual spot ages ranging from 356 Ma to 904 Ma (Figure 1). All spot ages older than 500 Ma are associated with above average Ca/K values (calculated from the $^{37}Ar/^{39}Ar$ ratios) and are the same age or younger than local country rock cooling ages (around 900 Ma). It seems likely that these ages are influenced by clasts either partially reset or mixed with younger melt material in the analysis. All but one of the remaining spot ages are all older than 370 Ma (the Frasnian/Famennian boundary is generally thought to be at 364 Ma, see Figure 1) and thus the Ar-Ar data confirm field observations and indicate that the Charlevoix impact did not occur at the Frasnian/Famennian boundary.

The other peaks in age are sometimes attributable to one sample, for example all ages in the peak at 375 Ma result from one sample (4 analyses) and two samples dominate the age peak around 410 Ma. However, all samples show some peaks in the range 450-480 Ma and two of the three *in situ* melt rocks yield age spectra peaking in the range 460 to 470 Ma (the other yielded more scattered ages). Unfortunately the low potassium and high calcium content of the pseudotachylyte prevented high precision ages being determined.

The best constraint upon the age of a resetting event might be cooling from the Acadian orogeny, which has been dated in slightly higher grade rocks some 200-250 km further south at 377 ± 4 Ma [7]. It seems likely that the low grade metamorphism affected the glassy and fine grained rocks of the Charlevoix impact leading to young K-Ar ages. The Ar-Ar samples of the present study avoid some of the later alteration effects. However, the preliminary Ar-Ar data clearly indicate a complicated age pattern, but one which seems to corroborate the field data and indicates that an Ordovcian impact in the age range 450-480 Ma, probably close to 460-470 Ma. Identifying the precise impact age seems to be hampered by later low grade metamorphism and thrusting, which have caused partial argon loss during heating and alteration of the primary mineral and glass assemblage. Further work will be undertaken, including step heating selected samples and further sample collection, to obtain a better constraint on the age of the impact.

Conclusions: The Charlevoix impact is not Devonian, as indicated both by field data and new Ar-Ar ages. The impact was probably Ordovician (Llanvirn using the timescale of [8]). Scattering of the ages has been caused by later thrusting, low grade metamorphism and fault movements coupled with various degrees of excess argon from the target rocks. The three previously published K-Ar ages [3] will also have been disturbed by these factors and therefore are of limited use.

The association between the Charlevoix impact event and the Frasnian/Famennian extinction event is no longer tenable. However, if the Charlevoix impact was generated approximately 460 to 470 Ma ago then it may have been broadly contemporaneous with the Ames, Granby and Neugrund structures in Oklahoma, Sweden and Estonia, respectively. In addition, a high flux of potentially coincident meteorites has recently been reported for the Orodovician [9]. Despite the coincidence of these events with the probable new age for Charlevoix, no genetic association should be made until the isotopic age of Charlevoix is further refined.

References: [1] Earth Impact Database, 2003. <www.unb.ca/passc/ImpactDatabase/>(Accessed: 11th May, 2003). [2] McLaren D. (1970) *J. Palaeont, 44,* 801-815. [3] Rondot J. (1971) *JGR, 76,* 5414-5423. [4] Steiger R.H. and Jäger E. (1977) *EPSL, 36,* 359-362. [5] Grieve R. A. F. et al. (1995). *GSA Today, 5*, 193-196. [6] Whitehead J. et al (2002) *Geology, 30,* 431-434. [7] Whitehead J. et al (1996) *Geology 24*, 359-362. [8] Gradstein F. M and Ogg J. (1996) *Episodes,19*, 3-5. [9] Schmitz B. et al. (2003) *Science, 300,* 961-964.