LASER ARGON DATING OF MELT BRECCIAS FROM THE SILJAN IMPACT STRUCTURE, SWEDEN – IMPLICATIONS FOR POSSIBLE RELATIONSHIP TO LATE DEVONIAN EXTINCTION EVENTS. Reimold, W.U.[1], Kelley, S.P.[2], Sherlock, S.[2], Henkel, H.[3], and Koeberl, C.[4] [1]ICRG, School of Geosciences. Univ. of the Witwatersrand, Private Bag 3, P.O. Wits 2050, Johannesburg, RSA (reimoldw@geosciences.wits.ac.za), [2]Department of Earth Sciences, Open University, Walton Hall, Milton Keynes MK7 6AA, U.K. (S.P.Kelley@open.ac.uk) (s.sherlock@open.ac.uk), [3]Dept. Land and Water Resources Engineering, Div. Eng. Geol. and Geophys., Royal Institute of Technology, Teknikringen 72, SE 1—44 Stockholm, Sweden (Herbert@kth.se), [4]Department of Geological Sciences, University of Vienna, Althanstr. 14, A-1090 Vienna, Austria (Christian.koeberl@univie.ac.at).

Summary: A well defined laser argon age of 376.8±1.7 Ma (95% confidence limits) is presented for impact melt breccias from the Siljan impact structure (Sweden). This impact event has been previously related to a mass extinction event at the Frasnian/Fammenian boundary (End-Devonian), but these new results clearly separate the Siljan event from the 364 Ma [1] F/F boundary.

Introduction: The Siljan structure is located in south-central Sweden. At 65 km diameter [2] – some favour even 75 km - Siljan represents the largest confirmed impact structure known in Western Europe. The structure is deeply eroded and comprises a central topographic high of 28-30 km diameter, considered the central uplift, surrounded by a ring-shaped depression. The central uplift is composed of shocked and brecciated Gothnian and Dalslandian granites and granitic gneisses of ca. 1.8 to 1.0 Ga ages [3-7]. Impact melt is very rare and only a few, relatively small dike occurrences and boulder locations are known. The ring structure involves downfaulted sedimentary rocks of Ordovician and Silurian age.

Previous age dating of this impact event includes the ^{40}Ar-^{39}Ar stepheating results for two presumed impact melt rock samples (S3A and S3B), for which integrated ages of 361.9±1.1 Ma and 368±1.1 Ma were reported by [2] and [3], respectively. These authors did not provide much detail on sample localities, but it is believed that our sample Si-1 could be from the same site. It has also remained unclear why the same data were regressed to different ages in these publications. In addition, a K-Ar age of 349 Ma for "shock melt" from another locality was quoted by [5]. Juhlin et al. [6] also list one ^{40}Ar-^{39}Ar dates for a "granitic pseudotachylite" of 359±4 Ma, and two K-Ar ages for "doleritic pseudotachylite" of 342±3 and 349±2 Ma. Their dolerite ages vary from 789 to 1098 Ma. The previous ages for the impact event fall into an intriguing part of the Late Devonian, in which several important events occurred. These include the Frasnian/Famennian mass extinction (364 Ma) that has been associated with impact evidence (including iridium enrichment and microtektite layers), the Amönau (Central Germany) catastrophic event that has been tentatively linked to impact as well and is placed at the Givetian/Frasnian boundary at 370 Ma, the Alamo impact event (Southern Nevada) of the early Frasnian *punctata zone* at about 367 Ma, and a mass extinction at the Devonian/Carboniferous period boundary at 357 Ma [as reviewed by 7]. The Frasnian/Famennian event is of global importance and represents one of the five most significant mass extinction events in the Phanerozoic. Sandberg et al. [8] suggested that several subcritical oceanic impact events could best explain the evidence from various, widely separated regions in the world. The Siljan impact structure has been cited as a possible cause of the Belgian impact evidence [9]. It is clearly important to investigate whether the Siljan impact event can be correlated with any of these late Devonian events. Thus, we have carried out laser argon spot analysis on 6 samples from the central uplift of the Siljan Structure, which represent all melt breccias known from Siljan to date, and report the first results.

Samples: Si-1, from a 1 m wide and > 10 m long dyke or pod exposure at Trollberget near the center of the structure, cross-cutting granite and a mafic dike, which is thought to represent the same material as dated by [2,3]. It has an aphanitic to very fine-grained crystalline matrix and ca. 15 vol% clasts of granitie origin. Clasts are partially annealed; no evidence of shock deformation has been noted. Si-2 is a cataclastic granitoid with significant secondary carbonate. It originates from Stumsnäs near the edge of the central uplift. This sample contains narrow (< 2 mm wide) veinlets that have all the characteristics of pseudotachylitic breccia but could be pure cataclasite. Si-3 is from a melt breccia boulder from the central part of the uplift region. The glassy to cryptocrystalline matrix contains annealed, locally melted, or shocked granite-derived clasts. Some quartz and feldspar crystals display PDFs. Si-4 is from a boulder from the NW part of the central uplift. This breccia is clast-rich, has a fine-grained clastic matrix, contains internally brecciated clasts, and some melt fragments. Besides local melting of clasts, no characteristioc shock deformation was observed.

Sample Si-5 is a clast-rich melt breccia from a boulder,, close to Si-1. PDFs were noted in both quartz and feldspar of granitic clasts. The matrix is partially glassy, and partially microlite-rich, indicative of incipient crystallization. Si-6 is from a melt dike boulder that also shows some granitic host rock. It was sampled near Hättberg in the northern part of the central uplift. The material comprises fluidal glass with melted clasts and local incipient crystallization. Some plagioclase has alternate melted twin lamellae, and diaplectic glass of both quartz and feldspar is present.

Methodology: Ar-Ar analyses were performed using a focused Nd-YAG laser, and argon isotopes were measured on an MAP 215-50 mass spectrometer. The irradiation was monitored using the GA1550 international biotite age standard with an age of 98.79 Ma [10]. Analytical techniques were similar to those in [11]. Laser spot dating allowed us to avoid clasts derived from precursor rocks at a scale of around 100 µm, though there was little effect from these clasts other than in sample Si-2.

Results: Cataclasite sample Si-2 only yielded Precambrian ages (integrated to 643±77 Ma, with individual ages ranging from 586±6 Ma to 737±8 Ma It is clear that this sample was not entirely degassed by the impact event. However, the other five samples yielded much more reproducible data. Mean ages were calculated for Si-1 (15 anal.) at 356.8±8.6 Ma, for Si-4 (n = 12) at 366.9±4.2 Ma, and Si-6 (n = 12) at 382.0±8.4 Ma. The results for these samples are affected by 10% atmospheric contamination. More significantly, melt breccias Si-3 and Si-5 yielded measurements with generally less than 1% atmospheric argon contamination and very reproducible results: The mean ages calculated are for Si-3 (n = 15) 377.6±2.7 and for Si-5 (n = 12) 375.3±1.8 Ma, respectively. The difference in atmospheric contamination levels is likely to be the result of differing alteration of the samples. Combining the data for Si-3 and Si-5 yields our prefered age of 376.8±1.7 Ma for the Siljan impact event. Within their error limits, the new results for sample Si-6 overlap with this preferred age and all samples other than Si-2 yielded several ages within error of the prefered age. It is planned to carry out additional step heating experiments with some of these samples to report results at the conference.

Conclusions: These new results significantly (by +9.5 Ma) revise and improve the best currently available age for the Siljan impact event. This age does not correlate within error limits with any of the catastrophic events, or extinction events, in the late Devonian interval. Note that impacts of the size of Siljan probably occur on Earth on average every 5 million years, so that any of the phenomena in the Late Devonian might be related to another Siljan sized crater not detected yet or obscured by the Earth's active surface renewal.

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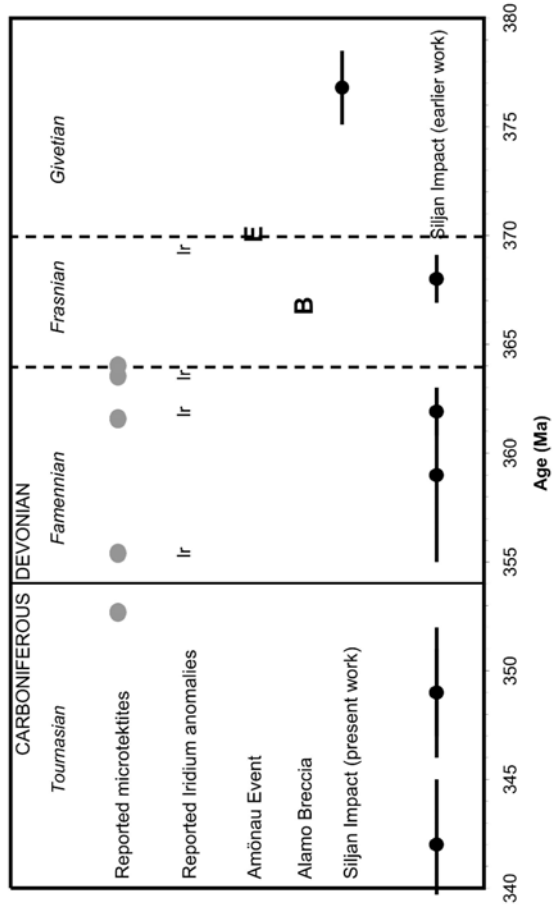

The figure compares the ages of catastrophic events known in the late Devonian with previous and our new ages for the Siljan impact event.