lithologies. This suggests that certain components of pseudotachylitic Sudbury Breccia have undergone significant transport (?kilometers) during their formation.

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$^{40}$Ar-$^{39}$Ar AGES OF THE LARGE IMPACT STRUCTURES KARA AND MANICOUAGAN AND THEIR RELEVANCE TO THE CRETACEOUS-TERTIARY AND THE TRIASSIC-JURASSIC BOUNDARY. M. Trieloff and E. K. Jessberger, Max-Planck-Institut für Kernphysik, P.O. Box 103980, W-6900 Heidelberg, Germany.

Since the discovery of the Ir enrichment in Cretaceous-Tertiary boundary clays in 1980 by [1] the effects of a 10-km asteroid impacting on the Earth 65 Ma ago are discussed as the possible reason for the mass extinction— including the extinction of the dinosaurs—at the end of the Cretaceous. But up to now no crater of this age that is large enough (ca. 200 km in diameter) has been found. The Manson Crater in north America is 65 Ma old [2], but too small—only 35 km in diameter. A recently discovered candidate is the Chicxulub structure in Yucatan, Mexico, but intensive investigations have to be done to identify it as the K-T impact crater. Petrographic signs at the K-T boundary seem to point to an impact into the oceans as well as onto the continental crust; multiple impacts were considered [3].

Another candidate is the Kara Crater in northern Siberia. Kolesnikov et al. [4] determined a K-Ar isochron of 65.6 ± 0.5 Ma, indistinguishable from the age of the K-T boundary and interpreted this as confirmation of earlier proposals that the Kara bolide would have been at least one of the K-T impactors. Koeberl et al. [5] determined $^{40}$Ar-$^{39}$Ar ages ranging from 70 to 82 Ma and suggested an association to the Campanian-Maastrichtian boundary, another important extinction horizon 73 Ma ago.

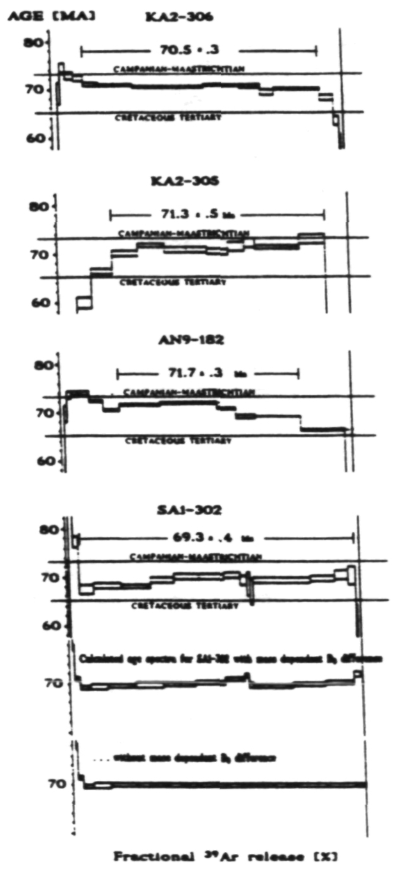


Fig. 1.

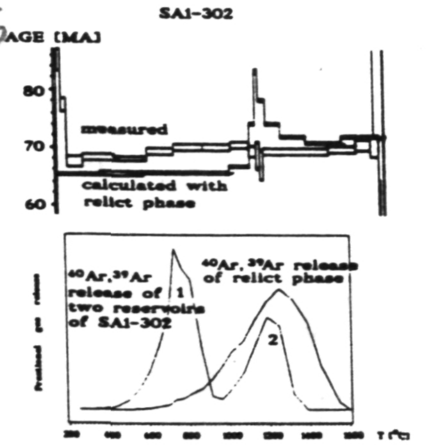


Fig. 2.

We dated four impact melts, KA2-306, KA2-305, SA1-302, and AN9-182. All spectra show well-defined plateaus. They are shown with a strong extended age scale (Figs. 1 and 2). Our ages range from 69.3 to 71.7 Ma, and it is clearly visible that our data suggest neither an association with the Cretaceous-Tertiary nor the Campanian-Maastrichtian boundary. Errors are given as 1σ errors computed of the deviation of the plateau fractions. The systematic error induced by the NL25 hornblende standard is 0.6 Ma. It may be argued that our ages—old in comparison to the K-T boundary—could be caused by relict target rocks incorporated in the melt. At the first sight this seems to be possible: If only 1% of the sample's potassium is located in a relict phase of paleozoic age of 500 Ma, this is enough to lift the sample's K-Ar age from 65 Ma to 70.S Ma. We consider SA1-302 to test whether the age pattern would then still show a plateau or if the relict phase would be recognizable. The degassing pattern shows two distinct reservoirs. We calculated the diffusion parameters, activation energy Q and frequency factor $D_0$, by Arrhenius plots for each reservoir and simulated the gas release by two phases having different diffusion parameters. We assumed an age of 65 Ma for the two phases and added an arbitrarily chosen relict phase having

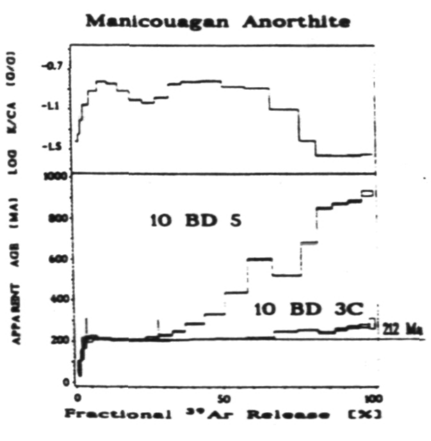


Fig. 3.

diffusion parameters of a typical anorthite, with an age of 500 Ma constituting 0.8% of the samples' potassium. The degassing peak of the relict phase coincides by and large with the second reservoir of SA1-302 but the degassing feature is broader (Fig. 3). The resulting calculated age pattern shows a low-temperature plateau of 65 Ma and an irregular shape in the high-temperature steps. That means that the measured age pattern can only be interpreted as a result of 65-Ma age and a relict phase if the relict phase has exactly the same gas release pattern—but if this is the case, the relict phase should have been reset by the cratering event as well as the sample unless it would have been incorporated afterward, e.g., as contamination. A further condition that must be fulfilled to fit this scenario is that the K fraction of 500-Ma old relict phases in the different samples must be nearly the same (1 ± 0.2%), or another proper combination of age and K content. We regard this as improbable.

Although the age spectra show well-defined plateaus, the plateau fractions still exhibit fine-scale structures that deviate from a theoretical calculated plateau (Fig. 2, bottom) as expected for a maximum precise measurement of an undisturbed sample. Normally the mass-dependent diffusion difference of $^{40}Ar$ and $^{39}Ar$ is considered as negligible, but if we induce it in our calculations in the case of SA1-302 we get an age spectra as shown in Fig. 2 with slightly increasing ages within each reservoir. This strengthens the assumption that these deviations are not of statistical, but of systematic nature, an artifact induced by the $^{40}Ar$-$^{39}Ar$ stepheating technique. In this sense, the spectrum of SA1-302 seems to represent the "ideal" spectrum of an undisturbed sample. For the fine-scale deviations of the other three impact melts $^{39}Ar$ recoil redistribution seems to play a major role, but this has to be investigated by further petrographic studies on grain size and potassium distribution.

We conclude an age of 69–71 Ma for the Kara impact structure. Hydrogen isotopic measurements by Nazarov et al. [6] show that the impact occurred on dry land and the authors concluded a maximum age of 69–70 Ma, the time of the end of the last regression within the crater's region before the end of the Cretaceous. Our data are consistent with an impact a short time after the regression.

Figure 4 shows the K/Ca and the age spectra of two impact metamorphic anorthite samples (10BD5 and 10BD3C) of the Manicouagan Crater, Canada. As visible in the K/Ca spectra (only 10BD5 is shown), the samples consists of two different phases, one degassing at low temperatures having an age plateau indistinguishable from the cratering event of 212 Ma (7), the second one showing the signature of a partially degassed phase, having ages increasing up to 950 Ma (10BD5), the age of the target rocks [8]. 10BD3C suffered a more complete degassing, having ages ranging only up to 300 Ma. The low-temperature plateaus are in agreement with the crater age of 212 Ma and do not improve the age of the impact structure. Anyway, while the crater age is quite accurate, the ages of the adjacent geologic boundaries seem not to be. The last revision [9] of the Triassic-Jurassic boundary in 1982 delivered an age of 213 Ma, while a later determination [10] gives a lower age of 208 Ma. We think so far as ages are concerned it is not possible to conclude or exclude an association of the two events until the age of the boundary is determined more precisely.

Our measurements enable us to estimate the intensity of the thermal event induced by the cratering event for the two Manicouagan samples. Our results are consistent with a time-temperature combination of 1 Ma at 337°C or 12 hr at 1100°C for 10BD5 and 1 Ma at 361°C or 50 hr at 1100°C for 10BD3C. Future investigations may allow us to infer a cooling model for the Manicouagan impact melt sheet.

**References:** [1] Alvarez L. W. et al. (1980) *Science, 208,* 1095. [2] Hartung J. B. and Anderson R. R. (1988) *LPI Tech. Rept. 88-08.* [3] Alvarez L. W. and Asaro F. (1990) *Sci. Am.,* 362. [4] Kolesnikov E. M. et al. (1988) In *LPI Contrib. No. 673.* [5] Koeberl C. et al. (1990) *Geology, 18,* 50. [6] Nazarov M. A. et al. (1991) *LPSC XXII,* 961. [7] Grieve R. A. F. (1991) *Meteoritics, 26,* 175. [8] Wolfe S. H. (1971) *JGR, 76,* 5424. [9] Harland W. B. et al. (1982) *A Geologic Time Scale,* Cambridge Univ. [10] Palmer A. R. (1983) *Geology, 11,* 103.



## $^{40}Ar$-$^{39}Ar$ DATING OF PSEUDOTACHYLITES FROM THE WITWATERSRAND BASIN, SOUTH AFRICA, WITH IMPLICATIONS FOR THE FORMATION OF THE VREDEFORT DOME.

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The formation of the Vredefort dome, a structure in excess of 100 km in diameter and located in the approximate center of the Witwatersrand basin, is still the subject of lively geological controversy. It is widely accepted that its formation seems to have taken place in a single sudden event, herein referred to as the Vredefort event, accompanied by the release of gigantic amounts of energy. It is debated, however, whether this central event was an internal one, i.e., a cryptoexplosion triggered by volcanic or tectonic processes, or the impact of an extraterrestrial body.

Ages obtained on rocks from the Vredefort structure cluster largely around 2.0 Ga (e.g., review by [1]). Granophyre, an unusual melt rock forming dykes in the Vredefort Dome and thought to be related to the Vredefort event, yielded a Pb-Pb zircon age of 2002 ± 52 Ma [2]. Pseudotachylite, a melt breccia first discovered and

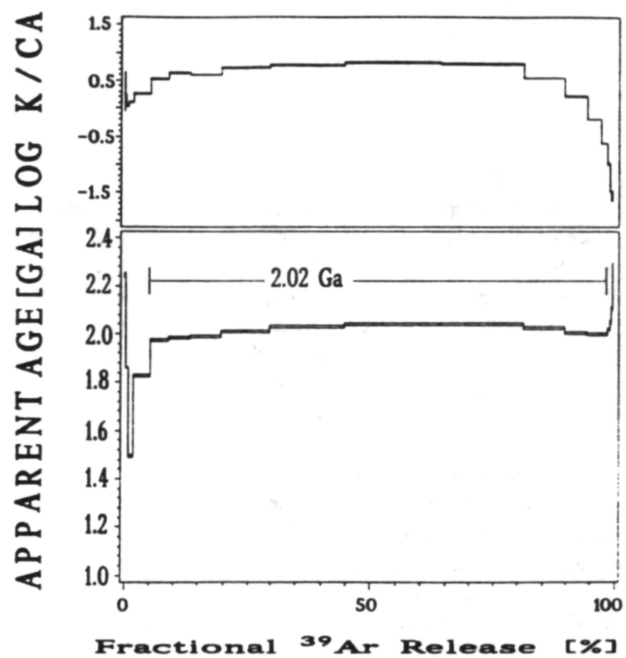


Fig. 1. Age spectrum for EL-28B.