Upper age limit of cosmogenic $^{39}\text{Ar}$ dating extended to 1,800 years

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Cosmogenic $^{39}\text{Ar}$ dating is an emerging technique in tracing groundwater flow, dating mountain glacier ice, and mapping ocean circulation. We have realized a system for atom trap trace analysis of the radioactive isotope $^{39}\text{Ar}$ (half-life = 269 years) in environmental samples. The system is capable of analysing small (1 - 5 kg) environmental water or ice samples, and achieves a count rate of 10 atoms/h for $^{39}\text{Ar}$ at the modern isotopic abundance level of $8 \times 10^{-16}$. By switching frequently between counting $^{39}\text{Ar}$ atoms and measuring the stable and abundant isotope $^{38}\text{Ar}$, drift effects in the trapping efficiency are largely suppressed, leading to a more precise measurement of the isotope ratio $^{39}\text{Ar}/^{38}\text{Ar}$. These advances allow us to determine the $^{39}\text{Ar}$ age in the range of 250 – 1,300 years with precisions better than 15%. Moreover, cleaning techniques are developed to alleviate cross-sample contamination. This has made it possible to achieve a detection limit at 1% of the modern $^{39}\text{Ar}/\text{Ar}$ level. The upper age reach of $^{39}\text{Ar}$ dating has thus been extended to 1,800 years.

Furthermore, technical developments that may increase the $^{39}\text{Ar}$ count rate by orders of magnitude will also be discussed. This includes a pre-enrichment system that can increase the isotopic abundance of $^{39}\text{Ar}$ in the Ar sample by a factor of 100 before the atom-trap analysis. These developments, if successful, will enable large scale applications of $^{39}\text{Ar}$ dating.

As of 2021, the laboratory for radio-noble gas dating at the University of Science of Technology of China has full capabilities to perform analysis of $^{81}\text{Kr}$, $^{85}\text{Kr}$ and $^{39}\text{Ar}$. Together with $^{14}\text{C}$ they can cover a wide age range from a few years to 1.3 million years.

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