

The virtual spot approach: a simple method for image U-Pb carbonate geochronology by high-repetition rate LA-ICP-MS

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We present an approach to laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) U-Pb dating of carbonate minerals from isotopic image maps, made possible using a high repetition rate femtosecond laser ablation system. The isotopic ratio maps are built from 25- μm -height linear scans, at a minimal repetition rate of 100 Hz. The analysis of ^{238}U , ^{232}Th , ^{208}Pb , ^{207}Pb and ^{206}Pb masses by a sector field ICP-MS is set to maximize the number of mass sweeps, and thus of pixels on the produced image maps (~ 8 to 19 scans s^{-1}). After normalization by sample standard bracketing using the Iolite 4 software, the isotopic image maps are discretized into squares. The squares correspond to virtual spots of chosen dimension, for which the mean and its uncertainty are calculated, allowing to plot corresponding concordia diagrams commonly used to obtain an absolute age. Because the ratios can vary strongly at the pixel scale, the values obtained from the virtual spots display higher uncertainties compared to static spots of similar size. However, their size, and thus the number of virtual spots can be easily adapted. A low size will result in higher uncertainty of individual spots, but their higher number and potentially larger spread along the isochron can result in a more precise age. Reliability of this approach is improved by using a mobile grid for the virtual spot dataset of a set size, returning numerous concordia allowing to select the more statistically robust result. One can also select from all the possible spot locations on the image map, those that will enable regression to be obtained with the best goodness of fit. We present examples of the virtual spot approach, for which in the most favorable cases ($\text{U} > 1 \text{ ppm}$, $^{238}\text{U}/^{206}\text{Pb} \gg 1$, and highly variable U/Pb ratios) a valid age can be obtained within reasonable uncertainty ($< 5\text{-}10\%$) from maps as small as $100 \mu\text{m} \times 100 \mu\text{m}$, i.e. the size of a single spot in common in situ approaches. Although the method has been developed on carbonates, it should be applicable to other minerals suited to U-Pb geochronology.