Fission Track Dating of Obsidian Artifacts: A Geochronological Approach to Provenance*

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Fission-track dating (FTD) is a radiometric technique that can be used for dating both very old samples materials (e.g., meteorites) and younger objects (e.g., artifacts from archaeological sites) [1]. The spontaneous nuclear fission of ^{238}U within minerals creates damage trails, the fission tracks (FT), that can be etched and observed with an optical microscope: the density of fission tracks on an internal surface of the mineral represents a measure of the time over which tracks accumulate. To calculate the fission-track age, it is necessary to measure the amount of uranium present, too. This is done by irradiating the sample with thermal neutrons in a nuclear reactor which artificially induces fission in a tiny fraction of ^{235}U atoms present. Both spontaneous and induced track densities are measured and their ratio is used to calculate the fission track age: in this way, the parent and daughter isotope concentrations need not to be measured with a mass spectrometer. Among the wide variety of minerals, natural and artificial glasses that can be dated through fission-track method, obsidian remains of great interest in archaeological research, especially for tracking prehistoric trade networks. Indeed, obsidian is a naturally occurring volcanic glass formed when lava extruded from a volcano cools rapidly with minimal crystal growth; the cooling moment marks time zero for radiometric dating. In the Neolithic period it represented the sharpest known material and was used to make tools because of its durability; its trade played an important role in the Mediterranean area and it is of particular interest for tracing prehistoric commercial routes, considering that obsidian from the Mediterranean basin has been found in southern France, Dalmazia, Sicily and mainland Italy [2]. Chemical characterization methods, also simple ones such as X-Ray Fluorescence [3], allow us to classify the provenance of obsidian artifacts accurately when referring to different sources, mostly if used in combination with statistical methods. If discrimination among sub-sources, i.e. various lava flow within the same volcano, is required, dating methods are more suitable. Fission-track dating can thus be used to estimate the age of obsidian and correlate it with volcanic events, becoming at all effects a provenance study [4]. The FTD laboratory at the Department of Physics "Aldo Pontremoli" (University of Milan) is currently one of the few FTD laboratory working on archaeological materials worldwide. We are developing an automated image scanning method combined with efficient track recognition to replace the traditional approach, where a trained operator manually scans, varying the focal plan, and counts the entire sample surface to identify fission tracks among inclusions, residual resin bubbles, and rock vesicles. Our first step will be to exploit a motorized focus controller to obtain a focus stack image sequence of the sample and reconstruct the shape of the tracks using "depth from focus" methods. A full-frame DSLR camera back will be connected to the microscope and coupled with the Z-axis motion to obtain the stack of transmitted light images of the obsidian. Using the stack of images, it may be possible to render the 3D model of the sample features to recognize the tracks associated with fission through imaging techniques, possibly using machine learning for a significant improvement in the efficiency and accuracy of track counting.

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