New perspectives on an “old” technique: Lipari obsidian and Neolithic communities investigated by Fission Track Dating

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Abstract. "Lipari obsidian and Neolithic human communities in the Aeolian islands" is a project aimed at studying the connection between obsidian flows on the island of Lipari and Neolithic populations on the Aeolian archipelago, in Italy. As it is well known, obsidian is of particular interest to trace prehistorical trading patterns; indeed, Lipari obsidian has the widest distribution and has been found in southern France, Dalmazia, Sicily and mainland Italy. The project outputs will give a general vision of both archaeological and volcanological aspects through the stratigraphic and radiometric dating of eruptions which produced obsidian, in relationship with the first phases of the human settlements and row material exploitation. To reach this goal, we are considering both raw materials (geological samples) from different flows and artefacts from Neolithic settlements (archaeological samples) on the Aeolian islands, and performing fission-track dating to get the age of obsidian sources and artefacts. Obtained results are expected to shed some new light on the raw material procurement and on the ability of the Neolithic populations to move from their locations, with particular attention to the consequences of environmental features on the first human settlements on the Aeolian islands.

1. Fission-track dating in archaeology

Fission-track dating (FTD) is a radiometric technique that has been used for dating both very old samples (e.g., meteorites) and younger specimens (e.g., artifacts from archaeological sites). The nuclear fission of uranium within minerals creates damage trails, the fission tracks, that can be etched and observed with an optical microscope [1]: 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 the ^{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. This method was developed in the 1960s: the first fission tracks (FT) were observed in 1959 by means of an electron microscope and in 1962 a chemical method to enlarge the tracks was discovered, allowing their observation using an optical microscope.

A wide variety of minerals, natural and artificial glasses have been dated through fission-track method; as far as obsidian dating is concerned, the fission-track technique has proved to be useful for dating young obsidian artefacts owing to their high uranium content, allowing source identification and provenance studies [2]. Obsidian is a naturally occurring volcanic glass formed when lava extruded from a volcano cools rapidly with minimal crystal growth. As material sources are few and well known, obsidian artifacts are considered some of the earliest evidence of commerce; moreover, differences in the trace elements in each volcanic source let archeologists trace the origin of individual obsidian artifacts and reconstruct trade routes. Indeed, during the first decades after the setting of the FTD method, fission-track dating of obsidian has assisted provenance studies of prehistoric artifacts and the chronological study of related volcanic activity. Intense investigations have been carried out in the Mediterranean and other regions [3], comprehending also Aeolian Islands [4], but lately this technique become a prerogative of geochronology studies [5].

2. Prehistorical Obsidian Sources in the Island of Lipari (Aeolian Islands)

The present work is a small part of the project "Lipari obsidian and Neolithic human communities in the Aeolian islands", started in 2018 as a collaboration between several Italian research institutes. Its aim is to study the connection between obsidian flows from Lipari Island (see figure 1) and the Neolithic populations of the Aeolian Archipelago (Italy) [6], approaching the problem from different perspectives. The starting point is the in-depth analysis of former archaeological studies on the Lipari obsidian; on these bases, new dating by Radiocarbon on charcoals remains have been made on Neolithic settlements, and sampling and analysis of supply sources and obsidian tools through NAA (neutron activation analysis) and XRF (X-ray fluorescence spectroscopy) will support FTD. This challenging project is thus a good occasion to focus again on a very powerful technique, lately so few applied in the archaeological field, gathering the geological and historical aspect of the research. On this occasion, the FTD laboratory at the University of Milan Department of Physics "Aldo Pontremoli" has been rearranged and its activity has re-started; currently, it is one of the few FTD laboratory working on archaeological materials worldwide.

Figure 1. Localization of Aeolian archipelago in southern Tyrrhenian Sea.

3. FTD of obsidian from Aeolian Neolithic settlements

Geological (raw materials) and archaeological samples were selected, in order to study the connection between obsidian flows on the island of Lipari and Neolithic populations on the Aeolian archipelago. Geological samples were identified by the geographical coordinates, while archaeological ones were selected among obsidian artefacts from Neolithic sites. The field sampling of geological materials was conducted in March 2018, May and October 2019 and comprehend obsidian blocks collected in various pyroclastic deposits and lava flows, and obsidian fragments collected by pyroclastic deposits, relating

to dated volcanic phase [7]. More in detail [6], geological samples were collected in pumice formations linked to Vallone Bianco eruptive phases at Vallone Bianco (dating 7.17ky [8], Pomiciazzo-Gabellotto (dating 8.6 ky [7]) and Canneto Dentro (no previous dating), as these eruptions are supposed to have originated the obsidian used in the Neolithic period. The archaeological group includes some waste artefacts, such as splinters and blades, found in the Neolithic settlements of Lipari island and covering a total period from 5500 to 4000 BC. For each location, more than one fragment was collected (see figure 2 as an example).

Figure 2. Archaeological samples from Salina island (sample MU9, see table 2).

This selection was though to give a general vision of both archaeological and volcanological aspects through the stratigraphic and radiometric dating of eruptions which produced obsidian, in relationship with the first phases of the human settlements and row material exploitation, casting light over the chronology of specific stratigraphic units of sites and lava flows. To this end, a subset of both geological and archaeological available samples was considered for first FTD investigations, which details are reported respectively in table 1 and table 2.

Table 1. Geological samples submitted to FTD analysis

Sample code	Sampling area	GPS coordinates
LIP4	Vallone Fiume Bianco	38°29’44’’N; 14°56’2’’ E
LIP7	Vallone Gabellotto	38°29’42’’N 14°57’24.839’’E
LIP9	Rocche Rosse	38°29’40.2’’N 14°57’28.44’’E
LIP11	Forgia Vecchia	38°29’18.24’’N 14°57’39.96’’E
LIP13A	Gabellotto	38°29’37.68’’N 14°57’29.129’’E
LIP14	Lami	

Table 2. Archaeological samples submitted to FTD analysis

Sample code	Sampling Neolithic sites	Excavation year
MU2	Lipari contrada Diana	1953
MU4	Lipari Castellaro	1957
MU9	Salina Rinicedda	2008
MU10	Salina Rinicedda	2008
MU12	Salina Rinicedda	2008
MU13	Salina Rinicedda	2008
MU14	Lipari, Canneto-Acquacalda	1977

3.1 Method

Each obsidian sample has been divided in two fractions, one of which was irradiated at the TRIGA Mark II Research Nuclear Reactor of the LENA Laboratory (University of Pavia, Italy). Standard glasses, together with mica foils acting as external detectors, were also irradiated for thermal neutron flux determination. The irradiated and non-irradiated fraction of obsidian samples have been then etched and mounted in epoxy resin for track counting [9] under the microscope. Etching was performed with HF in monitored conditions and samples were observed with total 500x magnification for spontaneous and induced fission track identification and counting. This procedure allowed to get the density of fossil and neutron induced tracks and therefore the age of obsidian source and artefacts. Analyses of obtained results are still in progress.

4. Conclusions

The research project here presented concerns the study, analysis and dating of obsidian flows on the island of Lipari, in relation to the Neolithic settlements of the Aeolian Islands. Collecting and processing obsidian characterize the Neolithic population of Lipari, together with the subsequent diffusion of artifacts in the entire Mediterranean. The improvement of the knowledge about the obsidian supplying in the territory makes possible to speculate about the chronology of the sources and the way of collecting raw materials: both aspects are linked to the mobility of the Neolithic communities in the Aeolian Islands that will be better defined thanks to the synergy between archaeological aspects and geological studies.

References

[1] Price P B and Walker R M 1962 Chemical Etching of Charged-Particle Tracks in Solids *Journal of Applied Physics* 33, p. 3407
Price P ., Walker R M Fossil tracks of charged particles in mica and the age of *minerals Journal of Geophysical Research* Volume 68, Issue16 Pages 4847-4862 1963 https://doi.org/10.1029/JZ068i016p04847
Fleischer R L, Price P BTechniques for geological dating of minerals by chemical etching of fission fragment tracks *Geochimica et Cosmochimica Acta* Volume 28, Issues 10–11, October–November 1964, Pages 1705-1712, IN3-IN21, 1713-1714

[2] Bonetti R, Di Cesare P, Guglielmetti A, Malerba F, Migliorini E, Oddone M, Bird J R, Torrence R, Bultitude R J 1998 Fission track dating of obsidian source samples from the Willaumez Peninsula, Papua New Guinea and eastern Australia *Record of the Australian Museum* 50, 277
R. Bonetti, A. Guglielmetti, F. Malerba, E. Migliorini, M. Oddone, R. Bird "Age determination of obsidian source samples from North Queensland and New South Wales, Australia" in "Advances in Fission-Track Geochronology" Kluver Academic Publishers, 1998
Bonetti R, Bongiorno L, Guglielmetti A 1995 L'uso delle tracce di fossili di fissione nella datazione di ossidiane *Rendiconti dell'Istituto Lombardo Accademia di Scienze e Lettere* Milano

[3] Bigazzi G, Bonadonna F P and Radi G. 1982. Fission track dating of Obsidian and Prehistory. *Workshop track dating, Abstracts. Fifth* International Conference on Geochronology, Cosmochronology and Isotope Geology. Nikko National Park Japan, 30 June 1982, pp 1-4
Bigazzi G, Màrton P, Norelli P, Rozložnik L Fission track dating of Carpathian obsidians and provenance identification *International Journal of Radiation Applications and Instrumentation. Part D. Nuclear Tracks and Radiation Measurements* Volume 17, Issue 3, 1990, Pages 391-396
Bigazzi G, Ercan T, Oddone M, Özdoğan M, Yeğingil Z 1993 Application of fission track dating to archaeometry: Provenance studies of prehistoric obsidian artifacts, *Nuclear Tracks and Radiation Measurements* Volume 22, Issues 1–4, Pages 757-762

[4] Bigazzi G, Bonadonna F P 1973 Fission Track Dating of the Obsidian of Lipari Island (Italy) *Nature*, Vol.242(5396), p.322-323 DOI: 10.1038/242322a0

[5] Westgate J A, Naeser N D, Alloway B V 2013 Fission-Track Dating *The Encyclopedia of Quaternary Science*, 2nd edition. (Amsterdam: Elsevier)

[6] Martinelli M C, Coltelli M, Manni M, Bonizzoni L, Guglielmetti A, Oddone M, Balestrieri M L

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[7] Forni F, Lucchi F, Peccerillo A, Tranne C A, Rossi P L and Frezzotti M L 2013 Stratigraphy and geological evolution of the Lipari volcanic complex (central Aeolian Archipelago). In F.Lucchi, A. Peccerillo, J. Keller, C.A. Tranne, & P. L. Rossi (Eds.), *The Aeolian Islands Volcanoes* (pp. 213–279). London: The Geological Society. https://doi.org/10.1144/M37.10

[8] Bigazzi G, Coltelli M, Norelli P 2003 Nuove età delle ossidiane di Lipari determinate con il metodo delle tracce di fissione - GeoItalia, 4th Forum FIST, Bellaria, 2003

[9] Hurford A J, Green P F 1982 A users' guide to fission track dating calibration. *Earth and Planetary Science Letters*, *59*(2), 343-354.