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Obsidian and volcanic glass shards: Characterization and provenancing

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Obsidian is a volcanic product that forms under particular geological conditions, and hence occurs in limited areas of the Earth. In ancient times, obsidian was used successfully by various peoples to produce artistic artefacts, but also to make tools and weapons used in everyday life. For this reason, obsidian was transported from geological sources to other locations. The study of methods used to identify the provenance of obsidian artefacts has become crucial for understanding commercial relations between distant ancient populations. Other volcanic products, generally associated with obsidian, are volcanic glass shards. Glass shards were used in Mexico as aggregates to produce plasters, and recent studies have shown that they were also transported along commercial routes. This chapter presents an introductory overview of the sources of obsidian in the Tyrrhenian area, showing how minor, trace and rare earth elements can be used to solve provenance problems. A case study regarding the provenance of glass shards inside archaeological plasters taken from Teopacazco (Teotihuacan, Mexico) is also presented.

1. Introduction

Obsidian is a volcanic glass, generally aphyric and chemically homogeneous, formed from a rapid solidification of rhyolitic magma. Because of its properties, such as fracture predictability and exceptional cutting-edge quality, obsidian was an important raw material extracted and processed to produce blades, razors, knives and weapons before the discovery of metallurgy. The importance of obsidian in human history is also testified by the diffusion of obsidian tools in most archaeological contexts. Each source of obsidian has a distinct chemical fingerprint, and obsidian artefacts are chemically stable on an archaeological time-scale; hence, the chemical characterization of obsidian artefacts is central to studies focused on long-distance trade and the development of market systems.

Although the major-element composition of obsidian from different origins may present some variability that could help to identify their geological provenance, trace-element concentrations, which vary strongly from source to source, allow a sound discrimination of sources and identification of obsidian raw material used for artefacts.

To characterize geochemically obsidian for archaeometric purposes, non-destructive analytical techniques are preferred, such as X-ray fluorescence (XRF) applied in a non-

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destructive way, proton-induced X-ray emission (PIXE), neutron activation analysis (NAA) and scanning electron microscopy (SEM). Among the various techniques applied by researchers for provenance studies, Laser Ablation-Inductively Coupled-Plasma Mass Spectrometry (LA-ICP-MS), a micro-destructive analytical methodology, has also proved to be a powerful tool for *in situ* determination of trace-element patterns in archaeological obsidian fragments.

Recent studies have also shown that other techniques, such as portable-XRF (pXRF) and Raman micro-spectroscopy, have have also been deployed for obsidian analyses. In particular, pXRF analysis combines non-destructivity with rapidity, and can be done also within museums (Craig *et al*., 2007; Millhauser *et al*., 2011; Forster and Grave, 2012; Tykot *et al*., 2013). Raman micro-spectroscopy can also be considered to be a promising tool to determine the provenance of the obsidian (Bellot-Gurlet *et al*., 2004; Carter *et al*., 2009).

The aim of this chapter is to give a brief overview of the geochemical characteristics of obsidian sources in the Tyrrhenian area, focusing on the geochemical differences that can discriminate among source areas and establish their provenance for archaeometric purposes. In addition, the study will focus on the provenance of volcanic glass shards of rhyolitic composition (Barca *et al*., 2013) which are used as an aggregate in the plasters of Teotihuacan (the so called "City of Gods"), the main city in Central Mexico during the Classic Period (200–600 AD). The comparison between the data from the analyses of the shards in the floor plasters and the data from all Mexican obsidian outcrops has allowed us to identify the magmatic systems exploited by Mesoamerican peoples.

Hence, this chapter will show that the study of provenance is a powerful tool for testing models regarding prehistoric trades, people's interactions and access to resources.

2. The origin and geochemical classification of obsidian

Obsidian is the name given to a glassy rock formed from a polymerized silicate melt that was cooled too rapidly for crystallization to occur (Best, 2003). Obsidian is usually dark in colour; however, because of the presence of impurities and the variable iron and magnesium contents, it can occur in different shades of colour varying from grey-green to black. Rare obsidian samples show a mixture of deep purple and black.

Obsidian composition is extremely felsic, usually with 70% or more of SiO_2. The oxide percentages of other major element (Al_2O_3, Na_2O, K_2O and CaO) and the trace- and rare earth -element (*REE*) contents vary significantly among the various geological sources; for this reason, the chemical characterization of obsidian can be used to discriminate among them and is particularly productive in the provenance research field (Cann and Renfrew, 1964; Crisci *et al*., 1994; Tykot, 1997; Acquafredda *et al*., 1999).

The most common analytical methods employed to characterize obsidian are partially destructive and, thus, cannot always be used for archaeometric research. Even non-destructive methods such as XRF applied in a non-destructive way, PIXE, NAA and SEM have various limitations related to the shape of the surface, the size or the weight of the object studied, and it is sometimes impossible to determine the concentrations of all the elements which are useful for identifying the various obsidian sources for archaeometric purposes. The LA-ICP-MS technique combines micro-destructivity with the capacity to analyse a great number of trace elements and *REE* with high sensitivity in a very short time. The only limitation is that the sample size must be compatible with the ablation cell (Barca *et al*., 2007, 2012).

Although natural, massive, high-silica glass (or obsidian) in hand specimen often appears to have zero crystallinity, few natural glasses do not contain any crystals at all (Best, 2003). Indeed, high magnification almost always reveals that obsidian contains crystallites. The nature of these microphenocrysts can also be used to discriminate obsidians from different sources (Acquafredda *et al*., 1999).

3. Distribution and geochemical characteristics of obsidian sources in the Mediterranean area (the peri-Tyrrhenian)

In the Western Mediterranean, only four islands are known to have obsidian sources likely to have been exploited in Neolithic times: Lipari, Palmarola, Pantelleria and Sardinia (Fig. 1) (Barca *et al*., 2007, 2008; De Francesco *et al*., 2008; Tykot, 1997, 2002).

3.1. Lipari

With an area of 37 km^2, Lipari is the largest of the Aeolian Islands (Aeolian Archipelago, Southern Tyrrhenian Sea). The subaerial volcanic activity on Lipari started 223 ka ago with the emission of mafic products (Gillot and Villari, 1980), and ended in 1230±40 AD with the emplacement of the Rocche Rosse rhyolitic lava flow (Tanguy *et al*., 2003). Rhyolites are characteristic of volcanic events younger than 42 ka. The early rhyolitic subaphyric products belong to the Valle Muria Synthem (42–20 ka; Tranne *et al*., 2002). The renewal of the activity is dated at 10 ka, with pyroclastic surges and obsidian lava flows of the Vallone Fiume Bianco Synthem. During historical times, an unusual Strombolian-type explosive activity formed the Monte Pilato pumice cone, followed, in 1230 AD, by the Rocche Rosse eruption.

The early rhyolitic products cover large areas in the southern part of the island, whereas those erupted during the youngest phase of activity dated at 10 ka cover almost the whole northeastern part of Lipari. Considering the age of the rhyolitic products, the obsidians erupted in historical times (ForgiaVecchia and Rocche Rosse) were not available for exploitation in prehistoric time. For this reason, only older obsidian may have provided raw material for Neolithic artefacts (Buchner, 1949; Pichler, 1980; Bigazzi and Bonadonna, 1973; Cortese *et al*., 1986; Gillot and Cornette, 1986; Lefèvre and Gillot, 1994). In addition, analyses conducted by fission-track on 66 archaeological obsidian samples indicate that Vallone Gabellotto (Fiume Bianco) was the main outcrop exploited in the past (Arias-Radi *et al*., 1972; Bigazzi and Radi, 1981; Arias *et*

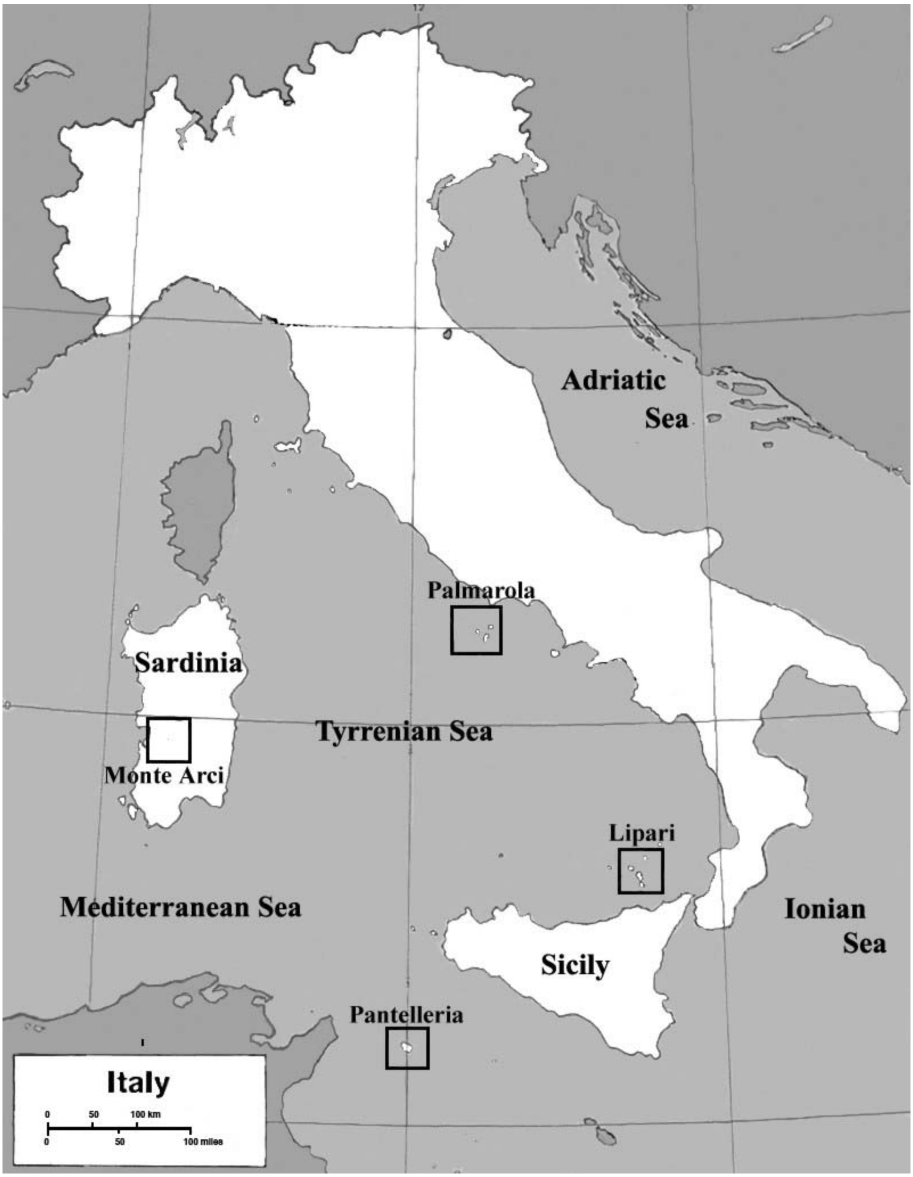

Figure 1. Locations of obsidian outcrops (squares) in the peri-Tyrrhenian area.

al., 1986; Tykot *et al*., 2013). In addition, a recent study published by Forni *et al*. (2013) on the geological evolution of the Lipari volcanic complex, examines the various eruptions that produced obsidian, and highlighted the importance of the outcrops at Gabellotto and Canneto Dentro.

The Lipari obsidian has a composition varying from alkali-rhyolite to rhyolite with calcalkaline affinity; these geochemical characteristics led scientists to correlate Aeolian volcanism with the subduction of the Ionian Plate below the Calabrian Arc (Beccaluva *et al*., 1982; Ellam *et al*., 1989). Nevertheless, recent works have suggested that the geochemical evolution of the magmas could reflect the transition from collisional volcanism to post-collisional/rifting volcanism (Crisci *et al*., 1991; De Astis *et al*., 2003).

Lipari obsidian is of excellent quality, black in colour, very shiny and sometimes perlitic. It is generally subaphyric and contains clinopyroxene micro-phenocrysts (10−50 m), almost always in synneusis with magnetite and olivine micro-phenocrysts (Acquafredda *et al*., 1999).

3.2. Sardinia: Monte Arci

In Sardinia, obsidian crops out only at Mt Arci, a volcanic complex covering ~30 km^2 and located in the hinterland of the gulf of Oristano. The volcanic activity developed during two distinct cycles in the Pliocene and Pleistocene, and therefore it belongs to the latest volcanism in Sardinia. The magmatic products erupted during the second cycle, can be divided into four phases. The lavas erupted in the first phase were very rich in silica, and consisted mainly of rhyolites, either massive or perlitic-obsidianaceous. Dacites and andesites, trachytes and trachyrhyolites followed in chronological succession, until the last stages of volcanic activity, which were characterized by quiet eruptions of basaltic lava flows (Piras, 2002; Bigazzi *et al*., 2005).

The obsidian outcrops were described for the first time in the 19^{th} century by De La Marmora (1839−40). Subsequently, in the 1980s, several independent studies contributed to the characterization of the multiple Monte Arci obsidian outcrops. Unfortunately, the results of these studies are available only in brief conference papers (Francaviglia, 1986; Mackey and Warren 1983) or in an unpublished dissertation (Herold, 1986).

More recently, considering the geochemical features the obsidian of Monte Arci, Tykot (2002) subdivided them into four groups, SA, SC, SB1 and SB2. The obsidian sampled near Conca Cannas and Uras are clustered within the SA group; those sampled near Pau, Perdas Urias and Sonnixeddu belong to the SC group; those sampled at Santa Maria Zuarbara and Marrubiu are in the SB1 and SB2 groups, respectively (Tykot, 2002; Barca *et al*., 2007; De Francesco *et al*., 2008). Due to their geochemical similarity, SB1 and SB2 have been grouped under the name SB in the present study.

Monte Arci obsidian populations are characterized by large biotite micro-phenocrysts (50−200 μm), abundant crystals of feldspar (plagioclase and alkali feldspar) 50 μm in size, orthopyroxene, magnetite, monazite and ilmenite (Acquafredda *et al*., 1999).

3.3. Palmarola

Palmarola is a small volcanic island (<3 km^2 in area) located in the western part of the Pontine Islands Archipelago in the Gaeta Gulf. Its volcanic activity can be related to the stretching of the Tyrrhenian Sea (De Rita *et al*., 1989; Acquafredda *et al*., 1999). Obsidian crops out in the southern part of Mt Tramontana, as a domal crust crossing the island from Il Porto to Scoglio Spermatore and on the eastern coast. In addition, abundant secondary obsidian deposits have been identified on the southeastern edge of the island at Punta Vardella (Buchner, 1949; Herold, 1986).

Geochronological data, obtained by fission-track analyses, indicate an age of 1.7±0.3 Ma for obsidian from Monte Tramontana (Bigazzi *et al*., 1971; Bigazzi and Radi, 1981). In a recent work Tykot *et al*. (2005) provided a detailed geochemical study of 80 samples, and were able to distinguish three source localities: Punta Vardella, the northern end of Punta Vardella and Monte Tramontana. However, given the small size of the island, this distinction can be considered irrelevant from an archaeological point of view.

Palmarola obsidian contains micro-phenocrysts of clinopyroxene (5−20 μm) and biotite. It is generally black in colour, glassy, poorly shiny and semi-opaque (Acquafredda *et al*., 1999). However, a small amount of highly transparent obsidian was found at Punta Vardella by Tykot *et al*. (2005).

3.4 Pantelleria

Pantelleria, a small island of ~83 km^2, is located in the NW−SE part of the Sicily Channel Rift Zone (SCRZ), ~90 km east of Cape Bon, Tunisia. Pantelleria is famous for its peralkaline rocks, and especially for its greenish obsidian enriched in sodium and iron, known as Pantellerite (Civetta *et al*., 1998; Acquafredda *et al*., 1999). Pantelleria has a bimodal distribution of magmatic products. Mafic lavas, exposed in the NW corner of the island, include transitional basalt and hawaiite (from ~46 to 49 wt.% SiO_2). Felsic lavas and tuffs, which include metaluminous trachyte, peralkaline trachyte and pantellerite (from ~62 to 72 wt.% SiO_2), prevail in the SE sector (White *et al*., 2009). K−Ar determinations of mafic lavas done on different basaltic units give ages of 118 ± 9, 83 ± 5 and ~29 ka BP (Civetta *et al*., 1984). Ages determined on felsic volcanic rocks range from 324 ka BP to 4 ka BP (Civetta *et al*., 1984, 1988, 1998; Mahood and Hildreth, 1986). The volcanic history of the island is characterized by large explosive eruptions, some of which produced caldera collapses, alternating with periods dominated by less energetic eruptions (Civetta *et al*., 1998). The oldest caldera, named La Vecchia, is dated at 114 ka BP (Mahood and Hildreth, 1986); the youngest caldera, named the Monastero caldera by Cornette *et al*. (1983) and the Cinque Denti caldera by Mahood and Hildreth (1983), is related to the eruption of the Green Tuff (50 ka BP; Orsi and Sheridan, 1984). The more recent (post-50 ka) history of the island has been subdivided by Civetta *et al*. (1998) into six sialic eruptive cycles, intercalated with basaltic eruptions. The Green Tuff is considered the first of these six cycles. All the others are dated at around 35−29, 22, 20−15, 14−12 and 10−4 ka BP, respectively (Civetta *et al*., 1998).

Francaviglia (1988) distinguished five groups of Pantelleria obsidian, which are characterized by different chemical compositions: three of the groups are from "vertically differentiated" mines exposed at Balata dei Turchi; the other two are in Gelkhamar and Lago di Venere. Chemical analyses of artefacts from Pantelleria, Malta and Sicily showed that the upper Balata dei Turchi mine (*i.e*. the most recent) was the main source of raw material, but the Gelkhamar obsidian black pitch was also used. Finally, the lower (*i.e*. at sea level) obsidian from Balata dei Turchi was not used for tool-making, at least during the Bronze Age (Francaviglia, 1988; Francaviglia and Piperno, 1987; Tykot, 1995, 1996; Tykot *et al.*, 2013).

Obsidian from Pantelleria is grey-greenish in colour, mildly shiny and transparent and easily distinguishable from other European obsidian by its peculiar colour. Samples are generally poor in micro-phenocrysts, which comprise relatively large crystals of anorthoclase (50−150 μm) and apatite; clinopyroxene, magnetite and olivine are also present (Acquafredda *et al*., 1999).

4. Provenance studies of archaeological obsidian in Italian Neolithic settlements

As stated peviously, obsidians can be distinguished on the basis of their chemical compositions. A large spectrum of techniques is generally used in order to determine such compositions and a great number of elements is determined ranging from major to minor, trace and rare earth.

Figure 2 shows the results obtained by Acquafredda *et al*. (1999), De Francesco *et al*. (2008) and Tykot (2002) on obsidian samples from different localities in the Tyrrhenian Sea; they are plotted on an alkalies *vs*. silica diagram (Le Bas *et al*., 1992). Lipari, Palmarola and Monte Arci (the SA, SB and SC groups, respectively) show similar silica and alkali contents; Pantelleria is characterized by higher alkali and lower silica contents than the other sources.

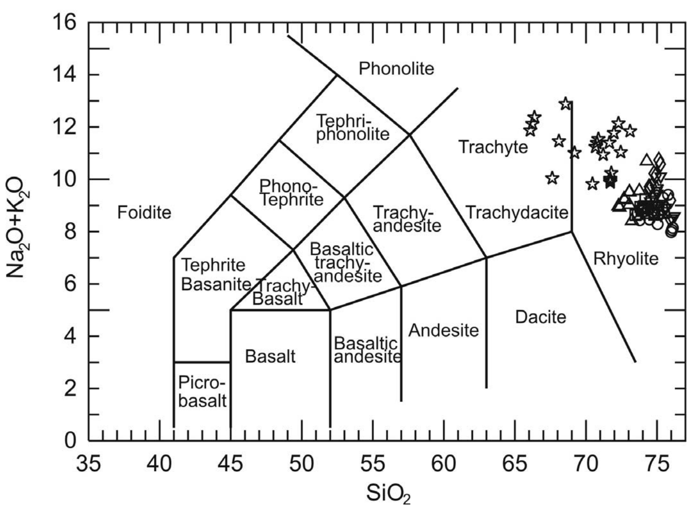

Figure 2. Total alkalies-silica diagram (Le Bas *et al*., 1992) of obsidian cropping out around the Tyrrhenian Sea. Data from Acquafredda *et al.* (1999), De Francesco *et al.* (2008) and Tykot (2002) are also plotted. Inverted triangles: Lipari; diamonds: Palmarola; stars: Pantelleria; circles: SA Mt Arci; squares: SB Mt Arci; triangles: SC t Arci.

In contrast, trace- and rare-earth-element compositions are extremely discriminatory and allow a precise separation of the sources. The binary diagram Zr/Y *vs*. La (Fig. 3) can be used to distinguish the six sources accurately. The diagram was constructed from data collected by Barca *et al.* (2007) and Tykot (2002), using different analytical techniques. Obsidians from Lipari and Palmarola show compositional homogeneity within their respective groups; obsidians from Pantelleria and from the other three groups belonging to the Monte Arci complex in Sardinia show a major dispersion of the data, but they are easily differentiated from one another, with significant variations among trace-element concentrations. A good discrimination of all geological sources (Lipari, Palmarola and Monte Arci SA, SB and SC groups) can also be obtained using the Aitchison approach to the geostatistical analysis of compositional data (Aitchison, 1982, 1983, 1986), by transforming the data in centred-log-ratio (clr). An example is shown in Fig. 4, where a three-dimensional scatterplot of the clr concentrations of Ce, Ba and Sr is plotted.

5. The obsidian sources in Mesoamerica

The Mesoamerican region is characterized by numerous obsidian-rich volcanoes. In detail, the area is dominated by the presence of two important volcanic provinces: the volcanic succession of the Sierra Madre Occidental (SMO) and the Trans-Mexican Volcanic Belt (TMVB) (Ferrari *et al*., 1999, 2005). The SMO is an ~1000 m thick succession, dominated by silicic ash flows, emplaced during the Eocene, Oligocene and Early Miocene.

The TMVB is a volcanic arc built on the southern edge of the North American plate. It runs east-west across Mexico (Ferrari *et al*., 1999) and was formed in response to subduction of the Cocos plate along the Acapulco trench beginning in the Middle Miocene (Ferrari *et al*., 1999). The TMVB volcanism is characterized by a wide range

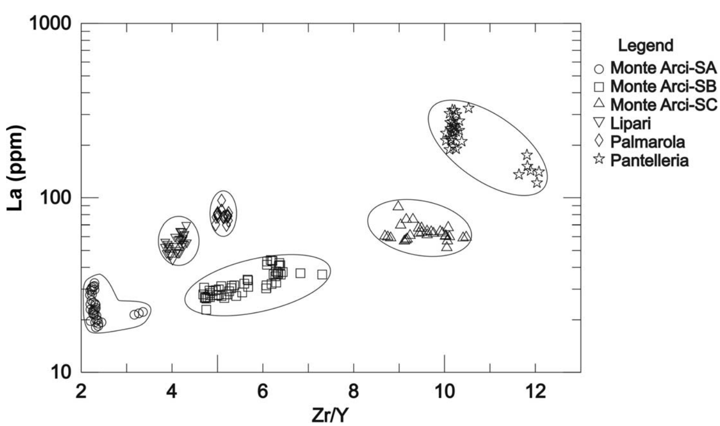

Figure 3. Zr/Y *vs*. La binary diagram for obsidian cropping out around the Tyrrhenian Sea. The diagram was drawn using data provided by Barca *et al*. (2007) and Tykot (2002).

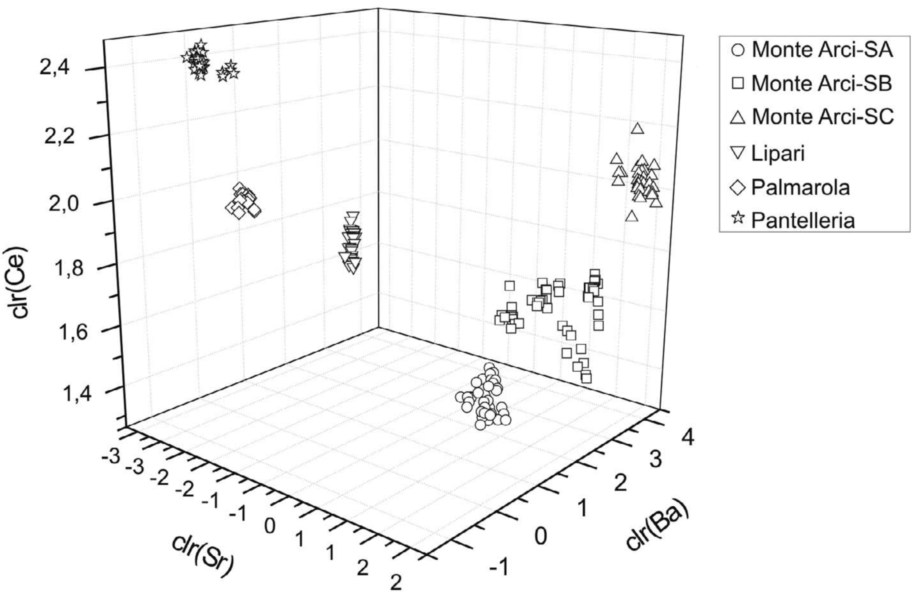

Figure 4. Three-dimensional scatterplot of the clr of the concentrations of Ce, Ba and Sr. The diagram was drawn using data provided by Barca *et al*. (2007) and Tykot (2002).

of chemical compositions. The emplacement of large volumes of rhyolites and minor ignimbrites occurred during the second magmatic episode between 8 and 5 Ma (Ferrari *et al*., 1999).

The complexity of the area is far greater in eastern Mexico; in Central Veracruz, products of alkaline volcanism (called the Eastern Alkaline Province) alternate with arc-related lavas (Ferrari *et al*., 2005). The extinct late-Pliocene peralkaline volcanic centre of Sierra de Pachuca crops out at the northern edge of the eastern TMVB (Lighthart Ponomanenko, 2004).

The rhyolitic components are interesting from an archaeological point of view, because they are often associated with obsidian lavas, exploited extensively by the Pre-Hispanic inhabitants of Mesoamerica.

Considering the rarity of obsidian in the world, the abundance of source zones in a relatively restricted area is of great interest from both geological and archaeological perspectives. In particular, the identification of the major obsidian sources in Central Mexico and their geochemical characterization has provided a database to be used for archaeological specimens (Cobean *et al*., 1991; Cobean, 2002; Carballo *et al.*, 2007; Gazzola *et al*., 2010; Barca *et al*., 2013).

Using Instrumental Neutron Activation Analysis (INAA), Cobean *et al.* (1991) provided high-precision trace-element analyses of 208 geological samples collected from 25 Mesoamerican obsidian sources. Based on their geographical distribution, the Mexican sources can be divided into two groups: (1) sources cropping out on Mexico's

Gulf Coast (Pico de Orizaba Veracruz, Altotonga Veracruz, Guadalupe Victoria Puebla, Derrumbadas Puebla, Zaragoza Puebla and Oyameles Puebla); and (2) sources cropping out in Central Mexico (Sierra de Pachuca Hidalgo, Tulancingo and Rancho Tenango Hidalgo, Paredon, Zacualtipan, Otumba State of Mexico, Zinapécuaro and Ucaréo Michoacan, Teuchitlan, Tequila and Magdalena Jalisco, Penjamo Guanajuato, El Paraiso and Fuentezuelas Querétaro; Fig. 5).

The abundance of outcrops in the area, as well as visual attractiveness and physical properties, made obsidian the raw material preferred by Mesoamerican inhabitants, who used it to make cutting tools such as knives, arrowheads and scrapers.

Nowadays, the different trace-element compositions observed in the different sources has allowed the reconstruction of trade routes and cultural exchange networks along which the materials and artefacts were transported (Cobean *et al*., 1991; Cobean, 2002; Carballo *et al*., 2007; Barca *et al*., 2013). In particular, an interesting study on obsidian procurement in Central Mexico has been conducted by Carballo *et al.* (2007). Firstly, these authors determined the chemical composition of the majority of Mexican obsidian sources using LA-ICP-MS. Secondly, they characterized the obsidian finds from four archaeological sites, and assigned a provenance to each sample. Among the

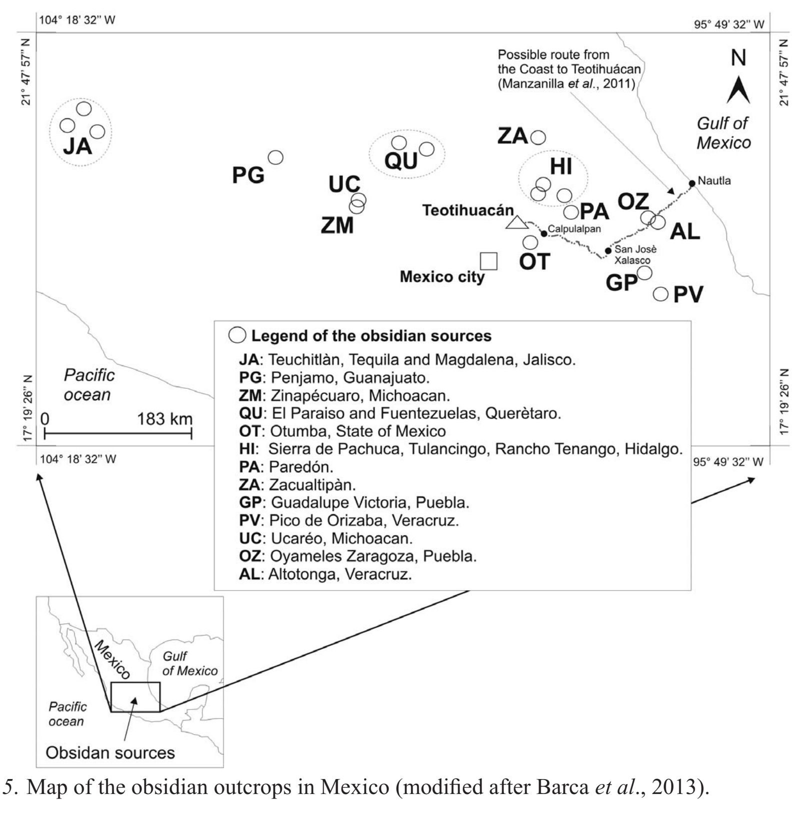

Figure 5. Map of the obsidian outcrops in Mexico (modified after Barca *et al*., 2013).

archaeological sites studied, three were rural villages of a few hectares, known as Amomoloc (900–600 BC), Tetel (700–400 BC) and Las Mesitas (500–350 BC), which are located in the modern state of Tlaxcala. The fourth is Teotihuacan, the most important city during the Classic Period (AD 350–550), which is located 45 km NE of Mexico City.

The study demonstrates a variable exploitation of the sources among the villages. It was extremely flexible at Amomoloc, including five or six quarries in both Central and Oriental source regions. The inhabitants of Tetel also collected obsidian from five different sources, but their procurement was focused on the source of Paredon. In the site of Las Mesitas, the exploitation of Central sources was conducted similarly, and Paredon was the preferred source. Finally, in Teotihuacan, 95% of obsidian was acquired from sources in the Central area and the favourite sources were Otumba, Pachuca and Tulancingo (Carballo *et al*., 2007). A further study conducted by Gazzola *et al*. (2010) on the use of obsidian in the pre-Hispanic city of Teotihuacan, confirmed that Teotihuacan controlled the two largest obsidian sources in Central Mexico: Otumba, which was located 10 km from the city and provided grey obsidian and Sierra de Pachuca (also known as Sierra de las Navajas), which was located 50 km from the city and was famous for green obsidian (Fig. 6).

6. Obsidian as a raw material in Mesoamerica – a particular case: the use of volcanic ash as an aggregate in plasters

Research carried out on Teotihuacan have shown that obsidian raw materials and hand-made products were valuable goods. Their circulation represented the main aspect of the economic and social development of the city. In addition, obsidian was a central

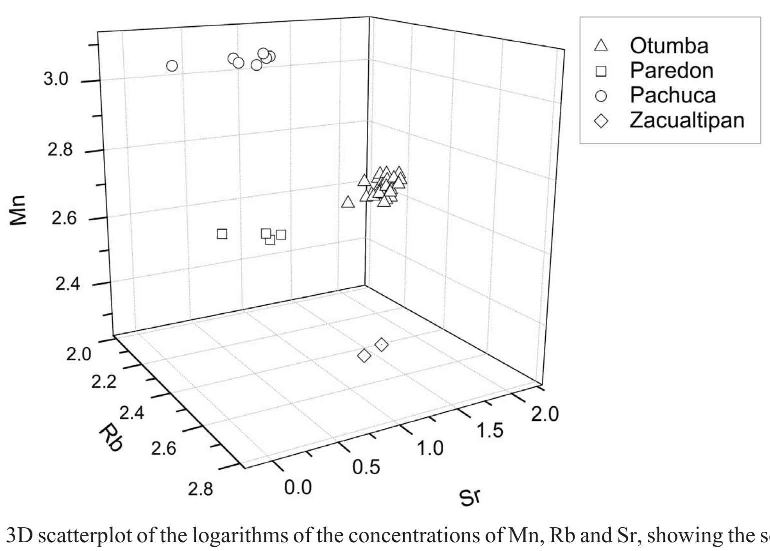

Figure 6. 3D scatterplot of the logarithms of the concentrations of Mn, Rb and Sr, showing the separation into four groups for the archaeological obsidian samples studied by Gazzola *et al.* (2010). Modified.

component in political rituals and it was essential for the arming of the city's military forces (Carballo, 2011).

Recent studies have shown also that people from Teotihuacan appreciated other types of volcanic material. Indeed, the study carried out in the courtyard of Teopancazco, a neighbourhood centre of Teotihuacan, has shown that volcanic glass shards of rhyolitic composition were used to produce plasters (Barba *et al*., 2009; Murakami, 2010; Barca *et al*., 2013).

Aiming to identify the provenance of glass shards used as an aggregate in plasters, Barca *et al*. (2013) compared their composition with those of obsidian from various sources. This comparison was justified by the authors by assuming that the same magma that produced obsidian lava flows could also generate pyroclastic deposits, rich in glass shards, during an explosive eruption. In order to obtain accurate analyses on micrometric glass shards within the plasters, two analytical techniques were used: SEM-EDS (scanning electron microscopy coupled with energy-dispersive X-ray spectrometry) and LA-ICP-MS. As stated above, Carballo *et al.* (2007), Gazzola *et al*. (2010), Pastrana (1998, 2010) and Spence (1981) identified the sources of Otumba and Sierra de Pachuca as those preferred for Teotihuacanos. Based on these previous studies, Barca *et al.* (2013) had hypothesized that the source material for glass shards was probably related either to the magmatic system of Otumba or Sierra de Pachuca. Nevertheless, comparison of the results obtained from the glass shards with the database of the geological obsidian sources, showed that the glass materials were collected from the magmatic system of Altotonga (Veracruz) although it is located 180 km. away from Teotihuacan along the route to the Gulf Coast (Fig. 5). In fact, the plot of Ba *vs.* Mn obtained by combining the analyses of the shards and bibliographic data from all Mexican obsidian outcrops (Fig. 7) shows clearly that the shards in the plaster samples are consistent with Altotonga (Veracruz). The authors propose two possible reasons to explain this choice. The first is technological: people from Teotihuacan appreciated the good quality of the Altotonga glass shards for plaster production. The second is, perhaps, symbolic: the inhabitants of Teopancazco wanted to build their compound with materials coming from the route they had followed from the Gulf Coast to Teotihuacan, tracing their identity to that distant land (Barca *et al*., 2013).

7. Reconstruction of an ancient route using obsidian

The acquisition of raw materials implies an accurate knowledge of the territory, and the movement needed to obtain them must be part of a network of routes also used for the acquisition of other resources required by the group. In the particular case of Teotihuacan, the results obtained by Gazzola *et al*. (2010) and by Carballo *et al*. (2007) support the idea that most of the obsidian artefacts found in that site were made of obsidian derived from the Otumba and Sierra de Pachuca sources. However, the results also indicate that some obsidian was obtained from other sources, such as Paredón (Puebla). Considering the presence of obsidian finds from other sources located on the way to Veracruz, Gazzola *et al*. (2010) suggested an early relationship with other

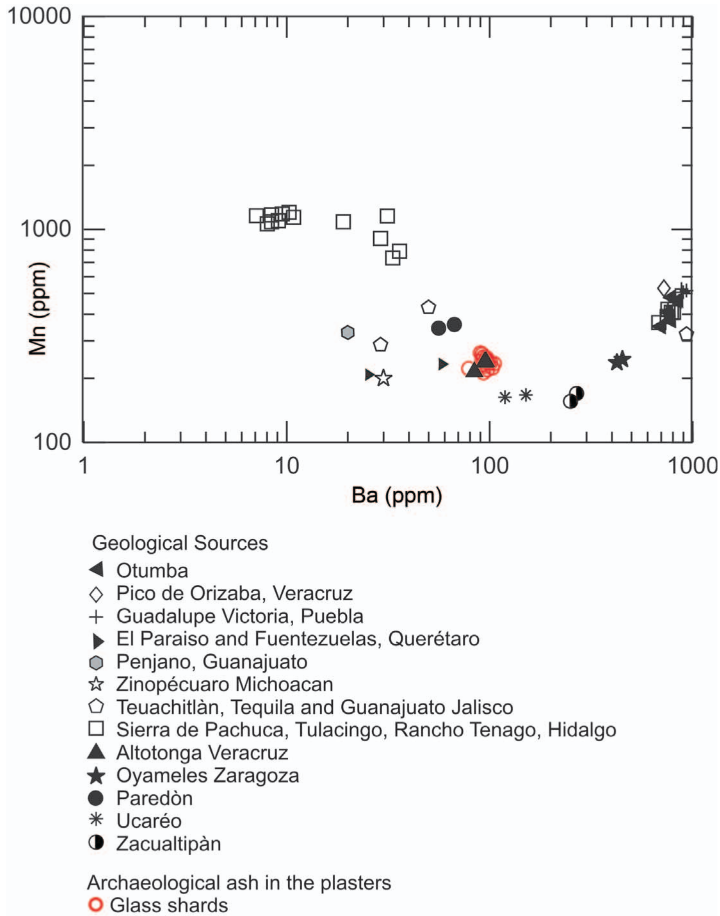

Figure. 7. Binary diagram Ba *vs*. Mn used to discriminate between the Mexican geological sources of obsidian. The diagram compares the data published by Carballo *et al*. (2007), Cobean *et al*. (1991), Cobean (2002) and Barca *et al.* (2013). The diagram shows that Altotonga (Veracruz) is the source of the glass shards within the plasters collected in Teotihuacan (modified after Barca *et al*., 2013).

communities inhabiting the Central Plateau, and an exchange of resources among these regions. In addition, they hypothesize the control exerted by Teotihuacanos on other sources, such as Zacualtipan and Paredón.

The evidence from the Teopancazco excavations indicates that there was an important link between Teopancazco and the Gulf Coast of Mexico (Manzanilla, 2011). Many archaeological materials recovered at the site, such as ornaments and garments, were produced with feathers, shells and other materials brought from the Gulf Coast. In addition, isotopic studies of human skeletons recovered at Teopancazco indicate the presence of people from the Gulf area, and from sites located along the corridor running from Teotihuacan to the coast (Manzanilla, 2012).

In general, these researches have revealed the close relationship between communities from Teopancazco and the Gulf Coast. In particular, the results obtained by Barca *et al*. (2013) suggested that people travelling from the coast to Teopancazco took glass shards from an Altotonga outcrop with them. The reason for using this material is still unknown. It is suggested that either they were aware of its properties or they used the material for symbolic reasons.

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