A prehistoric jade axe from Galicia (Northwestern Iberia): Researching its origin

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Abstract:

The Vilapedre axe (Lugo, Northwest Iberia) has been traditionally considered by archaeologists as evidence of prehistoric long-distance contacts along the Atlantic Coast of France and Spain. This artefact - as other “Tumiac type” axes (long polished blades, generally butt-perforated) - would have been produced in Brittany during the Neolithic (5th millennium BCE) using jadeitite as raw material, a green-coloured rock for which there are sources in the western Italian Alps. In this paper, we have traced the possible archaeological origin of this artefact back by examining the personal files of one of its first owners, Santiago de la Iglesia. Furthermore, we have conducted a mineralogical (X-Ray Diffraction, XRD) and an elemental analysis (Scanning Electron Microscopy with Energy Dispersive X-ray Detection, SEM-EDX) of both the Vilapedre axe and geological samples from several places at the Alps where prehistoric quarrying of greenstones has been reported. The aims were physicochemically characterizing the axe to provide information about its possible geological source. During our analyses, we have found significant compositional similarities between the Vilapedre axe and one of the geological samples coming from the Alps (Alp06). The results are therefore consistent with the alleged Alpine origin of this artefact. The presence of this axe in Northwest Spain, together with other evidence, such as the presence of objects of Iberian origin in Breton monuments, strongly suggests the existence of contacts between both regions of the Atlantic façade during the Neolithic onwards in which seafaring would undoubtedly have played an important role.

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1. Introduction

In 1908, Santiago de la Iglesia, a doctor and scholar interested in the prehistory and archaeology of Galicia (NW Iberian Peninsula), published a detailed account of his personal collection of archaeological artefacts (de la Iglesia 1908). The Vilapedre axe, a finely polished, butt-perforated greenstone axe head, stands out among the objects of such collection. The immediate parallels for this artefact, the so-called Tumiac axes, are found not in the Iberian Peninsula, but in Brittany (France), where they were produced during the local Neolithic (around the middle of the 5th Millennium BCE). More interestingly, the sources of the raw materials used for making such axes (jadeitite, omphacitite or fine-grained eclogite) are located in the Italian Alps, hundreds of kilometres away from both Brittany and Galicia (Pétrequin *et al*. 2012a).

For more than thirty years, the presence of this Tumiac type axe in Northwestern Spain has been listed by archaeologists as evidence for long-distance connections along the Atlantic facade of Western Europe during the Early Neolithic (Cassen *et al*. 2012; Fábregas Valcarce 1981; Fábregas Valcarce & Vázquez Varela 1982; Pétrequin *et al*. 2012b). The similar macroscopic features of the Vilapedre axe and Alpine natural samples (Errera *et al*. 2012) led one of us (P. P.) to argue for an origin in the South of Monviso massif (Cottian Alps), in the primary outcrops of Vallone di Porco, between 1700 and 2400 m a.s.l., or from the Pô river moraine -circa 400 m high (Pétrequin 2017).

In this paper, we have traced back the possible archaeological origin of this artefact by examining the personal files of one of its first owners, Santiago de la Iglesia. Furthermore, we have conducted a mineralogical (X-Ray Diffraction, XRD) and chemical composition analysis (Scanning Electron Microscopy with Energy Dispersive X-ray Detection, SEM-EDX) as well as a macroscopic analysis of the Vilapedre axe together with geological samples from the Alps, selected among the potential sources where prehistoric quarrying has been documented (Pétrequin & Pétrequin 2007; Pétrequin *et al*. 2012c). Our main objectives were:

- To characterize, from a macroscopic and analytical point of view, the composition of the Vilapedre axe and the geological samples.
- To compare the results obtained for both the archaeological and geological samples in order to elucidate the possible origin of the Vilapedre axe.

1.1. State of the art regarding the definition and analysis of Jade

The origin of the name jade seems to be that of the Spanish *"piedra de ijada"* ("loin stone"; Harlow *et al*. 2015) and it has been applied to different rocks, such as Na-pyroxenites, serpentinites, nephrites or minerals such as fibrolite, etc. Here, the term is used mainly for Na-pyroxenites. The "Na-pyroxenites" can be referred as jadeitites when they are composed mainly of jadeite, omphacitites when the omphacite is the predominant mineral, mixed jades when approximately equivalent amounts of jadeite and omphacite are present and "Na-pyroxene + garnet rocks" if garnets also occur (Giusteto & Compagnoni 2014).

Morimoto *et al*. (1988) reviewed the nomenclature of the pyroxene group of minerals according to the premises of the International Mineralogical Association; such review was slightly modified by Rock (1990) later on, who classified them based on their mineral formula. Morimoto and colleagues highlighted the Ca-Mg-Fe pyroxenes as one of the main subgroups: these can form a quadrilateral system (named Quad), whose vertices are occupied by diopside ($CaMgSi_2O_6$), hedenbergite ($CaFe^{2+}Si_2O_6$), enstatite ($Mg_2Si_2O_6$) and ferrosilite ($Fe_2^{2+}Si_2O_6$). These authors proposed a classification of the Na-pyroxenes based on a ternary diagram (Figure

1), where the aforementioned group (Quad) is placed in one of the vertices, while the jadeite ($NaAlSi_2O_6$) and the aegirine ($NaFe^{3+}Si_2O_6$) are located in the other two. Omphacite (Ca, Na) (Mg, Fe, Al) Si_2O_6, is located to the centre left of this diagram and it is usually considered a mineral, since it has its own crystalline structure (Morimoto *et al.* 1988). It is a major constituent of eclogite, usually forming from the metamorphism of basaltic rocks during high-pressure to low-temperature metamorphism.

Jadeitite has a density ranging between 3,30 and 3,36 g/cm^3 (though some New World jades have densities as low as 3,0), omphacitite's minimum is 3,33, while eclogite shows higher values than all the others (Errera 2014). However, it is worth noting that, sometimes, jadeitites and eclogites can display lower densities if retromorphism was important (chlorite and albite neoblastesis, *etc.*).

Jadeitites and mixed jades can be found in different regions of Asia and America. In Europe, jadeitite sources are found - for example - on the islands of Syros and Tinos (Cyclades, Greece), in the Monviso and the Voltri Group and in the western Italian Alps (Bröcker & Enders 2001; Compagnoni *et al.* 2007, 2012; Giustetto & Compagnoni 2014; Harlow *et al.* 2015; Pétrequin *et al.* 2012c, 2017a), and also in Norway and Brittany (Lozano *et al.* 2018). However, so far, there is no evidence of metaophiolite exploitation in the European Neolithic outside the Monviso and Voltri group areas (also in val Susa, but to a very lesser degree), where such activities have been documented by two authors of this paper (P.P., M.E.). Prehistoric quarrying of other greenstones (fine-grained eclogites) has been documented in the Baetic range, in Southern Spain (Lozano *et al.* 2018). Regarding our study area –Northwestern Spain–, the occurrence of jadeite minerals has also been described but only as a minor pseudomorph after plagioclase in granitic veins of decimetric width existing among the granodioritic orthogneiss of the Malpica-Lamego line (Gil Ibarguchi 1995).

Jadeitite and mixed jades have been the subject of many analytical studies, including geological and physicochemical (Cameron *et al.* 1973; Cisowski *et al.* 2004; Clark *et al.* 1969; Compagnoni *et al.* 2007; D'Amico *et al.* 1995; Delaitte *et al.* 2010-2011; Errera *et al.* 2012; Franz *et al.* 2014; Gil Ibarguchi 1995; Harlow 1993; Harlow *et al.* 1994, 2011, 2012a, 2012b, 2014, 2015; Hirajima & Compagnoni 1993; Kempe & Harvey 1983; Knaf *et al.* 2017; Lü *et al.* 2014; Macke *et al.* 2010; McClure 2012; Medaris *et al.* 1995; Mendoza *et al.* 2015; Morimoto *et al.* 1988; Ou Yang *et al.* 2011; Pétrequin *et al.* 2012a, 2017a, 2017c; Seitz *et al.* 2001; Taube *et al.* 2004; Theye & Seidel 1991), archaeological (Cassen *et al.* 2012; Harrison & Orozco 2001; Pétrequin *et al.* 2012a; Rodríguez Ramos 2011; Rodríguez Ramos & Pagán Jiménez 2006; Surmely *et al.* 2001) and archaeometric, on Asian (Bishop *et al.* 1985, Chang *et al.* 2010; Cook, 2013; Franz *et al.* 2014; Harlow *et al.* 2012b; Ou Yang *et al.* 2011; Rösch *et al.* 1997; Wang 2011; Wen & Jing 1992; Yang *et al.* 2004), American (Foshag & Leslie 1955; García-Casco *et al.* 2013; Harlow *et al.* 2006; Lange 1993; Ruvalcaba-Sil *et al.* 2008) and European samples (Coccato *et al.* 2014; Compagnoni *et al.* 2007, 2012; D´Amico 2005, 2012; D´Amico *et al.* 1995, 2003; Domínguez-Bella *et al.* 2004; Domínguez-Bella *et al.* 2012, 2016; Errera *et al.* 2012; Giustetto *et al.* 2018; Giustetto & Compagnoni 2014; Lozano *et al.*, 2018; Odriozola *et al.* 2015; Pétrequin 2017; Pétrequin & Errera 2017; Pétrequin *et al.* 2012c; Querré *et al.* 2008; Rapp 2001; Ricq-de Bouard & Fedele 1993; Spišiak & Hovorka 2005). In all these approaches, information is provided regarding the nomenclature, the main and accessory minerals of jadeitite and mixed jades, the techniques used for their analysis and archaeometric information such as the identification of the source areas and the evidence of circulation of the artefacts made of this raw material.

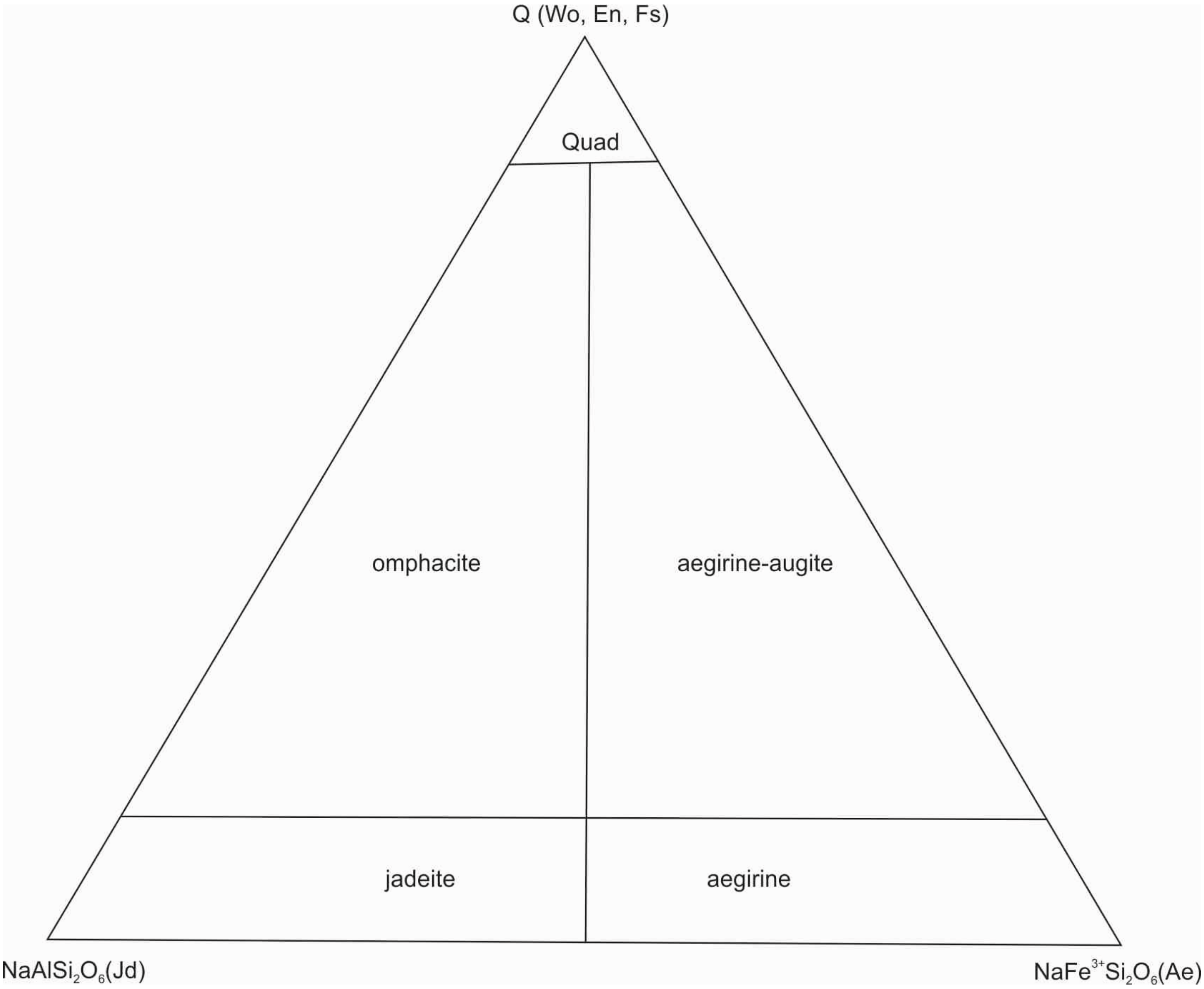

Figure 1. Simplified ternary diagram of Na-pyroxenes. Q: QUAD; Wo: wollastonite; En: enstatite; Fs: ferrosilite; Jd: jadeite; Ae: aegirine. Modified from Morimoto et al. (1988).

1.2. Alpine jades in prehistoric Western Europe

Jade has been highly valued for adornments or tools in Europe since prehistoric times: polished axes made from Alpine rocks such as jadeitite, omphacitite or fine-grained eclogite travelled across Western Europe during the 5th and 4th Millennia BCE over distances up to 1700 km (Figure 2). From the Italian Alps, where primary and mainly secondary deposits of these rocks were exploited in the massifs of Monviso and Voltri Group during Neolithic times (Pétrequin *et al*. 2012c), the long-distance transfers reached the Atlantic seashore and Great Britain in the West, Denmark to the North, the Black Sea shores and the Turkish coast to the East and –finally– Malta to the South (Pétrequin *et al*. 2012a, 2017b; Sørensen *et al*. 2017).

The choice of the Alpine jades by the prehistoric communities of Western Europe may be explained by the rarity of these precious raw materials and by their physical characteristics: a remarkable tenacity, a light-catching colour and fine-grained structure, allowing bright and sometimes extraordinarily polished surfaces (Pétrequin *et al*. 2017a). An added value might lay on the difficulty of quarrying at Monviso, between 1700 and 2400 m a.s.l. (Pétrequin & Pétrequin 2007, Pétrequin *et al*. 2006, 2012d).

The production and distribution of Alpine axes has been intensively analyzed in the framework of two research projects of pan-European scope funded by the French National Research Agency (JADE and JADE-2 programs). The results led to the identification of more than 2000 Alpine axes longer than 13,5 cm (Pétrequin 2017), the geological origin of many being traced mainly through spectroradiometric (Errera *et al.* 2007, 2012) or macroscopic and XRD analyses (Pétrequin *et al*. 2012c).

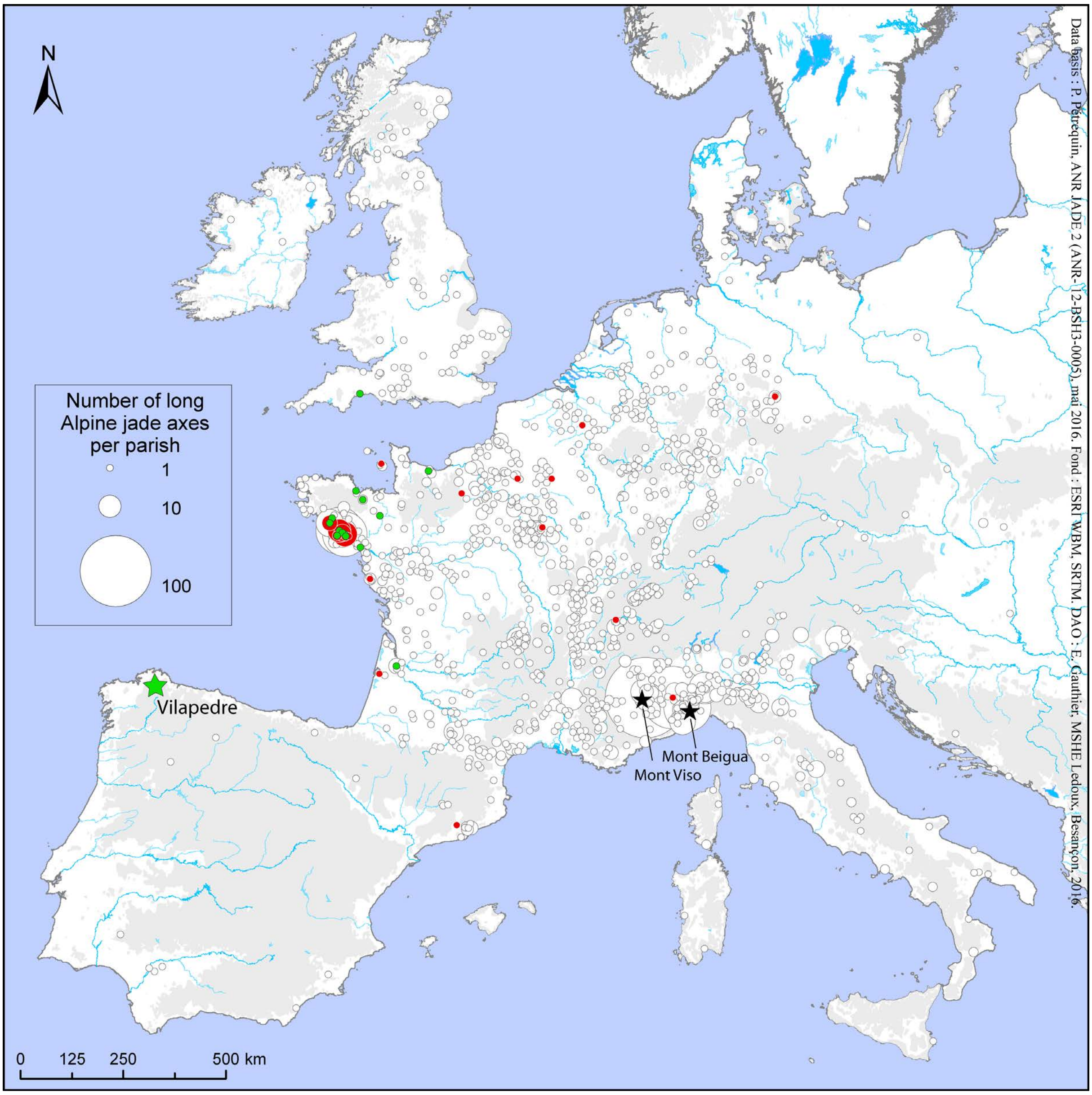

Figure 2. Distribution of long Alpine jade axes in Western Europe (white circles). Green circles: Butt-perforated Tumiac axes, as Vilapedre (green star). Red circles: Tumiac axes. Data base: P. Pétrequin. Mapping: E. Gauthier. NASA - Shuttle Radar Topography Mission (SRTM 3 arc-seconds) version 2.1, USGS., ESRI Basemap Data (licence MSHE C.N. Ledoux).

1.3. Alpine jades in the Iberian Peninsula

For a long time, it was assumed that, with the partial exception of Catalonia, the Iberian Peninsula was barely reached by the jade network (Ricq-De Bouard 1996). Outside the Catalonian lands, the few axes of alleged Alpine origin known in Iberia seemed to endorse such a view. However, this impression has significantly changed after the research conducted in the framework of the JADE projects, leading us to identify over forty presumably Alpine axes in Spain and Portugal (Fábregas Valcarce *et al.* 2017). The Alpine origin of the rocks used for making these artefacts has been suggested by means of spectroradiometric analysis in twelve of the Catalonian samples (Vaquer *et al*. 2012). Two other pieces from the Spanish Meseta were characterized as jadeitite by using XRF analysis; this same technique, together with XRD and µ-Raman Spectroscopy, reported –respectively– jadeitite and other related rocks for another two axes from Western Andalusia (Domínguez-Bella *et al*. 2016; Odriozola Lloret *et al*. 2016). In a recent work, Villalobos and Odriozola (2017) analyzed five axes from the Spanish Meseta using Raman and UV-VIS-NIR. Their results suggest an Alpine origin in Monviso and Voltri Group. Finally, an axe from Portugal was identified also as jadeitite through XRD and UV-VIS-NIR Spectroscopy (Odriozola Lloret *et al*. 2015).

As elsewhere in Europe, most Iberian specimens come from insecure contexts, isolated findings or old private collections (Domínguez-Bella *et al*. 2016; Fábregas Valcarce *et al*. 2012, 2017; Odriozola Lloret *et al*. 2016). In the Northeast of the Iberian Peninsula, though, some of the Alpine axes came from burials (sepulture 83 of Can Badosa, Caserna de Sant Pau) ranging from the end of the 5th to the mid-4th Millennium BCE (Molist & Gibaja 2012; Pétrequin *et al*. 2012a; Vaquer *et al*. 2012). In the rest of the Iberian Peninsula, no secure contexts have been reported for genuine Alpine axes, although the presence of local imitations (namely, “Cangas” type axes) in passage-graves suggests that these artefacts may have been deposited there at least from the first half of the 4th Millennium BCE, therefore providing an *ante quem* yardstick for their Alpine models (Fábregas Valcarce *et al*. 2012).

1.3.1. Vilapedre: An Alpine axe in Galicia (Northwestern Iberian Peninsula)

The existence of the Vilapedre axe (Figure 3: left) was revealed in 1908 by Santiago de la Iglesia in a paper where he stated that the axe, *“made on beautiful sea-green jasper”*, was *“found in the Vilapedre parish (Vilalba)”* (de la Iglesia 1908: 62), a council located in the Northern part of the Lugo province (Galicia) (Figure 4: top left). As usual, this artefact lacks a clear archaeological context, thus making imperative that –in addition to ascertaining its Alpine origin– a thorough research of the circumstances of the find ought to be undertaken. This was done in order to rule out a recent arrival to Northwestern Spain of the axe as a result, for example, of the trade in antiquities (see Domínguez-Bella *et al*. 2016 or Odriozola *et al*. 2016 for similar problems with other Iberian axes).

According to Santiago de la Iglesia, the axe and other objects in his collection were donated to him by Manuel Mato Vizoso, a scholar from Vilalba, who wrote extensively about the history of this council. De la Iglesia gave no specific information about the exact spot within the Vilapedre parish where this piece was found. Meanwhile, Mato Vizoso´s personal documents kept in the archives of the *Real Academia Galega* do refer to his “inspection” of several mounds and hillforts located in the vicinities of Vilalba (Mato Vizoso 1872?). This circumstance –together with the documents lacking any reference regarding the purchase or trade of archaeological artefacts from other scholars– seems to reinforce the idea of the Vilapedre axe having a local origin.

However, the documents do not clarify if Mato Vizoso –like Santiago de la Iglesia– personally carried out any excavation in mounds or if he merely inspected the remains of those monuments looted or destroyed by local peasants. The latter seems to be the case of a mound in the Guitiriz council (Lugo), where he recovered pottery, a mill, and other remains “left there by those who conducted the excavations”. Less clear is the case of, among others, an unidentified mound located in Vilapedre, where several pottery sherds “were recovered inside the chamber”, these “were torn up, finding inside nothing but black, compact soil”.

Figure 3. Comparison between the Vilapedre axe (left) and a perforated Tumiac type from the "tumulus de Tumiac" (Brittany, France) (right). Photos P. Pétrequin and R. Fábregas.

Besides this unidentified monument, Mato Vizoso mentioned very few mounds located in the Vilapedre parish. In his papers and notes, he only referred “three mounds distributed in a South to North axis” located close to the small villages of Fraguas and Garea, and near to the limits between the parishes of Vilapedre and Lanzós. According to his description, it is likely that these are the mounds known nowadays as *Bouza* or *Veiga da Garea*. Three of them (Bouza 1 to 3) display an N-S distribution, and they are also located near to the two aforementioned towns and to the limit with Lanzós (Figure 4: bottom). These monuments show evidence of having been looted, but –unfortunately– Mato Vizoso did not specify if the Vilapedre axe was recovered in any of them.

The looting of funerary mounds has been a very frequent practice in Northwest Spain for at least the last 300 years. As a result, probably less than the 2% of the more than 3.000 Galician catalogued mounds are intact nowadays. The 20 monuments located in the Vilapedre parish are not an exception, most of them showing eloquent evidences of this kind of damage. Moreover, there are references to the existence of at least another nine mounds that were destroyed in the last 50 or 60 years (Figure 4: top right), most of them due to farming activities. Any of these or other unknown archaeological sites could be the place from where the Vilapedre axe was originally recovered, probably by local peasants from whom Mato Vizoso would have bought it or –otherwise– being found by Mato Vizoso himself in the course of his “inspections” of local monuments.

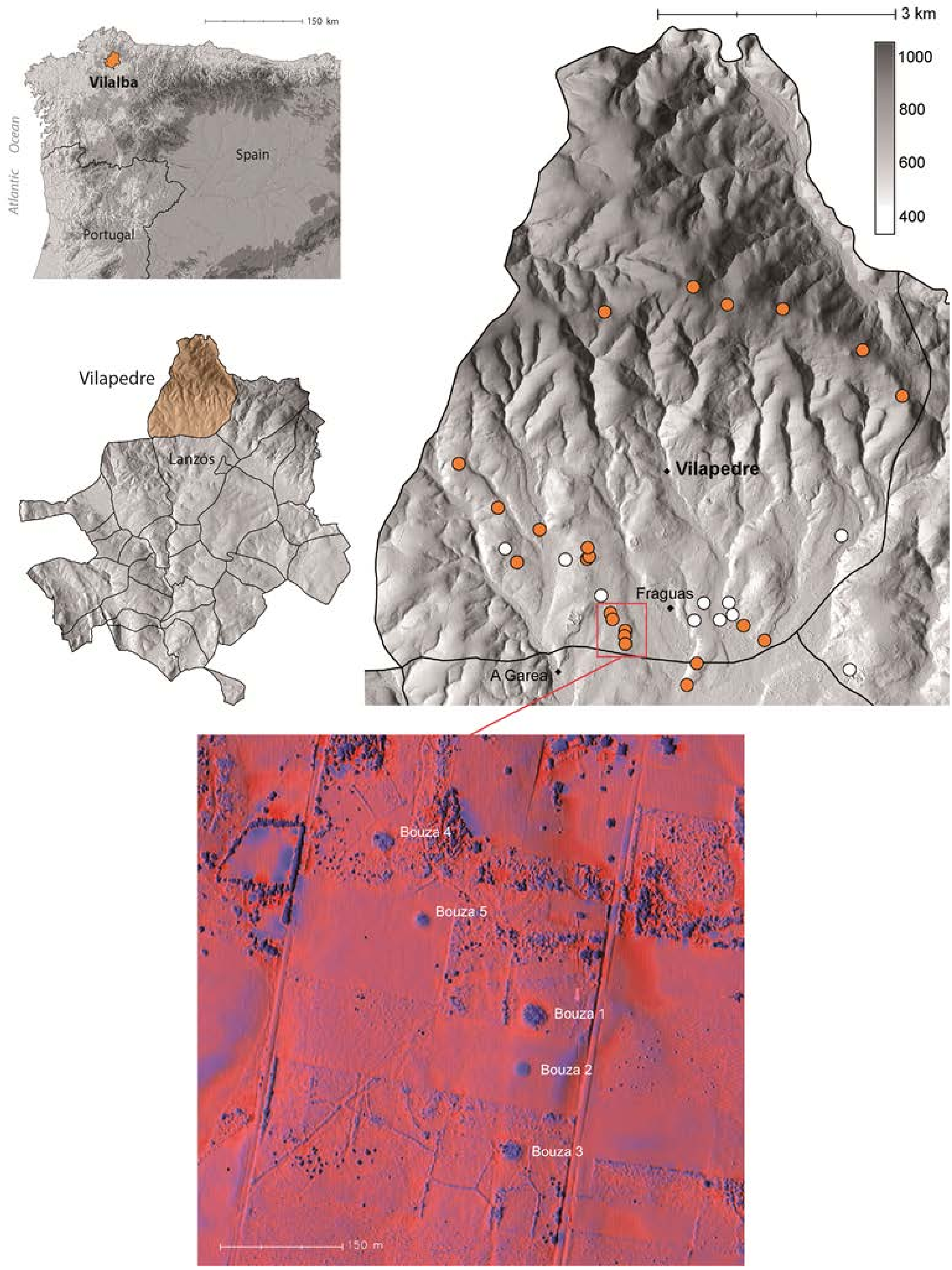

Figure 4. Location of the Vilalba council and Vilapedre parish (Lugo) (top left). Catalogued mounds either preserved (orange) or destroyed (white) (top right). Map showing the location of the Bouza or Veiga da Garea necropolis (bottom). Mapping C. Rodríguez. LiDAR data (max.res. c. 0.5 points/m^2) PNOA. Instituto Geográfico Nacional. Spain. GRASS GIS v. 7.3.

The Vilapedre axe, together with other artefacts, was probably donated to Santiago de la Iglesia by Manuel Mato Vizoso in the decade of 1890. Thus, in 1896, de la Iglesia publishes one of the objects of his collection, a bronze dagger found in a mound in San Martín de Lanzós (Vilalba), coming from Mato Vizoso. A year later, in 1897, de la Iglesia made a four day trip to different places in Northern Galicia, including Vilalba and, during this trip, he was in contact with Manuel Mato Vizoso and it may be in this moment when Mato gave him the artefacts. After de la Iglesia's death in 1931, his collection was donated to the Santiago de Compostela University, in whose Department of History it is kept today.

2. Materials and methods

2.1. The archaeological specimen

The Vilapedre axe (Figure 3: left) is a butt-perforated greenstone axe whose surface has a glossy aspect due to an intense, fine polish. It has an elongated, narrow triangular shape, an acute proximal end, sides almost rectilinear and a convex edge. Its cross-section is thin, with an oval –almost lenticular– outline and the preserved length is 12,9 cm, its width 5,4 cm and its thickness 1,2 cm. The proximal perforation has a rather uncommon biconical section with a maximum and minimum diameter of 8 and 3 mm, respectively.

The raw material of the Vilapedre axe (hereafter MPVV) has a density –measured using a hydrostatic balance– of 3,33 g/cm^3 (dt: 0,00; C.V.: 0,11 %) compatible with a mixed jade and other greenstones.

It is a rock with thin, discontinuous, whitish, partly wavy bands arranged parallel to the schistosity of the raw material (Figure 5). Due to the existence of a slight patina generated after millennia, the current colour is neither the observable on a fresh break, nor that showed by the rock extracted at the original source. The original colour (under the patina) is a pale-milky to light-bright-green, suggestive of the presence of slightly translucent omphacite. The examination under x2 and x10 magnifications revealed the following characteristics:

-narrow fissures clogged with a medium bright-green raw material

-some whitish inclusions forming a "crown" around small reddish black nodules (rutile?) (Figure 5);

-deformed garnets (determined by microscopic comparison with natural reference samples) with a blurred contour and ranging between 1 and 3 mm in size (Figure 5). The most characteristic examples marked with a white hexagon and

-other small garnets (0,2 to 0,4 mm) displaying hollow cores (Figure 5)

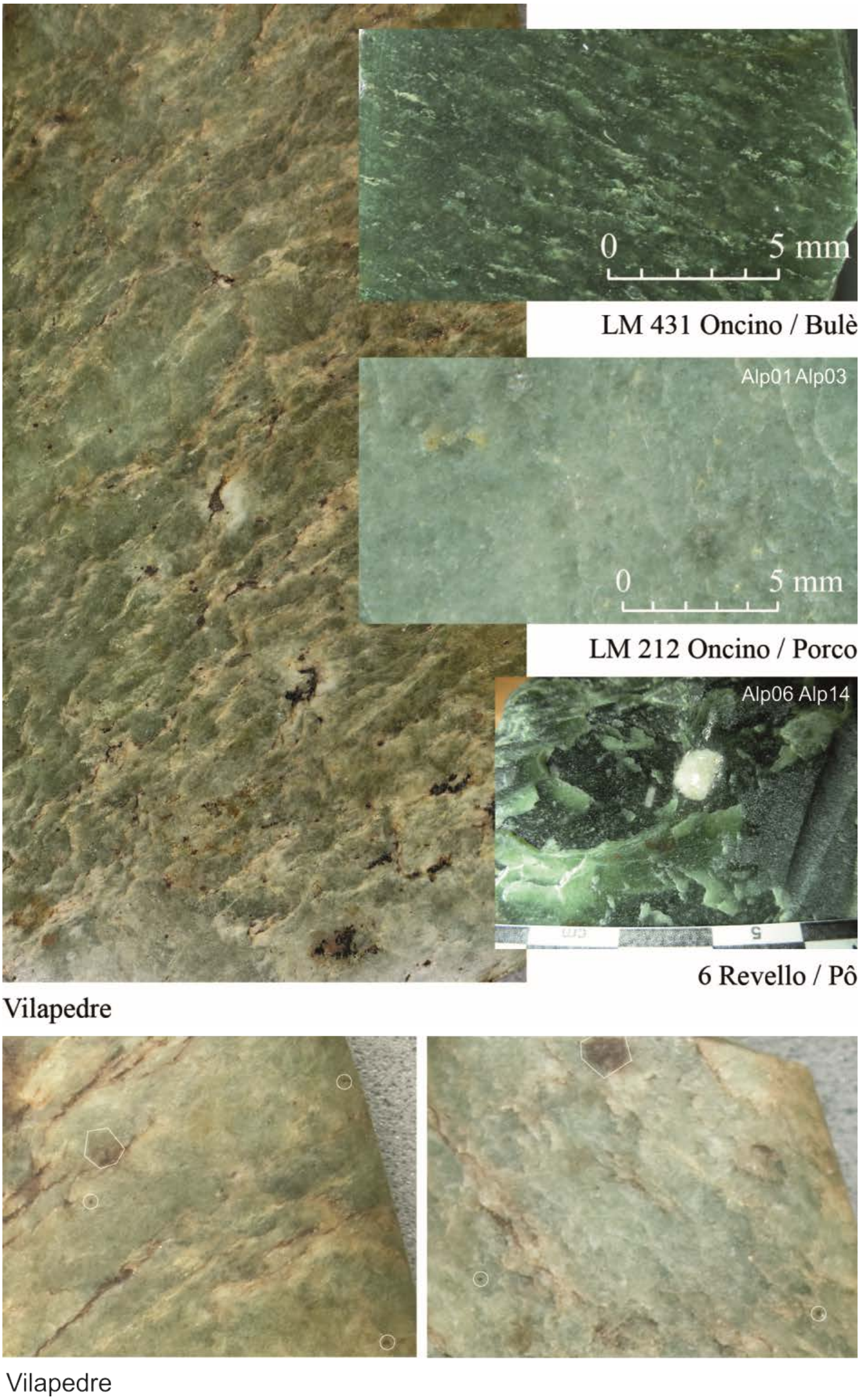

Figure 5. Macroscopic detail of the Vilapedre axe and of several Alpine geological samples. White hexagons: deformed garnets. White circles: hollow-core small garnets. Vilapedre images are shown at different scales. Photos P. Pétrequin and O. Lantes.

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2.2. Geological samples

The petrological features and archaeometric data of many prehistoric jade axes suggest that the raw materials on which they were made might have originated in the Western Alps slopes (either from primary outcrops, secondary deposits in riverbeds and alluvial plains, or out of Tertiary conglomerates). Moreover, there are clear archaeological evidences of prehistoric quarrying in this area, mostly in the Monviso massif, including large concentrations of axe rough-outs, hammer-stones and flakes (Pétrequin *et al*. 2007, 2012d).

Different geological samples of jade were collected from Monviso, taking into account macroscopic similarities with the raw material of the Vilapedre axe and, above all, the evidence –in those specific spots– of prehistoric activities related to the exploitation of Alpine jades and the production of axe-heads, eight of them coming from the Cuneo district, and another (Alp30) from Alexandria. These criteria make sure that the sampling was carried out in the most important outcrops where prehistoric activity has been detected so far (Table 1, Figures 6, 7). Naturally, we cannot rule out further surveys leading to the discovery of other sources whose composition might have higher similarities to Vilapedre's, but presently the geological samples included in this paper offer a reliable representation of those areas of Monviso where prehistoric activities have been reported.

Table 1. Description of the geological samples. Produced by P Pétrequin and O. Lantes.

Sample	Region	Site	Color	Texture
ALP1	Oncino (Cuneo, Piedmont)	Porco, vallone de	pale green	massive-foliated
ALP3	Oncino (Cuneo, Piedmont)	Porco, vallone de	green	granoblastic-foliated
ALP4	Sanfront (Cuneo, Piedmont)	Pô riv., Rocchetta, morain	green	foliated-granoblastic
ALP6	Revello (Cuneo, Piedmont)	Pô riv.	green	foliated
ALP10	Martiniana (Cuneo, Piedmont)	Pô riv.	pale green	foliated-granoblastic
ALP14	Revello (Cuneo, Piedmont)	Pô riv.	pale green	foliated
ALP17	Sanfront (Cuneo, Piedmont)	Pô riv., Rocchetta, morain	green	massive-foliated
ALP30	Ponzone (Alexandria, Piedmont)	Fondoferle, Orba riv.	green	massive-granoblastic

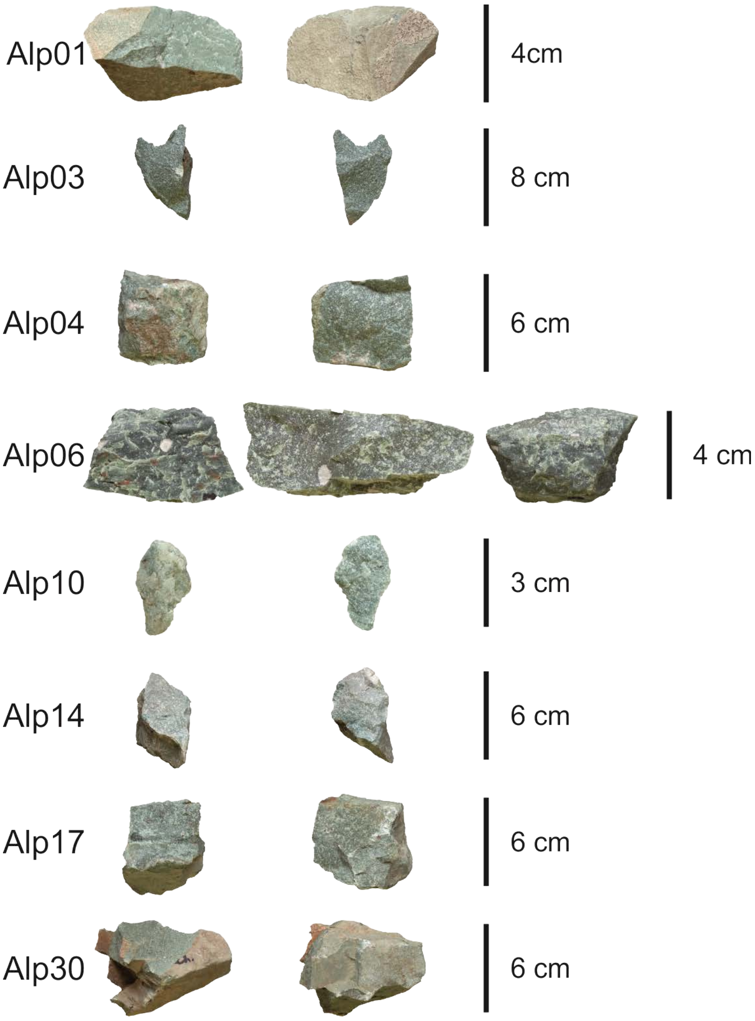


Figure 6. Photographs of the Alpine geological samples. See Table 1 for details. A general similarity with a minor variation in range can be observed from a petrographic point of view. Photos R. Fábregas and O. Lantes.

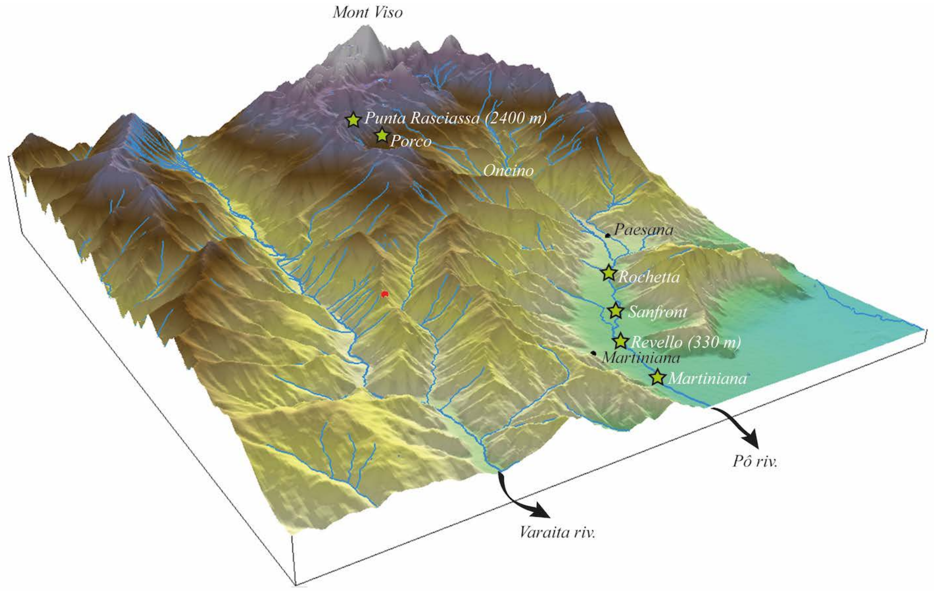


Figure 7. Location of the geological samples. Mapping F. Prodéo, ESRI Data and Maps (licence MSHE C.N. Ledoux et NASA-SRTM).

2.3. Experimental design

Archaeometric analysis is usually a complex task: the sampling of archaeological artefacts for analytical purposes is often restricted, when not directly forbidden, by Heritage authorities. Thus, assays are nearly always limited in terms of size or volume.

We have implemented a micro-sampling design oriented to obtain powder to be submitted to chemical and mineralogical analysis, in a similar way to Marinova *et al*. (2018). Three independent small areas - previously cleaned by polishing and located in mechanically induced fractures during transport and use - were abraded using a diamond tool (1x2 mm). None of these fractures were near areas of natural alteration. Since these modifications are barely visible to the naked eye, they do not compromise the structural integrity of the piece or its future exhibition. We used X-Ray powder diffraction (XRD) to identify and semi-quantify the mineralogy and Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDX) for the determination of the chemical composition of the samples. The geological samples were subjected to the same micro-sampling protocol, choosing “freshly cut” surfaces and avoiding alteration crusts as well.

2.4. Equipment and measuring conditions

2.4.1. X-ray Powder Diffraction (XRD)

We employed a Philips PW1710 diffractometer with a vertical goniometer with Bragg-Brentano geometry θ/2θ, generator with tube of 2,2 kW with Cu anode, graphite monochromator and proportional detector PW1711/10. Some milligrams of the sample, previously crushed, were deposited on a zero-background sample-holder (U-1.2rd, Gem Dugot: Dana Smith, Princeton) trying to get randomly oriented crystal grains. The measurement time for each sample was 3 seconds per step, between 2° and 65° 2θ and a step size of 0,02°. The identification and semi-quantification were conducted on the DIFFRACplus EVA software (Bruker AXS), combined with the HighScore Plus 2011 (PANalytical B.V.). The Reference Intensity Ratio (RIR) (Chung 1974) was used for the semi-quantification.

2.4.2. Scanning Electronic Microscopy coupled with Energy-Dispersive X-ray Spectroscopy (SEM-EDX)

The equipment used was an EVO LS15 microscope, which works in variable pressure mode, coupled with INCA microanalysis and a backscattered electron detector. The measurements were conducted under the following conditions: 100 s for the spectra acquisition; 20,3 s for the photograph scanning, *l-probe* of 1 to 1,8 nA, 20 Kv of voltage, and an 8,5-mm focus distance. The INCA detector was calibrated for the quantitative analysis using a cobalt standard (Micro-Analysis Consultants, Ltd. Cambridgeshire U.K.). The powder sub-samples (three for each sample, located in different areas) were deposited in a standard SEM sample holder (metallic body covered by an organic sticker) without any SEM-shading. Five analyses were conducted on each sub-sample (a total of 15 analyses per sample). Figure 8 (displaying the sample ALP17, as an example) shows the aspect of the extracted powder and the area analysed in each EDX analysis (rectangle A).

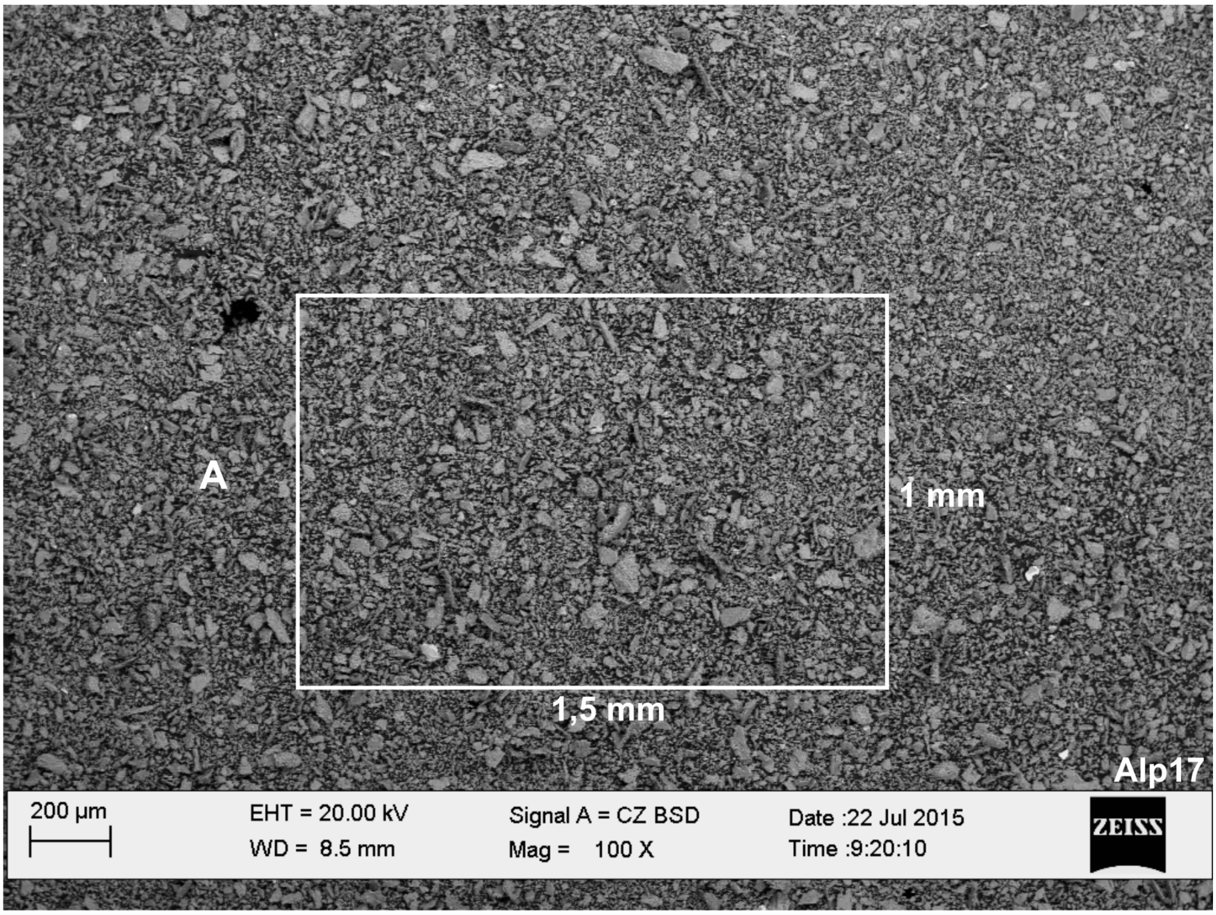


Figure 8. Electronic microphotography of the powder sub-samples extracted with the micromotor. A: size of the scanned area analysed in EDX. Produced by A. González.

2.4.3. Statistical analysis

The statistical analysis was carried out with the SPSS Statistics software version 20 (IBM®). The main statistical methods used were ANOVA and hierarchical clustering, which were applied to the chemical compositions with the data normalized to the concentration of silicon. We used this normalization for improving the statistical analysis through the removal of the carbon contribution from the sticker at the holder (the analysis area was multigrain and, in the interstices, we received the carbon signal of the sticker of the sample holder). Regarding the cluster analysis, the data were transformed into Z-scores. The intergroup linking was used as clustering method and the Euclidean distance as measure of the interval. The elements included in the analysis were Na, Mg, Al, P, S, Ca, Ti, Fe and Cu, some of them not related to the crystal-chemistry of pyroxenes, as for example P (related to apatite), S (related to sulfides), Ti (related to a Ti-bearing phase) and Cu (possibly related to chalcopyrite - CuFeS2, a sulfide) but they were included to show similarities between samples.

2.4.4. Other determinations

A macroscopic analysis was conducted on the Vilapedre axe and on the geological samples using a stereographic microscope. The rocks were preliminarily identified with Diffrac Plus EVA as a poorly garnet-bearing Na-pyroxenite. Density analysis was conducted following the method proposed for this specific kind of archaeological artefacts by Errera (2014).

3. Results and discussion

3.1. Mineralogy

Except in samples Alp10 and Alp17, where only omphacite was detected (Table 2, Figure 9), jadeite and omphacite were the main minerals identified in the geological samples using XRD. Some of these contain analcime, albite and clinochlore as secondary minerals, which were probably formed during the retrogression of the rocks (also detected by D´Amico *et al*. 2003). The Vilapedre axe only showed the presence of jadeite (73 %, semiquantification in weight) and omphacite (27 %), confirming it as a mixed jade. From a mineralogical point of view, the results show that ALP06 and ALP03 were the analysed geological samples more similar to our axe, since the three have a similar composition, based exclusively on jadeite and omphacite (Table 2).

Table 2. Mineralogical semi-quantification obtained from X-Ray Diffraction. Besides, optical analysis revealed the presence of garnets (deformed garnets or hollow-core small garnets) in both the archaeological and geological samples. Produced by O. Lantes.

Sample	Jadeite	Omphacite	Analcime	Clinochlore	Albite
ALP01	64	19	17	-	-
ALP03	61	39	-	-	-
ALP04	51	45	5	-	-
ALP06	85	15	-	-	-
ALP10	-	100	-	-	-
ALP14	31	21	-	-	48
ALP17	-	100	-	-	-
ALP30	57	28	-	15	-
MPVV	73	27	-	-	-

3.2 Chemical composition

Table 3 shows the results of the EDX elemental analysis (five independent determinations per subsample, five subsamples per sample). We must stress that we were interested in a global composition, so that we measured polycrystalline areas to achieve it. The major chemical components detected during the analyses were Na, Mg, Al, Si, Ca and Fe, while the minor elements identified were P, S, Ti, Cu and K. The major elements are characteristic of jadeite and omphacite. Regarding the minor elements, Ti could appear in this kind of rocks as part of a minor trace phase as rutile or titanite and K as phengite or K-Na paragonite (Harlow *et al.* 2015). P could appear as part of apatite (one of the accessory minerals in both omphacitite and jadeitite). The presence of S, also rare, could be explained by its role as component of the occasional pyrite, pyrrhotite or chalcopyrite. The occurrence of the latter mineral, together with apatite, has been repeatedly reported in Alpine jades (D’Amico 1995, 2012; D’Amico *et al*. 2003). The detailed SEM exploration of the Vilapedre axe, in this case in individual grains, led us to detect a very occasional presence of shining crystals or grains, interpreted either as La, Nd and Ce phosphates (monazite) or as zircon (Figure 10), the latter already referred as a trace mineral in Alpine jade (D’Amico *et al*. 1995, 2003, Pétrequin *et al*. 2012b). Cu is present in small quantities in those samples with secondary minerals, such as oxides and sulphides, and its presence in samples of jadeite and omphacite coming from the Alps has been referred by Coccato *et al.* (2014).

We conducted an ANOVA test of the global chemical data finding no significant differences between the sub-samples at a general level (Table 3 shows the average of the five determinations in each sub-sample). This points out to a compositional homogeneity and it may be seen as an evidence of the representativeness of our sampling strategy.

Table 3. Elemental composition. Mean value, expressed as the percentage in weight relative to Si, of the five determinations in EDX defined for each sub-sample. The absence of superscripts means that the ANOVA test did not detect significant differences between sub-samples (they belong to the same statistical group). Produced by O. Lantes.

	zone	Na	Mg	Al	Si	P	S	K	Ca	Ti	Fe	Cu
Alp01	1	0.402	0.040	0.413	1.000	0.000	0.000	0.000	0.095^{a}	0.009	0.074	0.022
	2	0.400	0.042	0.409	1.000	0.000	0.000	0.000	0.099^{ab}	0.009	0.075	0.023
	3	0.403	0.039	0.410	1.000	0.000	0.000	0.000	0.100^{b}	0.013	0.074	0.023
Alp03	1	0.339	0.108	0.309	1.000	0.000	0.000	0.000	0.178	0.014	0.187	0.000
	2	0.331	0.107	0.307	1.000	0.000	0.000	0.000	0.178	0.013	0.189	0.000
	3	0.333	0.108	0.307	1.000	0.000	0.000	0.000	0.176	0.014	0.181	0.000
Alp04	1	0.321^{b}	0.098	0.330	1.000	0.000	0.000	0.000	0.084	0.001	0.114	0.019
	2	0.314^{ab}	0.097	0.327	1.000	0.000	0.000	0.000	0.084	0.003	0.116	0.019
	3	0.312^{a}	0.097	0.326	1.000	0.000	0.000	0.000	0.084	0.004	0.117	0.017
Alp06	1	0.382^{ab}	0.036	0.351	1.000	0.000	0.000	0.000	0.098	0.024	0.240	0.000
	2	0.379^{a}	0.035	0.352	1.000	0.001	0.000	0.000	0.098	0.022	0.237	0.000
	3	0.385^{b}	0.036	0.354	1.000	0.000	0.000	0.000	0.097	0.024	0.239	0.000
Alp10	1	0.221^{a}	0.184^{a}	0.227^{ab}	1.000	0.000	0.000	0.000	0.385	0.024	0.090	0.000
	2	0.219^{a}	0.185^{a}	0.225^{a}	1.000	0.000	0.000	0.000	0.385	0.025	0.089	0.000
	3	0.229^{b}	0.189^{b}	0.231^{b}	1.000	0.000	0.000	0.000	0.383	0.023	0.091	0.000
Alp14	1	0.314	0.064	0.377	1.000	0.000	0.000	0.000	0.119	0.010	0.055	0.017
	2	0.319	0.066	0.376	1.000	0.000	0.000	0.000	0.119	0.009	0.056	0.019
	3	0.314	0.064	0.378	1.000	0.000	0.000	0.000	0.118	0.010	0.056	0.017
Alp17	1	0.255^{a}	0.151	0.217	1.000	0.000	0.000	0.000	0.308^{a}	0.021^{b}	0.263	0.000
	2	0.261^{b}	0.152	0.216	1.000	0.000	0.000	0.000	0.302^{b}	0.016^{a}	0.255	0.000
	3	0.255^{a}	0.152	0.215	1.000	0.000	0.000	0.000	0.307^{a}	0.014^{a}	0.260	0.000
Alp30	1	0.298^{b}	0.155^{c}	0.282	1.000	0.011	0.050	0.000	0.210	0.045	0.398	0.021
	2	0.293^{a}	0.147^{a}	0.282	1.000	0.009	0.051	0.000	0.214	0.124	0.319	0.020
	3	0.299^{b}	0.150^{b}	0.285	1.000	0.011	0.049	0.000	0.213	0.122	0.313	0.020
MPVV	1	0.360	0.032	0.379	1.000	0.002	0.000	0.007^{a}	0.072	0.011	0.137	0.000
	2	0.362	0.032	0.382	1.000	0.000	0.000	0.008^{ab}	0.071	0.010	0.140	0.000
	3	0.359	0.032	0.379	1.000	0.004	0.000	0.009^{b}	0.070	0.011	0.131	0.000

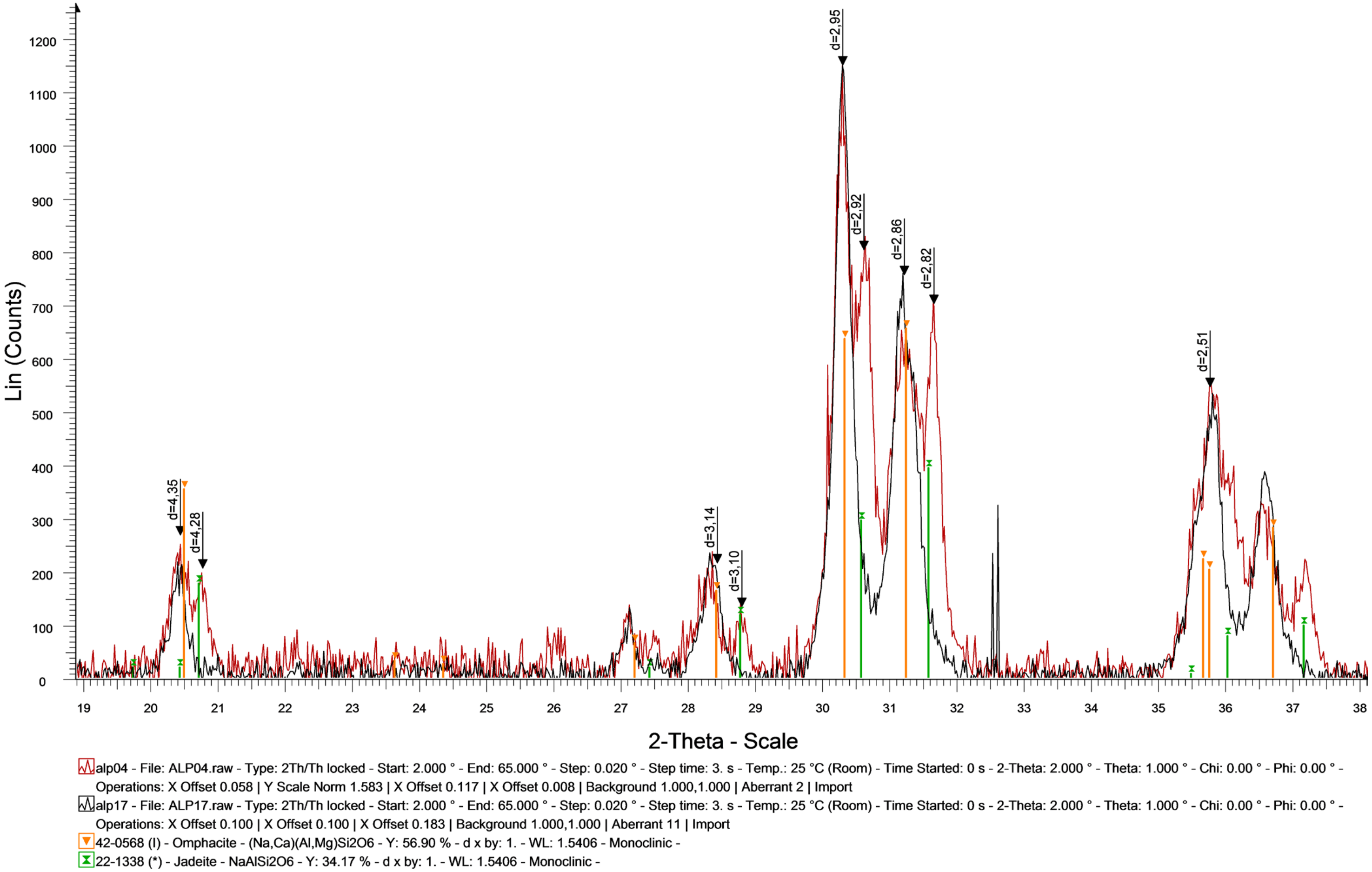
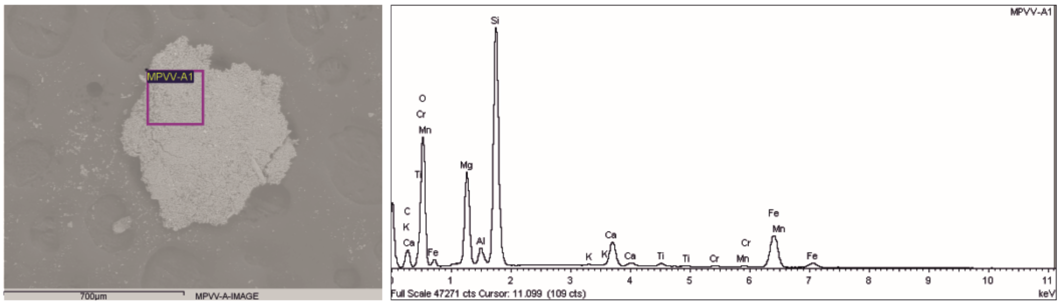
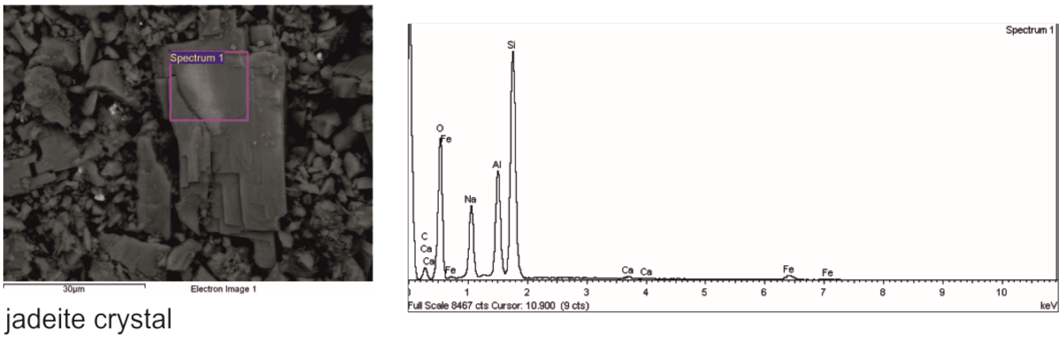


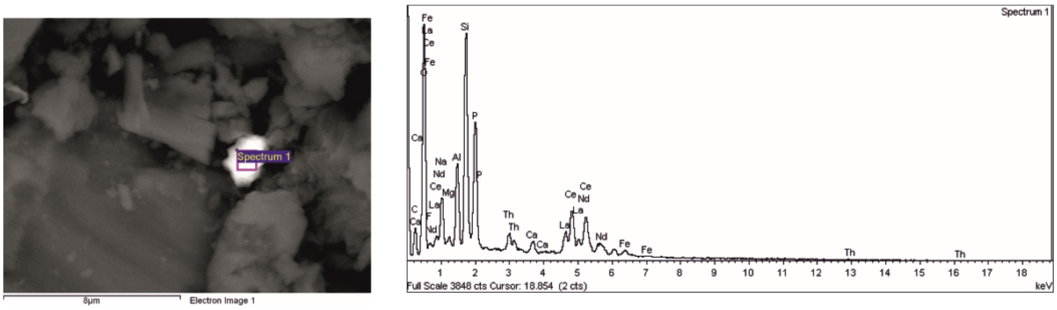
Figure 9. Example of a diffractogram (zoom between 20 and 40 2θ) of some Alpine samples as examples of various Na-Px compositions. Alp04 (red) and Alp17 (black) samples (superimposed). Orange bars: peaks corresponding to omphacite; red bars: peaks corresponding to jadeite. Alp17 does not show traces of jadeite. Produced by O. Lantes from DIFFRACplus EVA software © PANALYTICAL.



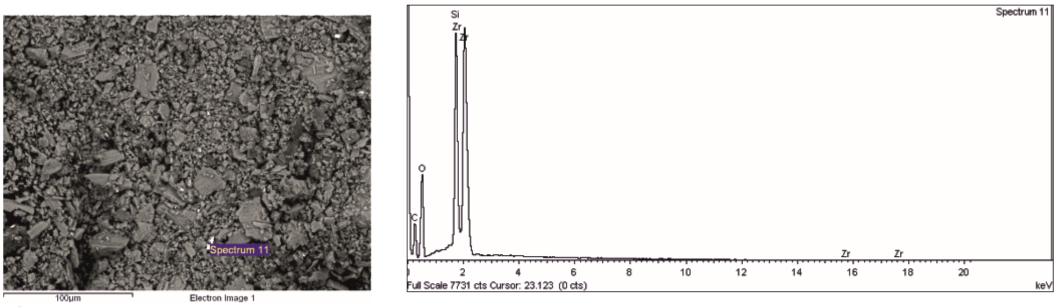
general scan



jadeite crystal



La, Nd, Ce phosphate



zircon

Figure 10. Different trace minerals detected by SEM-EDX in the Vilapedre axe (MPVV). Produced by A González.

3.3. Similarity between the archaeological artefact and the geological samples

A simple visual examination suggests, or at the very least does not contradict, an Alpine origin for Vilapedre's raw material, given the existence of several similarities between the geological and archaeological samples. Such macroscopic analysis could allow also to provisionally suggest a more specific source for the raw material, since the macroscopic traits identified in the Vilapedre axe –in particular the garnets (Figure 5)– are akin to those documented in geological samples from Monviso. Conversely, these seem to be absent in the Voltri Group samples (Pétrequin *et al*. 2012b; Pétrequin & Errera 2017). The jadeite-omphacite association observed in the Vilapedre axe, with its characteristic schistose structure, is also well represented in the Monviso samples collected to the south of the massif, regardless of whether they are natural blocks, prehistoric axe rough-outs or debris of the workshops documented in the area, but we ought to bear in mind that the Voltri group display, occasionally, a schistose structure too.

The statistical analysis points to the Vilapedre item being more similar, from a chemical point of view, to the geological sample ALP06, followed by ALP03 (Figure 11). Such results are consistent with the similarities detected at a mineralogical level, therefore suggesting that ALP06 –a decimetric block collected in the Pô River at Revello (Piedmont, in the Italian Alps)– could be a raw material similar to Vilapedre's. In addition to the analytical data, the external aspect (green colour and flakiness) of ALP06 is the closest to MPVV among the samples analysed for this paper. The presence of zircon as trace mineral points also towards an Alpine origin of the MPVV raw material, since zircon has been referred as an important trace mineral in Alpine jade (D'Amico 1995, Pétrequin *et al*. 2012b), both in Monviso and Voltri. Likewise, apatite and –to a lesser extent– titanium minerals have been frequently identified as minor phases of the Alpine jades (D'Amico 1995). The only difference between MPVV and ALP06, detected in the performed analysis is the absence of K in the latter, maybe included in phengite (Harlow *et al*. 2015), but this dissimilarity could be due to a lower concentration of this mineral.

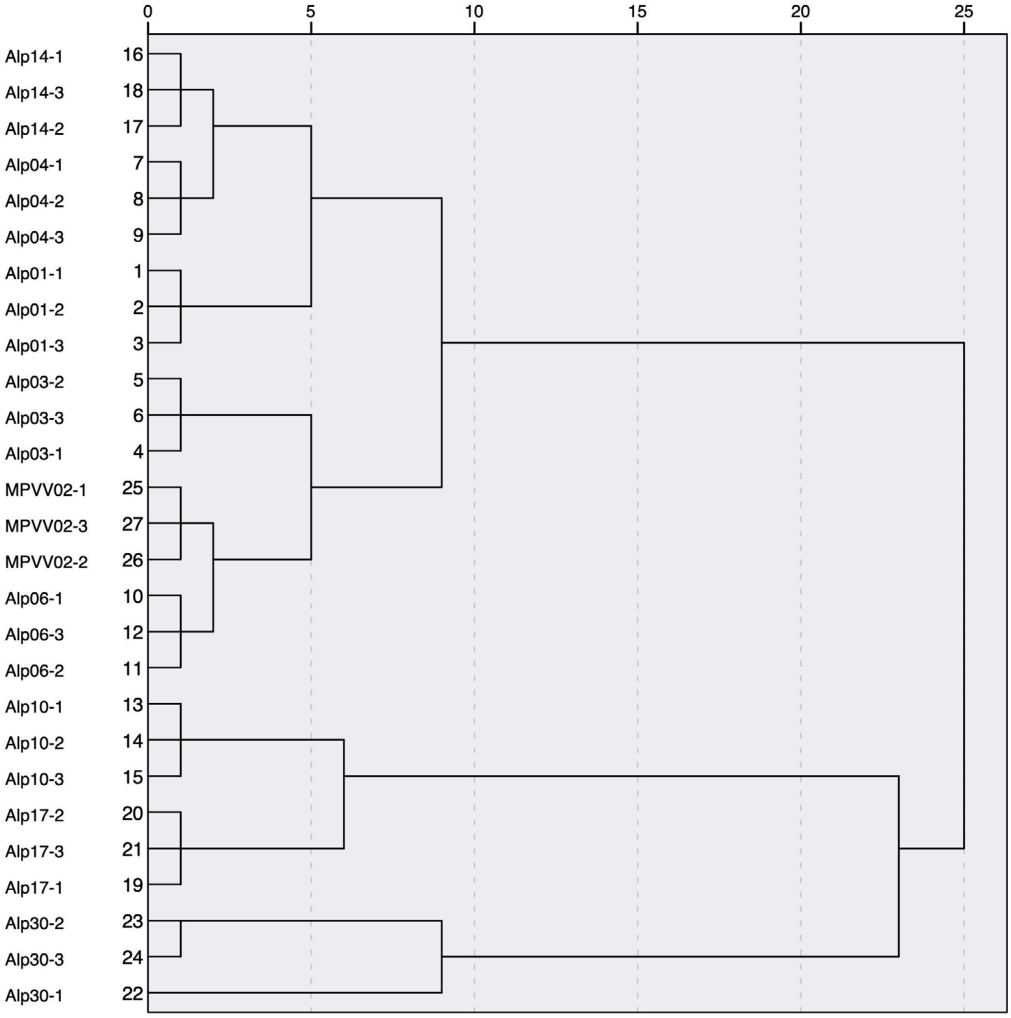


Figure 11. Dendrogram of samples. -1, -2, -3: independent sub-samples obtained for each sample. In all cases, sub-samples corresponding to the same sample are grouped together. This suggests a very similar and homogenous composition of the subsamples. Produced by O Lantes from SPSS Statistics software version 20 (IBM®).

3.4. Vilapedre as evidence of prehistoric contacts between two Atlantic land ends?

Parallels for the Vilapedre axe cannot be found elsewhere in the Iberian Peninsula, but in Brittany (France): research has shown the Gulf of Morbihan acting as a powerful attractor for large polished blades within the distribution network of Alpine jades. Such artefacts were often re-polished to create specific regional models: the so-called “Carnacean axes”, whose most emblematic examples –the Tumiac type– are butt-perforated (Figure 3: right). Between the mid-5th Millennium and approximately 4300 BCE, this coastal area of France delivered some repolished Alpine pieces towards the Paris Basin, Germany and –as we suggest in this paper– the northwest of the Iberian Peninsula (Cassen *et al*. 2012; Pétrequin *et al*. 2012b).

The presence of a Tumiac axe in Northwestern Spain has been repeatedly mentioned as an evidence of the existence of links between the French and Iberian western outposts, starting at least from the early 4th Millennium BCE (Cassen *et al*. 2012; Pétrequin *et al*. 2012b), an hypothesis that is also supported by the presence of other Iberian artefacts (namely variscite beads from Palazuelo de las Cuevas and Encinasola) amidst the grave-goods at several sepultures of Western France, most of them found in the gigantic Carnacean tumuli around the Morbihan gulf –Tumiac in Arzon, Mané er Hroëck in Locmariaquer, and Saint-Michel in Carnac– (Cassen *et al*. 2012; Querré *et al*. 2008, 2012, 2015). Recent approaches (Cassen *et al*. 2019) have added Tumiac axes made on calcium amphibole/actinolite to the possible list of artefacts exchanged between these two regions.

The peculiar spatial distribution of some of these objects, with few or no examples in regions between Brittany and Galicia (Figure 2), has led several authors to point out the possibility of direct contacts by sea between these two areas, which would provide interesting insights on the possible development of relatively advanced seafaring techniques in Southwest Europe as early as in the 5th millennium BCE (Cassen *et al*. 2019).

4. Conclusions

The mineralogical, chemical and macroscopic analyses have identified ALP06 –a decimetric block collected in the Pô River at Revello (Piedmont, in the Italian Alps)– as the closest to Vilapedre’s raw material among the geological samples analysed for this paper. Such similarity, together with the fact that the selection of samples was conducted considering all the archaeological data available for the potential source areas known in Western Europe to this day, points out that it could be the probable raw material employed for manufacturing the Vilapedre axe, perhaps from blocks close to Revello or others located in areas with similar features, including primary sources higher up in the mountains. That said, other potential sources appearing in the future may make further geological analyses necessary to tighten with greater accuracy a precise location.

The determination of an Alpine origin for the Vilapedre axe is a significant contribution to the study of the Prehistory of the Atlantic Façade, since it links two of its major “land-ends” and stepping stones (Brittany and Galicia) within an exchange network that –from the Italian Alps– reached most part of Western Europe. Although other Alpine axes had been previously documented in the Iberian Peninsula, Vilapedre is the only clearly Carnacean axe of Morbihan style found so far in the area. As other authors have repeatedly noted, this circumstance reinforces the traditional hypotheses suggesting the existence of contacts between Brittany and Galicia since, at least, the Neolithic period. Such a view is endorsed by the striking similarities in certain artefacts, such as the unusual concentration of Cangas-type perforated axes in NW Iberia, the Castellic pottery found in the passage-grave of Dombate or the presence of West Iberian variscite in Breton tumuli; noteworthy is, too, the so-called “The Thing” carved on Dombate’s uprights –also in other NW Iberian dolmens– that has been related to motifs found in Breton megaliths (Cassen *et al.* 2012; Fábregas Valcarce *et al.* 2012).

It is also remarkable the current absence of parallels for Vilapedre and other perforated Tumiac axes in other regions of Spain or Portugal, namely in the whole Cantabrian strip, perhaps hinting at the existence of direct sea contacts between Brittany and Galicia. Such a peculiar distribution of material items seems to persist in later, Chalcolithic times, for Bell Beakers are very well represented in Galician territory, while extremely scarce in neighbouring Cantabrian regions and, again, quite present in Brittany with, furthermore, clear coincidences as to the design and decorative techniques of the vessels (Blas & Rodríguez 2015; Prieto & Salanova 2009).

With the necessary caveats linked to the difficult context of the piece, we would like to propose the path followed by the Vilapedre axe: from the extraction and manufacture, probably in the Western Alps, to its circulation towards the Paris basin and then to Brittany, where the final polishing and perforation would have taken place. Finally, having lost its original function as a working tool and becoming an item with a strong social or religious significance, the Vilapedre axe would have departed the Gulf of Morbihan to reach the northwest of the Iberian Peninsula, after completing a journey of more than 1.400 km.

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References

Bishop, R.L., Sayre, E.V. & Lamburtus, V.Z. 1985, Characterization of Mesoamerican jade. In: *Application of science in examination of works of art, Proceedings of the seminar, September 7-9, 1983* (England, P.A., Van Zelst, L., Eds.), Museum of Fine Arts. Boston: p. 151-156.

Blas Cortina, M.A. de & Rodríguez del Cueto, F. 2015, La cuestión campaniforme en el Cantábrico Central y las minas de cobre prehistóricas de la sierra del Áramo. *Cuadernos de Prehistoria y Arqueología de la UAM*, 41: 165-179. (in Spanish) ("The bell-shaped issue in the Central Cantabrian Sea and the prehistoric copper mines of the Sierra del Aramo").

Bröcker, M. & Enders, M. 2001. Unusual bulk-rock compositions in eclogite-facies rocks from Syros and Tinos (Cyclades, Greece): Implications for U–Pb zircon geochronology. *Chemical Geology*, 175: 581-603.

Cameron, M., Sueno, S., Prwitt, C.T. & Papike, T.T. 1973, High temperature crystal chemistry of acmite, diopside, hedenbergite, jadeite, spodumene and ureyite. *American Mineralogy*, 58: 594-618.

Cassen, S., Boujot Ch., Dominguez-Bella, S., Guiavarc'h, M., Le Pennec, Ch., Prieto Martínez, M. P., Querré, G., Santrot, M- H. & Vigier, E. 2012, Dépôts bretons, tumulus carnacéens et circulations à longue distance. In: *Grandes haches alpines du Néolithique européen, Ve et IVe millénaires av. J.-C.* Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 2 (Pétrequin, P. *et al*. Eds.), Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 918-995. (in French) (“Breton deposits, Carnaceous mounds and long-distance traffic”).

Cassen, S., Rodríguez-Rellán, C., Fábregas Valcarce, R., Grimaud, V., Pailler, Y. & Schulz Paulsson, B. 2019, Real and ideal European maritime transfers along the Atlantic coast during the Neolithic. *Documenta Praehistorica*, XLVI: 308-325.

Cisowski, J., Voiron, J., Heimann, J., Czaja, M. & Mazurka, Z., 2004, Magnetization and magnetic susceptibility of jadeite. *European Journal of Mineralogy*, 16: 671-675.

Chang, S., Yinxin Mao, Y., Chang, G. & Flueraru, C. 2010, Jade detection and analysis based on optical coherence tomography images. *Optical Engineering*, 49(6): 1-8.

Chung, F.H. 1974, Quantitative interpretation of X-ray diffraction patterns. I. Matrix-flushing method of quantitative multicomponent analysis. *Journal of Applied Crystallography*, 7: 519-525.

Clark, J.R., Daniel, E., Appleman, E. & Papike, J.J. 1969, Crystal-chemical characterization of clinopyroxenes based on eight new structure refinements. *MSA Special Paper*, 2: 31-50.

Coccato, A., Karampelas, S., Wörle, M., Willigen, S.V. & Pétrequin, P. 2014, Gem quality and archeological green ‘jadeite jade’ versus ‘omphacite jade’. *Journal of Raman Spectroscopy*, 45: 1260-1265.

Compagnoni, R., Rolfo, F., Manavella, F. & Salusso, F. 2007, Jadeitite in the Monviso meta-ophiolite, Piemonte Zone, Italian Western Alps. *Periodico di Mineralogia*, 76(2-3): 78-89.

Compagnoni, R., Rolfo, F. & Castelli, D. 2012, Jadeitite from the Monviso meta-ophiolite, western Alps: occurrence and genesis. *European Journal of Mineralogy*, 24: 333-343.

Cook, F.A. 2013, Raised relief on nephrite jade artifacts: observations, explanations and implications. *Journal of Archaeological Science*, 40(2): 943-954.

D’Amico, C. 2005, Neolithic ‘greenstone’ axe blades from northwestern Italy across Europe: a first petrographic comparison. *Archaeometry*, 47: 235-252.

D'Amico, C. 2012, Jades and other greenstones from the Western Alps. A petrographic study of the geological sampling Jade. In: *Jade. Grandes haches alpines du Néolithique européen, Ve et IVe millénaires av. J.-C., Sources de matières premières*, Cap. 7. (Pétrequin, P. *et al*., Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l'Ain. Besançon: p. 440-533.

D’Amico, C., Campana, R., Felice, G. & Ghedini, M. 1995, Eclogites and jades as prehistoric implements in Europe. A case of petrology applied to cultural heritage. *European Journal of Mineralogy*, 7: 29-41.

D’Amico, C., Starnini, E., Gasparotto, G. & Ghedin, M. 2003, Eclogites, jades and other HP-metaophiolites employed for prehistoric polished stone implements in Italy and Europe. *Periodico di Mineralogy,* 73 (Special issue 3): 17-42.

De la Iglesia, S. 1908, Catálogo de la sección de protohistoria gallega de la colección de Santiago de la Iglesia. *Almanaque Ferrolano,* 4: 59-67. (in Spanish) (“Catalogue of the Galician protohistory section of the Santiago de la Iglesia collection”).

Delaitte, H., Errera, M., Jadin I., Lawarrée, G. & Pétrequin, P. 2010-2011, Une hache-pendeloque néolithique en néphrite alpine à Ouffet “Houp-le Loup”. *Bulletin des Chercheurs de la Wallonie,* 49: 77-94. (in French) (“A Neolithic alpine nephrite pendulum axe at Ouffet “Houp-le Loup””).

Domínguez-Bella, S., Calado, D., Cardoso, J.L., Clop, X. & Tarriño, A. 2004, Raw materials in the Neolithic-Aeneolithic of the Iberian Peninsula. *Slovak Geology Magazine,* 10(1-2): 17-42.

Domínguez-Bella, S., Ramos, J., Maate, A., Pérez, M., Vijande, E. & Martínez, J. 2012, Matières premières des industries polies néolithiques du détroit de Gibraltar. In: *Roches et sociétés de la préhistoire entre massifs cristallins et bassins sédimentaires, Le Nord-Ouest de la France dans son contexte Européen.* (Querré, G., Marchand, G., Eds.), PUR, Presses Universitaires de Rennes. Rennes: p. 197-205. (in French) (“Raw materials for the Neolithic polished industries of the Strait of Gibraltar”).

Domínguez-Bella S., Cassen, S., Pétrequin, P., Přichystal, A., Martínez, J., Ramos, J. & Medina, N. 2016, Aroche (Huelva, Andalucía): a new Neolithic axehead of Alpine jade in the southwest of the Iberian Peninsula. *Archaeological and Anthropological Science,* 8: 205-222.

Errera, M. 2014, La mesure de densité en archéométrie: une méthode ringarde? In: *Entre archéologie et écologie, une Préhistoire de tous les milieux, Mélanges offerts à Pierre Pétrequin, Annales Littéraires de l’Université de Franche-Comté,* Vol. 928, Série Environnement, sociétés et archéologie. Tome 18. (Arbogast, R.M., Greffier-Richard, A., Eds.), Presses universitaires de Franche-Comté. Besançon: p. 505-520. (in French) (“Density measurement in archaeometry: a cheesy method?”).

Errera, M., Pétrequin, P. & Pétrequin, A.M. 2012, Spectroradiométrie, référentiel naturel et étude de la diffusion des haches alpines. In: *Jade. Grandes haches alpines du Néolithique européen, Ve et IVe millénaires av. J.-C.*, Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 1. (Pétrequin P *et al*., Eds.), Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 440-533. (in French) (“Spectroradiometry, natural reference and study of the diffusion of alpine axes”).

Errera, M., Pétrequin, P., Pétrequin, A.M., Cassen, S. & Croutsch, C. 2007, Contribution de la spectroradiométrie à la compréhension des transferts longue-distance des lames de hache au Néolithique. *Société Tournaisienne de Géologie, Préhistoire et Archéologie.* X(4): p. 101-142. (In French) (“Contribution of spectroradiometry to the understanding of long-distance transfers of axe blades in the Neolithic”).

Fábregas Valcarce, R. 1981, Os machados puimentados da colección de la Iglesia. *Brigantium* 2: 27-38. (in Spanish) (“Polished axes from the Iglesia´s Collection”).

Fábregas Valcarce, R. & Vázquez Varela, J.M. 1982, Hachas de piedra pulimentada con perforación proximal en el Noroeste de la Península Ibérica. *Museo de Pontevedra,* XXXVI: 125-142. (in Spanish) ("Axes of polished stone with proximal drilling in the Northwest of the Iberian Peninsula").

Fábregas Valcarce, R., de Lombera-Hermida, A. & Rodríguez-Rellán, C. 2012, Spain and Portugal: long chisels and perforated axes. Their context and distribution. In: *Jade. Grandes haches alpines du Néolithique européen, Ve et IVe millénaires av. J.-C.,* (Pétrequin, P. *et al*. Eds.). Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 2. Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l'Ain. Besançon: p. 1108-1135.

Fábregas Valcarce, R., Rodríguez-Rellán, C. & de Lombera-Hermida, A. 2017, Des Alpes à la péninsule Ibérique: une longue route sinueuse. In: *Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique*. (Pétrequin, P. *et al*., Eds.). Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 9. Tome 3. Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l'Ain, Besançon. Besançon: p. 419-430.

Foshag, W. F. & Leslie, R. 1955, Jadeite from Manzanal, Guatemala. *American Antiquity,* 21(1): 81-83.

Franz, L., Sun, T.T., Hänni, H.A., Capitani, Ch., Thanasuthipitak, T. & Atichat, W. 2014, A comparative study of jadeite, omphacite and kosmochlor jades from Myanmar and suggestions for a practical nomenclature. *Journal of Gemmology,* 34(3): 210-229.

García-Casco, A., Knippenberg, S., Rodríguez Ramos, R., Harlow, G.E., Hofman, C., Pomo, J. C. & Blanco-Quintero, I. F. 2013, Pre-Columbian jadeitite artifacts from the Golden Rock Site, St. Eustatius, Lesser Antilles, with special reference to jadeitite artifacts from Elliot's, Antigua: implications for potential source regions and long-distance exchange networks in the Greater Caribbean. *Journal of Archaeological Science,* 40: 3153-3169.

Gil Ibarguchi, J.I. 1995, Petrology of jadeite metagranite and associated orthogneiss from the Malpica-Tuy allochthon (northwest Spain). *European Journal of Mineralogy,* 7(2): 403-415.

Giustetto, R. & Compagnoni, R. 2014, Petrographic classification of unusual high-pressure metamorphic rocks of archaeometric interest. *European Journal of Mineralogy,* 26 (5), 635-642.

Giustetto, R., Barale, L. & Compagnoni, R. 2018, Mineral-petrographic study of greenstone cobbles from Quaternary alluvial deposits and Oligocene conglomerates of the Lemme valley (northwestern Italy): Comparison with analogous Neolithic polished stone implements and archaeometric implications. *Journal of Archaeological Science Reports,* 19: 312-322.

Harlow, G.E. 1993, Middle American Jade: Geologic and Petrologic Perspectives on Its Variability and Source. In: *Precolumbian Jade: New geological and cultural interpretations*. (Lange, F.W., Ed.). University of Utah Press. Salt Lake City: p. 9-29.

Harlow, G.E. 1994, Jadeitites, albitites and related rocks from the Motagua Fault Zone, Guatemala. *Journal of Metamorphic Geology,* 12: 49-68.

Harlow, G.E., Murphy, A.R., Hozjan, D.J., Mille, C.N. & Levinson, A.A. 2006, Pre-Columbian Jadeite Axes from Antigua, West Indies: Description and Possible Sources. *Canadian Mineralogy,* 44: 305-321.

Harlow, G.E., Sisson, V.B. & Sorensen S.S. 2011, Jadeitite from Guatemala: Distinctions among multiple occurrences. *Geological Acta,* 9(3): 363-387.

Harlow, G.E., Davies, H.L., Summerhayes, G.R. & Matisoo-Smith, E., 2012a, Archaeological jade mystery solve using a 119-year-old rock collection specimen. AGU Fall Meeting Abstracts, vol. 2012: p. ED41E-0706. Accessed 20 March 2018. URL: http://adsabs.harvard.edu/abs/2012AGUFMED41E0706H

Harlow, G. E., Summerhayes, G.R., Davies, H.L. & Matisoo-Smith, E. 2012b, A jade gouge from Emirau island, Papua-New Guinea (Early Lapita context: 3300 BP): A unique jadeitite. *European Journal of Mineralogy,* 24, 391-399.

Harlow, G.E., Sorensen, S.S., Sisson, V.B. & Shi, G.H. 2014, The Geology of Jade Deposits, Chapter 10. In: *The Geology of Gem Deposits. Short Course Handbook.* Series 44, 2nd Edition. (Groat, L.A., Ed.). Mineralogical Association of Canada. Quebec, p. 305-374.

Harlow, G.E., Tsujimori, T. & Sorensen, S.S. 2015, Jadeitites and Plate Tectonics. *Annual Review of Earth and Planetary Sciences,* 43: 105-138.

Harrison, R.J. & Orozco, T. 2001, Beyond characterisation. Polished stone exchange in the western Mediterranean 5500-2000 BC. *Oxford Journal of Archaeology*, 20(2): 107-127.

Hirajima, T. & Compagnoni, R. 1993, Petrology of a jadeite-quartz/coesite-almandine-phengite fels with retrograde ferro-nyböite from the Dora-Maira Massif, Western Alps. *European Journal of Mineralogy,* 5: 943-955.

Kempe, D.R.C. & Harvey,A. P., (Eds), 1983, *The petrology of archaeological artefacts*. Oxford University Press. Oxford, 380 p.

Knaf, A.C.S., Koornneef, J.M. & Davies, G.R. 2017, "Non-invasive" portable laser ablation sampling of art and archaeological materials with subsequent Sr-Nd isotope analysis by TIMS using 10^{13} Ω amplifiers. *Journal of Analytical Atomic Spectrometry,* 32: 2210-2216.

Lange, F.W. (Ed), 1993, *Precolumbian jade: New geological and cultural interpretations*. University of Utah Press, Utah, 378 p.

Lozano, J.A., Puga, E., Garcia-Casco, A., Martínez-Sevilla, F., Contreras Cortés, F., Carrasco Rus, J. & Martín-Algarra, A. 2018, First evidence of prehistoric eclogite quarrying for polished tools and their circulation on the Iberian Peninsula. *Geoarchaeology*, 33 (3): 364-385. doi:10.1002/gea.21646

Lü, Z., Zhang, L. & Chen, Z. 2014, Jadeite- and dolomite-bearing coesite eclogite from western Tianshan, NW China. *European Journal of Mineralogy*, 26(2): 245-256.

Macke, R.J., Britt, D.T. & Consolmagno, G.J. 2010, Analysis of systematic error in "bead method" measurements of meteorite bulk volume and density. *Planetary Space Science,* 58(3): 421-426.

Marinova, I., Ivanova, P., Tacheva, E. & Vitov, O. 2018, Mineral composition and rock provenance of a prehistoric stone axe head from the surroundings of Nevestino village, Kyustendil District, SW Bulgaria. *Archaeological and Anthropological Science*, 11: 2929-2936. doi:10.1007/s12520-018-0725-4

Mato Vizoso, M. (1872?) "Túmulos y Castros" (unpublished) Manuscript by Manuel Mato Vizoso, Arquivo da Real Academia Galega, A Coruña. 20 p.

McClure, S. 2012, Jadeite/omphacite nomenclature question. Gemological Institute of America, vol.10: p. 1-2. Accessed 14 January 2018. URL: https://www.gia.edu/doc/omphacite-nomenclature-0521.pdf

Medaris, G., Jelinek, E. & Misar, Z. 1995, Czech eclogites: Terrane settings and implications for Variscan tectonic evolution of the Bohemian Massif. *European Journal of Mineralogy,* 7(1): 7-28.

Mendoza Cuevas, A., Bernardini, F., Gianoncelli, A. & Tuniz, A. 2015, Energy dispersive X-ray diffraction and fluorescence portable system for cultural heritage applications. *X-Ray Spectrometry,* 44: 105-115.

Molist, M. & Gibaja, J.F. 2012, La caserna de Sant Pau del Camp (Barcelona): Una aproximación a los modelos de circulación de productos e ideas en un contexto funerario postcardial. *Rubricatum Revista del Museo de Gavà,* 5: 449-458. (in Spanish) ("La Caserna de Sant Pau del Camp (Barcelona): An approach to the circulation models of products and ideas in a postcardial funeral context").

Morimoto, N., Fabries, J., Fergurson, A.K., Ginzburg, I.V., Ross, M., Seifert, F.A., Zussman, J., Aoki, K. & Gottardi, G. 1988, Nomenclature of pyroxenes. *Mineralogical Magazine,* 52: 535-50.

Odriozola Lloret, C.P., Villalobos García, R., Boaventura, R., Sousa, A.C., Batata, C. & Martínez Blanes, J.M. 2015, El hacha de jadeita de Portela do Outeiro (Serta, Branco, Portugal). *Saguntum (PLAV)* 47: 256-260. (in Spanish) ("The jadeite ax of Portela do Outeiro (Serta, Branco, Portugal)").

Odriozola Lloret, C.P., Vargas Jiménez, J.M., Martínez-Blanes, J.M. & García-Sanjuan, L. 2016, El hacha pulimentada de jade de la colección Tubino (Museo Municipal, Valencina de la Concepción, Sevilla). *SPAL Revista de Prehistoria y Arqueología,* 25: 211-227. (in Spanish) ("The polished jade ax from the Tubino collection (Municipal Museum, Valencina de la Concepción, Seville)").

Ou Yang, C., Yen, H.K., Ng, M.F.Y. & Chan, S.Y. 2011: "Nomenclature and classification of Fei Cui (pyroxene jade)". *Proceedings of International Symposium on Jade,* 1-2 Sept. 2011. Peking University. Beijing: 23-34.

Pétrequin, P., Errera, M., Pétrequin, A.M. & Allard, P. 2006, The Neolithic Quarries of Monviso, Piedmont, Italy: Initial Radiocarbon Dates. *European Journal of Archaeology,* 9: 7-30.

Pétrequin, P. & Pétrequin, M.A. 2007, Les carrières néolithiques de jadéitite du Monviso (Piémont, Italie). In: *Actes du XIe Colloque sur les Alpes dans l'Antiquité, Champsec/Val de Bagnes/Valais-Suisse*. Bulletin d'Etudes Préhistoriques et Archéologiques Alpines. Aoste: p. 167-188. (in French) ("The Neolithic jadeitite quarries of Monviso (Piedmont, Italy)")

Pétrequin, P. Cassen, S., Gauthier, E., Klassen, L., Pailler, Y. & Sheridan, J. A. 2012a, Typologie, chronologie et répartition des grandes haches alpines en Europe occidentale. In: *Jade. Grandes haches alpines du Néolithique européen, Ve et IVe millénaires av. J.-C.*, Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 1. (Pétrequin, P. *et al*., Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l'Ain. Besançon: p. 574-727. (in French) ("Typology, chronology and distribution of large alpine axes in Western Europe").

Pétrequin, P., Pétrequin, M. A., Errera, M. & Rossy, M. 2012b, Viso ou Beigua: approche du référentiel des « jades alpins ». In: *Jade. Grandes haches alpines du Néolithique européen. Ve et IVe millénaires av. J.-C.*, Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 1. (Pétrequin, P. *et al*., Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 292-419. (in French) (“Viso or Beigua: approach to the “Alpine jade” frame of reference”).

Pétrequin, P., Cassen, S., Klassen, L. & Fábregas-Valcarce, R. 2012c, La circulation des haches carnacéennes en Europe occidentale. In: *Jade. Grandes haches alpines du Néolithique européen. Ve et IVe millénaires av. J.-C.*, Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 2. (Pétrequin, P. *et al*., Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 1015 - 1045. (in French) (“The circulation of Carnacean axes in Western Europe”).

Pétrequin, P., Pétrequin, M.A., Errera, M. & Prodeo, F. 2012d, Prospections alpines et sources de matières premières. Historique et résultats. In: *Jade. Grandes haches alpines du Néolithique européen. Ve et IVe millénaires av. J.-C.*, Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 1. (Pétrequin, P. *et al*., Eds.), Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 46-183. (in French) (“Alpine prospecting and sources of raw materials. History and results”).

Pétrequin, P., Buthod-Ruffier, D. & Cinquetti, M. 2017a, Le choix des jades alpins. In: *Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique,* Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 9. Tome 3. (Pétrequin, P. *et al*., Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 47-68. (in French) (“The choice of alpine jades”).

Pétrequin, P., Pétrequin, M.A., Errera, M. & Přichystal, A. 2017b, Les jadéitites de Syros (Cyclades, Grèce). In: *Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique*, Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 9. Tome 3. (Pétrequin, P. *et al*., Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 25-46. (in French) (“The jadeitites of Syros (Cyclades, Greece).”).

Pétrequin, P., Pétrequin, M. A., Gauthier, E. & Sheridan, A. 2017c, Alpine jades: from scientific analyses to Neolithic know-how. In: *The Exploitation of Raw Materials in Prehistory. Sourcing, processing and distribution*. (Pereira, T. *et al*., Eds.). Cambridge Scholars Publishing. Cambridge: p. 354-367.

Pétrequin, P. & Errera, M. 2017, Spectroradiométrie, approches macroscopiques et origine des jades alpins: Viso ou Beigua. In: *Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique,* Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 9. Tome 3. (Pétrequin, P. *et al*., Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 75-86. (in French) (“Spectroradiometry, macroscopic approaches and origin of alpine jades: Viso or Beigua.”).

Pétrequin, P. 2017, Inventaire européen des grandes lames polies en jades alpins. In: *Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique,* Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 9. Tome 4. (Pétrequin, P. *et al.*, Eds.). Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l’Ain. Besançon: p. 256-260. (in French) (“European inventory of large polished blades in Alpine jades”).

Prieto Martínez, P. & Salanova, L. 2009, Coquilles et Campaniforme en Galice et en Bretagne: mécanismes de circulation et stratégies identitaires. *Bulletin de la Société Préhistorique Française,* 106.1: 73-93. (in French) ("Shells and Campaniform in Galicia and Brittany: circulation mechanisms and identity strategies").

Querré, G., Cassen, S. & Calligaro, Th. 2015, Témoins d'échanges au Néolithique le long de la façade atlantique: la parure en variscite des tombes de l'ouest de la France. In: *Les systèmes de mobilité de la Préhistoire au Moyen Age,* XXXVe Rencontres internationales d'archéologie et d'histoire d'Antibes, 14-16 oct, 2014. (Naudinot, N. *et al*., Eds.), Editions APDCA. Antibes: p. 403-418. (in French) ("Witnesses to exchanges in the Neolithic along the Atlantic coast: the variscite adornment of the tombs of western France").

Querré, G., Domínguez-Bella, S. & Cassen, S. 2012, La variscite ibérique. Exploitation, diffusion au cours du Néolithique. In: *Roches et Sociétés de La Préhistoire: Entre Massifs Cristallins et Bassins Sédimentaires*. (Marchand, G., Querré, G., Eds.). Presses universitaires de Rennes. Rennes: p. 307-315. (in French) ("Iberian variscite. Exploitation, diffusion during the Neolithic").

Querré, G., Herbault, F., & Calligaro, Th. 2008, Transport of Neolithic variscites demonstrated by PIXE analysis. *X-Ray Spectrometry,* 37: 116-120.

Rapp, G.R. 2001, *Archaeomineralogy,* Springer, Berlin.

Ricq-de Bouard, M. & Fedele, F.G. 1993, Neolithic rock resources across the western alps: Circulation data and models. *Geoarchaeology,* 8(1): 1-22.

Ricq-de Bouard, M. 1996, *Pétrographie et sociétés néolithiques en France méditerranéenne, L'outillage en pierre polie.* Monographies du CRA, Vol. 16. CNRS éditions. Paris. 272 p. (in French) ("Petrography and Neolithic societies in Mediterranean France, Polished stone tools").

Rock, N.M.S. 1990, The International Mineralogical Association (IMA/CNMMN) Pyroxene Nomenclature Scheme: Computerization and its Consequences. *Mineralogy and Petrology,* 43: 99-119.

Rodríguez Ramos, R. 2011, The circulation of jadeitite across the Caribbean scape. In: *Communities in contact: Essays in archaeology, ethnohistory and ethnography of the Amerindian circum-Caribbean* (Hofman, C.L., van Duijvenbode, A. Eds.), Sidestone Press. Leiden, 143-162.

Rodríguez Ramos, R. & Pagán Jiménez, J. 2006, Interacciones multivectoriales en el Circum-Caribe precolonial: Un vistazo desde las Antillas. *Caribbean Studies,* 34(2): 103-143. (in Spanish) ("Multivectorial interactions in the pre-colonial Circum-Caribbean: A look from the Antilles").

Rösch, C., Hock, R., Schuessler, U., Yule, P. & Hannibel, A. 1997, Electron microprobe analysis and X-ray diffraction methods in archaeometry: Investigations on ancient beads from the Sultanate of Oman and from Sri Lanka. *European Journal of Mineralogy,* 9(4): 763-783.

Ruvalcaba-Sil, J.L., Manzanilla, L., Melgar, E. & Lozano Santa Cruz, R. 2008, PIXE and ionoluminescence for Mesoamerican jadeite characterization. *X-Ray Spectrometry,* 37(2): 96 - 99.

Seitz, R., Harlow, G.H., Sisson, V.B. & Taube, E. 2001, 'Olmec Blue' and Formative jade sources: new discoveries in Guatemala. *Antiquity,* 87: 687-688.

Spišiak, J. & Hovorka, D. 2005, Jadeite and eclogite: Peculiar raw materials of Neolithic stone implements in Slovakia and their possible sources. *Geoarchaeology,* 20: 229-242.

Sørensen, L., Pétrequin, P., Pétrequin, M. A., Errera, M., Barbara, H. & Herbaut, F. 2017, Les limites sud-orientales des jades alpins (Grèce et Turquie). In: *Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique,* Les Cahiers de la MSHE Ledoux, Vol. 17, Dynamiques territoriales, 10. Tome 3. Pétrequin, P. *et al.* (Eds.), Presses universitaires de Franche-Comté et Centre de recherche archéologique de la vallée de l'Ain. Besançon: p. 491-520. (in French) ("The south-eastern limits of the Alpine jades (Greece and Turkey)").

Surmely, F., DeGoer de Herve, A., Santallier D. & D´Amico, C. 2001, The distribution of axes in alpine metamorphic rocks (eclogites and jadeites) in central and southwest part of France. *Slovak Geology Magazine,* 7(4): 412-413.

Taube, K. A. Sisson, V.B., Seitz, R. & Harlow G.E. 2004, The sourcing of Mesoamerican jade: Expanded geological reconnaissance in the Motagua Region, Guatemala. In: *Olmec Art and Dumbarton Oaks, Pre-Columbian Art at Dumbarton Oaks, No. 2*. (Taube, K.A. Ed.), Dumbarton Oaks, Washington: p. 203-228.

Theye, T. & Seidel, E. 1991, Petrology of low-grade high-pressure metapelites from the External Hellenides (Crete, Peloponnese). A case study with attention to sodic minerals. *European Journal of Mineralogy,* 3(2): 343-366.

Vaquer, J., Martin, A., Pétrequin, P., Pétrequin, A.M. & Errera, M. 2012, Les haches alpines dans les sépultures du Néolithique moyen pyrénéen. In: *Jade. Grandes haches alpines du Néolithique européen. Ve et IVe millénaires av. J.-C.*, Cahiers de la MSHE Ledoux, Vol. 17, Série Dynamiques territoriales, 6. Tome 2. (Pétrequin, P. *et al*. Eds.), Presses Universitaires de Franche-Comté et Centre de Recherche Archéologique de la Vallée de l'Ain. Besançon: p. 872-917. (in French) ("Alpine axes in burials from the Middle Pyrenees Neolithic").

Villalobos García, R. & Odriozola, C. P. 2017, Circulación de hachas prehistóricas de jade alpino en el centro-occidente de la Península Ibérica. ¿Modelo "directional trade" o "down-the-line/prestige chain"? *Munibe Anthropological Archaeology,* 68. (in Spanish) ("Circulation of prehistoric alpine jade axes in the center-west of the Iberian Peninsula. "Directional trade" or "down-the-line / prestige chain" model?")

Wang, R. 2011, Progress review of the scientific study of Chinese ancient jade. *Archaeometry,* 53(4): 74-692.

Wen, G. & Jing, Z. 1992, Chinese neolithic jade: A preliminary geoarchaeological study. *Geoarchaeology,* 7: 251-275.

Yang, M. L., Lu, C.W., Hsu, I.J. & Yang, C.C. 2004, The Use of Optical Coherence Tomography for Monitoring the Subsurface Morphologies of Archaic Jades. *Archaeometry,* 46: 171-182.