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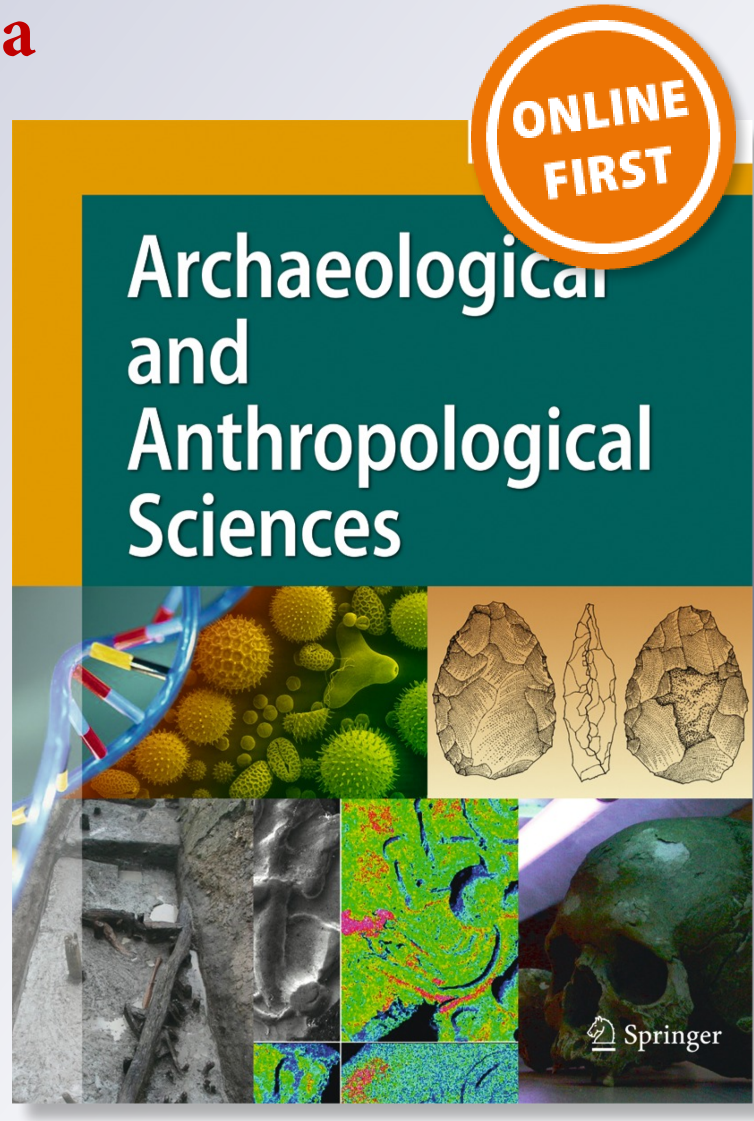

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ORIGINAL PAPER

Aroche (Huelva, Andalucía): a new Neolithic axehead of Alpine jade in the southwest of the Iberian Peninsula

Salvador Domínguez-Bella · Serge Cassen · Pierre Pétrequin · Antonín Přichystal · Javier Martínez · José Ramos · Nieves Medina

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Abstract The discovery of a Neolithic Alpine jade axehead in Aroche, in the southwest of Spain, revives the question of long-distance exchange between the Iberian Peninsula and the rest of Europe. This polished blade belongs to a typological model quite characteristic of Alpine production during the second half of the 5th millennium B.C. Different mineralogical approaches (macroscopic features examination, specific gravity, direct XRD, non-destructive μXRF spectroscopy, optical stereomicroscopy, magnetic susceptibility determination and microprobe analysis) have identified the rock as an omphacitic jadeitite (mixed jade) with some tiny garnets and a weak retromorphosis. This analysis and the comparison of the rock structure with the referential JADE of Alpine natural jade samples, as well as the extraction modalities and shaping of the axe, provide strong arguments to assign the Aroche axe to a production of Mont Viso: the origin of thousands of axes that circulated in Europe between Ireland and Sicily. The Aroche axe, discovered not far from the variscite mines of Encinasola, could be considered as part of a possible exchange system between the Iberian Peninsula and the Gulf of Morbihan, in Brittany.

Keywords Jadeitite-omphacitite · Alpine jade polished axehead · Mont Viso · Andalucía SW Spain · Neolithic exchanges · Variscite

Introduction

A remarkable polished axehead was identified in the collections of Aroche museum (Huelva, Andalucía, SW Spain) during field work to collect samples of variscite on geological deposits around Encinasola in October 2012 (conducted by S.C. and S.D-B.). Variscite was a prestigious raw material exploited from the early Neolithic for the production of beads and pendants, some of which circulated over 1000 km to the north, to the Gulf of Morbihan (Querré 2009; Querré et al. 2008, 2012, 2014).

This axe, made from green rock, is very regular and intensely polished and was easily identified from the approximately 150 other stone blades exhibited in the museum, because neither the raw material nor the shape and style could be related to regional Neolithic traditions. An initial examination allowed us to confidently associate it with the imported polished tools from northern Italy and with rocks similar to Alpine jades. These rocks are usually composed, in the Alpine outcrops, of jadeite/omphacite silicate minerals, but other

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references to jades in archaeological objects of Eastern Europe, have pointed to the presence of nephrite as a mineral in their composition.

Axes in Alpine jades are scarce in the Iberian peninsula (Pétrequin et al. 2012e; Vaquer et al. 2012)—at the very most 20 specimens—with a notable concentration around the variscite mines of Gavá, NE Iberian peninsula. The Aroche axehead, which is neither the largest nor the most remarkable axe from a polishing point of view, nevertheless has a very particular interest. On the one hand, it is the farthest from the Alps and, of course, from the potential origin of the raw material, and, on the other hand, it was discovered just a few kilometers from one of the variscite mines exploited during the Neolithic (Domínguez-Bella 2004; Odriozola et al. 2010); another raw material that was socially valued and involved in long-distance exchange.

This paper focuses on the significance of the Aroche axe in this context of circulation of rare and precious rocks—jades and variscite—in the form of polished axes and beads.

Our presentation will focus on six successive points:

- A literature review of Alpine jades and their circulation in Europe during the 5th and 4th millennia B.C.
- The typological description of the Aroche axe, with proposed dating and macroscopic description of the raw material
- The mineralogical and geochemical analysis
- The origin of the raw material and technical production
- The circulation of Alpine jades
- The Iberian variscite and their relationships with the Gulf of Morbihan, by overlaying the stelae world and their engraved representations.

The circulation of Alpine jade axes across Western Europe, a reminder

Under the term "Alpine jades" (D'Amico 2012; Pétrequin et al. 2012f) are grouped a series of metamorphic rocks (jadeitites, omphacitites, fine grained eclogites), which are rare in nature (less than 20 known sites across the planet; Tsujimori and Harlow 2012: 372, fig. 1) and exhibit remarkable characters: they are precious rocks, extremely hard, frequently translucent, and with a fine grain which allows a very high quality polish.These exceptional characteristics were recognized early on by numerous past and current societies: jade objects were often reserved for elites and gods, for the display of social inequalities (Pétrequin et al. 2012b: 1354–1423)

Mineral jadeite was defined for the first time by A. Damour in 1865 from the analysis of Neolithic axes discovered in France, and in Brittany in particular. This mineralogist also identified "chloromelanite" (a term now replaced by omphacite) among the raw materials used, such as jadeitites (rocks composed mainly of the mineral jadeite, a pyroxene with composition $NaAlSi_2O_6$) for the massive production of axes that circulated over long distances in Western Europe. Omphacite compositions are intermediate between calcium-rich augite and sodium-rich jadeite. The origin of these jades, according to this author, was probably situated in Mont Viso, in the Italian Alps (Damour 1881). Two of his German colleagues (Fischer 1880; Meyer 1891) have similarly identified long-distance transfers, even in northern Germany and Denmark.

In relation to the potential Alpine deposits, primary or secondary, blocks of fresh or rolled jade were described in 1903 by S. Franchi in the Mont Viso Massif (70 km SW of Turin) and in Mont Beigua (immediately to the north of Genoa), while G.B. Traverso (1898–1909) identified sets of blade preforms for axes and adzes in Alba (Cuneo, Piedmont), located midway between Mont Viso and Mont Beigua.

This pioneering work, however, has since been overlooked by geologists and mineralogists, who have only been interested in the Neolithic jade axes as artifacts. Of course, from the point of view of jade petrographical identification, considerable progress has been made by destructive sampling (cores) on archaeological artifacts, but the questions of the origin, extraction methods, production and long-distance circulation have been left aside (see, among others, Ricq-de Bouard 1993, 1996; Compagnoni et al. 1995; D'Amico et al. 2003). These works were focused according to an archaeometry without archaeologists or anthropologists, in a restricted area exclusively reserved to geologists, for the study of Neolithic axes and their circulation.

Multidisciplinary tradition formerly initiated by British researchers who studied these Neolithic jades from a petrographic, typological and chronological point of view (Campbell Smith 1963; Bishop et al. 1977; Woolley et al. 1979) has thus been forgotten. The origin of the Alpine jades was instead interpreted as being located—without demonstration—in secondary deposits of alpine streams, where they would have been simply collected as elongated pebbles (suggested to be already in the shape of axes) and quickly shaped to be exchanged nearby; that is to say, the most 'primitive' transfer modality possible to imagine.

However, this issue has changed towards a more interdisciplinary vision, with the participation of prehistorians and anthropologists. The introduction of a new paradigm—the ethno-archaeological models from current examples of New Guinea (Petrequin et al. 1993)—has certainly constituted an important aspect of the research on polished axes, renewing and multiplying working hypotheses beyond the indispensable petrographic determinations of the raw materials.

The complexity of the production techniques, from genuine quarrying operations and highly specialized processing, the deep integration of stone tools involved in the networks that supported the exchanges, the donations and transfers (see also Renfrew 1975), and the ideal significance of polished blades, appeared then as vivifying hypotheses for research. It became necessary to test these hypotheses with prudence and a critical spirit.

With this new approach, the partitions between disciplines have been demolished to establish a true egalitarian dialogue between different specialists. The achievements of this 'undisciplinary' approach were quickly demonstrated, with the predictable identification of large quarries for the production of axes in the southern Vosges (Petrequin et al. 1995), followed by the scheduled discovery of jade exploitations on the Mont Viso foothills (2003), between 1700 and 2400 m of altitude (and in the Beigua massif, to a lesser degree) (Pétrequin et al. 2006, 2012f, g). In the absence of working hypotheses, these deposits of jade, which have been frequented and exploited for three millennia, producing thousands of archaeological materials as flakes and broken preforms on the ground, were overlooked by the geologists that worked on Mont Viso (Lombardo et al. 1978; Compagnoni et al. 2007).

This project has profoundly modified the initial assumptions held by some archaeometry specialists. Instead of an opportunistic collection of jade pebbles in secondary deposits at low altitude and their direct transfer in a simple and closest exchange system, the production of sign-objects, which are the long axes made out of alpine jade, was concentrated at high-altitude, difficult to access outcroppings. The blocks were exploited with the use of fire (Pétrequin et al. 2008) during seasonal expeditions (Petrequin and Petrequin 2012).

Alpine jade does not simply represent a particularly hard rock adapted to woodworking, but a sacred matter, coming from the Underworld, charged with myths and surrounded by stories. We now better understand the production of axes, their social value, and their extraordinary success in exchanges over very long distances, extending 3300 km from west to east (from Ireland to Bulgaria) and more than 2000 km from north to south (from Denmark to Sicily) (Fig. 1). These polished blades participated in social events and were used by the elites in the context of religious rituals (Pétrequin et al. 2012b).

A Europe of jade, with Carnac as the epicenter in the west (Cassen et al. 2012), came to oppose a Europe of copper and gold, with Varna in the east (Fig. 1), in two social systems based on the imaginary interpretation of the world organization and its control by elites (Pétrequin et al. 2012c; Cassen 2012).

In this new heuristic context, we begin to consider the study of the Aroche axehead.

Materials

The Aroche axe description and dating in the context of the Sierra de Huelva, SW Iberian Peninsula recent Prehistory

The Municipal Archaeological Collection of Aroche (Huelva) was inaugurated on 9 May, 1959, at the request of the local consistory, due to the abundance of archaeological materials located in the municipality. We must not forget that this is the second municipality in the Huelva province with the biggest documented historical and archaeological heritage, with over 100 archaeological sites ranging from prehistoric times to the modern age.

The archaeological collection was mainly composed of donated objects found during construction work or municipality fields until the beginning of the twenty-first century. However, some residents have also donated pieces of unknown origins from other parts of the Iberian Peninsula and, unfortunately, these locations do not always appear in the Museum inventories. Therefore, we cannot say with certainty that this axe, number 119 in the inventory of the Municipal Archaeological Collection, derives from the municipal territory of Aroche. It is, however, part of a large number of stone objects ascribed to the Neolithic–Chalcolithic, some of which were published in 1988 by F. Piñón Varela as associated with megalithic monuments such as the dolmen de la Belleza, or areas such as Las Peñas (Piñón Varela 1988: 248).

The megalithism at the western border of the Sierra Morena is a socio-historic phenomenon that still offers great interest and research potential in this region. The initial focus was on mere descriptions (Cerdán et al. 1975), and it was not until the work of F. Piñón Varela that there was a turning point which unveiled the significant presence of large megalithic constructions in the Sierra Occidental de Huelva (Piñón Varela 1987, 1988). We can add to his work the Archaeological Chart of the Picos de Aroche (Pérez Macías 1987), in which the basis of information about the human occupation of this territory was established.

In the last decade, studies on megalithism have proliferated in this geographic area, generally introducing a renewed vision of these structures as well as new locations. However, the proliferation of the literature is notorious in the area in question, and with regards field research there has only been isolated and limited work on archaeological sites ascribed to the Late Neolithic–Chalcolithic, such as the one developed in the Pasada del Abad (Linares Catela 2010) or the dolmen de la Belleza (García Sanjuán et al. 2006).

The megalithic phenomena in this area are associated with the exploitation of a rich physical environment which favored agricultural and livestock activity from the 5th millennium B.C. It is for this reason that the greatest number of the most significant archaeological finds from this historical period were located in the valley of the Chanza River, a favorable environment for the initiation of these activities, as well as early metallurgical activity. The site of Las Peñas is equally relevant, assuming both acted as natural passes between the Extremadura peneplain, the western region of the Andévalo and the Bética region (Piñón Varela 1987: 242).

Until relatively recently, these megalithic structures were usually associated with funerary practices dating from the Copper Age. However, recent research and excavations have

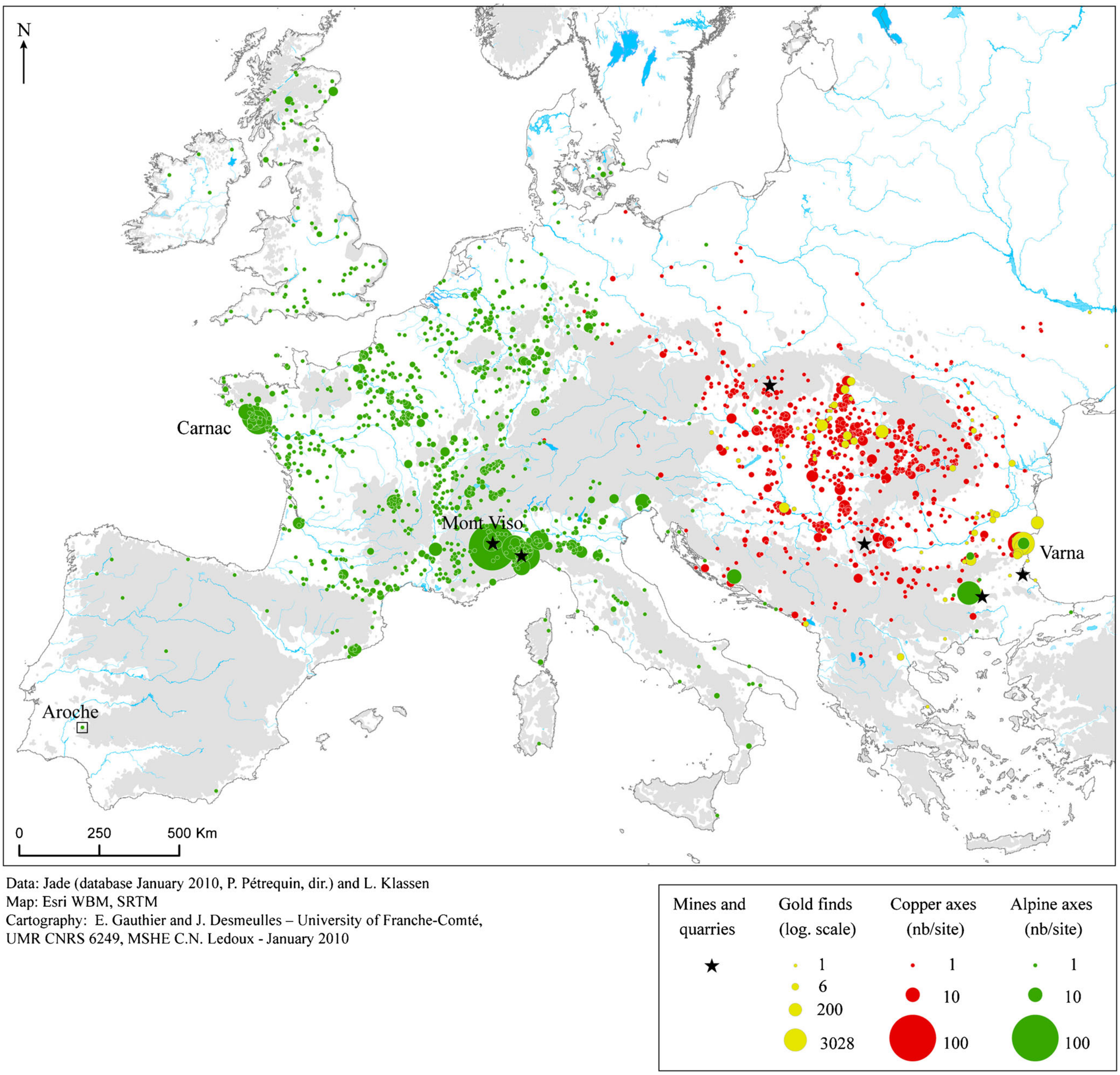


Fig. 1 Comparative distribution across Europe, of the large jade alpine axes (*green*) and copper objects (*red*) or gold (*yellow*) during the 5th and early 4th millennium. A western Europe of jade, with Carnac as the epicenter in the west and a Europe of copper, with Varna in the east, coming into opposition. Except for the enclave of Gavá, the Iberian Peninsula clearly appears outside these systems of social thought. Database: JADE 2010 (P. Pétrequin). DAO: E. Gauthier and F. Desmeulles

noted the presence of a megalithic non-funerary typology not previously documented in western Andalusia, such as the cromlechs or stone circles (Linares Catela 2010). This extends the beginning of these constructions back as far as the 5th–4th millennium B.C.

Isolated menhirs such as the Alcalaboza III and Monte Chico, more than 4 m in length and placed near the Ribera of the Alcalaboza in the area known as Las Peñas, highlight this non-funerary megalithism in the western Sierra de Huelva, which together with the Rivera de Chanza form the two great megalithic complexes of Aroche. Las Peñas, geologically a granite batholith, provides a good raw material for the construction of these structures. Equally important are the stone circles recently reinterpreted in the valley of the Chanza as La Pasada del Abad (Linares Catela 2010), the dolmen of El Torrejón, or the dolmen de la Belleza (García Sanjuán et al. 2006), identified as a cromlech, with menhir blocks later reused for construction of the dolmen.

Since the transition from the 4th–3rd millennium B.C., an expansion of funerary megalithism occurs, highlighting the presence of three well-documented types in the Aroche area such as the megalithic cists (Monteperro), the dolmens with a gallery (Los Puntales, Montero or Castellana III) and passage graves with a polygonal chamber (Los Praditos, Alcalaboza III or La Lamera) (Linares Catela 2010). Some of these, under tumulus burial structures, (which Piñón Varela 1987 termed as "Group of Aroche") may measure up to 30 m in diameter and, as we noted, are mostly found in the Vega del Chanza River (Pérez Macías 1987).

The villages associated with these cultures differ from those located in the valley areas of the Riveras del Chanza or Alcalaboza, for example Bejarano, or those located in the highlands, such as Alto el Naranjo or Pico de Ballesteros, where an intense territorial control is facilitated. They are generally relatively small villages, with circular huts with a stone base, outdoor houses made of branches and mud, or occupying small caves or rock shelters of natural granite blocks, using the granitic batholith of Las Peñas. Some of these walled settlements possibly appear due to incipient mining activity (Pérez Macías 1987) and within the framework of evident social contradictions that are seen through a broad regional analysis (Nocete and Linares 1999; Nocete 2001).

Recent studies are demonstrating ever more manifestations of Neolithic occupation in the regional surrounding, with open air sites (Nocete 2004; Vera et al. 2011; Martín et al. 2015) and non-funerary megalithic manifestations (Gavilán and Vera 2005). Interesting evidence has been found, such as the significant presence of geometric microliths, highlighting sites such as La Dehesa (Lucena del Puerto) (Vera et al. 2011: 121), together with El Retamar, in the Bay of Cádiz (Ramos and Lazarich 2002). Both settlements show incipient productive activities, with seasonal and/or periodic occupations in the context of the 5th–4th millennium B.C. and an acquisition strategy of extensive resources (Vera et al. 2011: 121).

These explanations open new historical avenues into these studies, such as socio-economic approaches to the early stages of the transition from the hunter-gatherers to the Neolithic community tribal societies, and show a clear population substrate of the societies that built the first stelae and megalithic manifestations.

The exact provenance of the Aroche axehead is not known. This polished blade was possibly discovered near the village along with two small, but very classic, polished adzes of sillimanite (fibrolite type), a rare material in Europe and scarce in the Iberian peninsula, but in any case with a far provenance (e.g. Sierra de Guadarrama, north of Madrid; Domínguez-Bella and Morata Céspedes 1995; Domínguez-Bella 2004). According to the museum inventory register, the three artifacts were deposited before the 1950s in the Aroche archaeological Museum by Mr. Manuel Fernandez Vaca. The absence of a conventional archaeological context—quite common with this kind of discovery (Pétrequin et al. 2012b)—means that it is not possible to directly date this polished axe.

The axe measures 20.6 cm in length (Fig. 2), with a width of 8.2 cm and a thickness of 3.7 cm; its weight is 656 g.

Although this is not the longest known jade item—far from it, the largest known jade axe (JADE 2008_698) from Locmariaquer/Mané-er-Hroëck (Morbihan) is not less than 46.6 cm in length—the Aroche axe can be unquestionably ranked among the objects of medium length, the lower limit being fixed at 13.5 cm (Pétrequin et al. 2012c). In Spain, it is surpassed by three axes of more impressive dimensions: JADE 2008_1616, Sabada (Zaragoza), 34.2 cm (Pétrequin et al. 2012c.); JADE 2008_1593 La Bisbal d'Empordà (Girona), 28.4 cm (Muñoz 1965; Vaquer et al. 2012); and JADE 2008_1596 Dima (Biscay), 25.8 cm (Fábregas Valcarce et al. 2012).

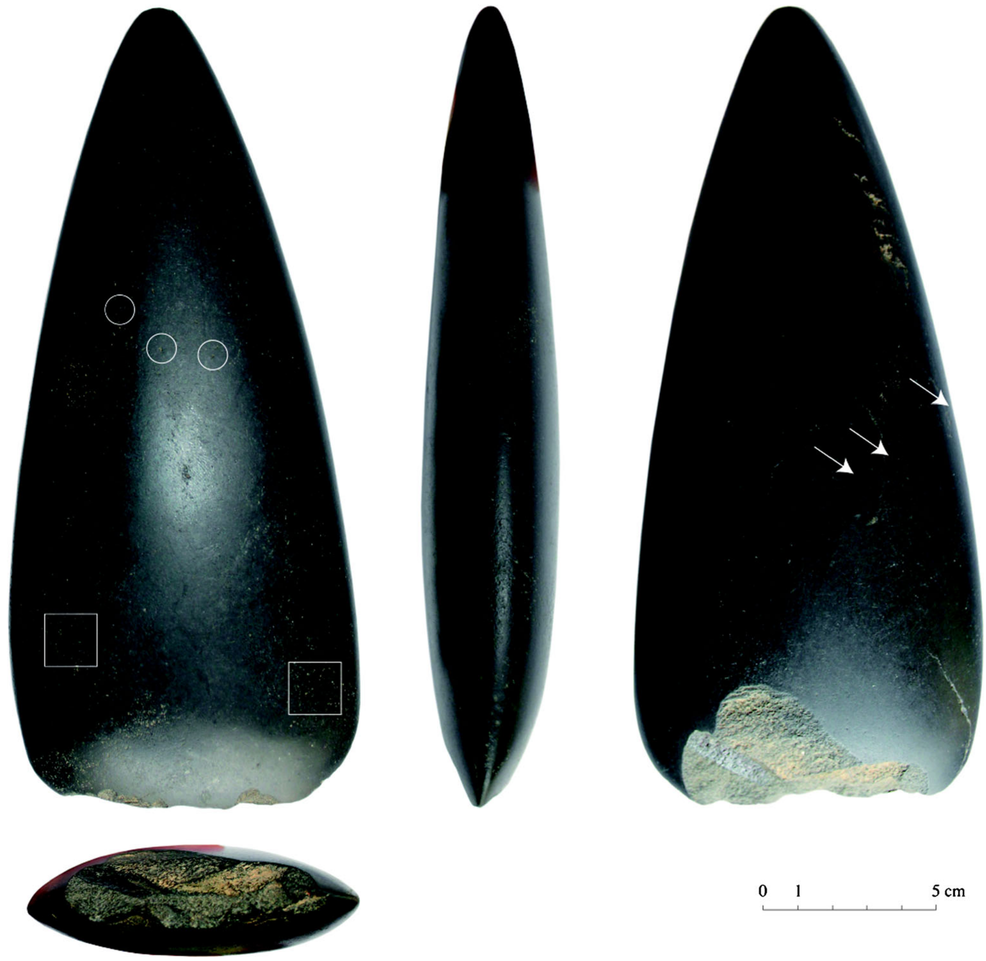
The general shape, with a pointed butt, slightly convex sides and a rounded cutting-edge—that gradually connects to the sides—belongs to the type known as 'tear drop'. In the initial typology of jade axes proposed by W. Campbell Smith (1963), this type is now better defined by the term 'Durrington large' from the systematic study of large European series (Pétrequin et al. 1998, 2012c). The biconvex cross-section of medium thickness is lenticular (type II E of the JADE typology), which suggests a fairly extensive polishing of the preform (polishing at level 5), although some flaking scars still remain near the butt (Fig. 2, top right) and of picketing on both sides of the axe (Fig. 2 in the center, profile view). The finishing of the surface with a slight polish is therefore not perfect; it does not reach the level of a mirror-like polish, often observed in axes made out of rocks with this quality of grain.

Among the axe blades made of Alpine jades, the type Durrington large spans a long time-range (Fig. 3), dating between 4600 and 4500 B.C. and around 4000 B.C. at the latest, when this type of axe is replaced, almost ubiquitously, by the Puy type axes, inspired by the shape of the copper axes (Pétrequin et al. 2012c). The Aroche axe can therefore be quite confidently attributed to approximately the second half of the 5th millennium B.C.

Finally, the Aroche axehead presents one last remarkable feature. Before its abandonment, the polished blade was partially broken with a hard hammer-stone, the cutting-edge being purposefully altered by flaking, making this tool unusable. The case of Aroche is not unique as examples of ritual breaking of large axes made of jade are common in the Gulf of Morbihan (Pétrequin et al. 2012b), the closest example probably being the axe JADE 2008_520 Carnac/Mané-Hui (Morbihan), whose edge was broken using a hammer-stone, before the axe itself was broken into four pieces and the fragments of the axe and one flake from the cutting edge were then deposited in the burial chamber (Cassen et al. 2012). This is a very characteristic ritual in the Gulf of Morbihan towards the middle of the 5th millennium B.C. and shortly thereafter.

Concerning the polishing, we have already noted some interesting residual flake-scars which help to understand the

Fig. 2 The Aroche axe, front and profile views. *White arrows* thermal cracking; *circles* altered microgarnets; *square* small white crystals. Photo: S. Domínguez-Bella and P. Pétrequin



shaping process from a preform to a nicely shaped, hammered and pecked axe-head. Other characteristic signs of exploitation of the raw material by fire also appear on closer examination (Pétrequin et al. 2008): at least three narrow cracks of thermal origin are visible on one side (Fig. 2, indicated by white arrows) and confirm this mode of detaching a large flake from the original block. Such a mode of extraction is well represented among the Alpine jades (Pétrequin et al. 2012a), not necessarily being exclusive to this type of raw material (Petrequin et al. 1993).

Methods

Mineralogical and geochemical analyses

Optical microscopy of a thin section of the axe was made using an Olympus petrographic microscope. Analysis was carried out by X-ray diffraction, directly on the polished surface of the axe, using Bruker D8 ADVANCE X-ray equipment at the University of Cádiz. Experimental conditions of the diffractogram register were: 40 kV and 40 mA, sweep 6–60 ° in 2θ, step-size: 0.01 ° 2θ, time per step: 1 s.

Data from X-ray diffraction processed with the software Spectra Plus of this equipment show that the main component is the mineral jadeite, ASTM file: 00-022-1338 (Fig. 4).

An analysis of the main chemical components was made by micro-X-ray fluorescence (Fig. 5a, b; Table 1, left). The measurement conditions in a micro-XRF spectrometer Bruker M4 Tornado were: multipoint measure mode (100 points), 50 kV–200uA, 100 s.

To determine the different parts of pyroxene grains in the sample and their chemical composition, we used back-scattered electron imaging and a microprobe Cameca SX100 at the Department of Geological Sciences, Masaryk University, Brno. We used a portable kappameter KT-6 of the Earth Sciences Department, Cadiz University, for the magnetic susceptibility measure of the axe.

Results and discussion

At least two factors identify the Italian Alps as the likely origin of the Aroche axe: the characteristic shape (however, there are also imitations made of local rocks), and the use of thermal

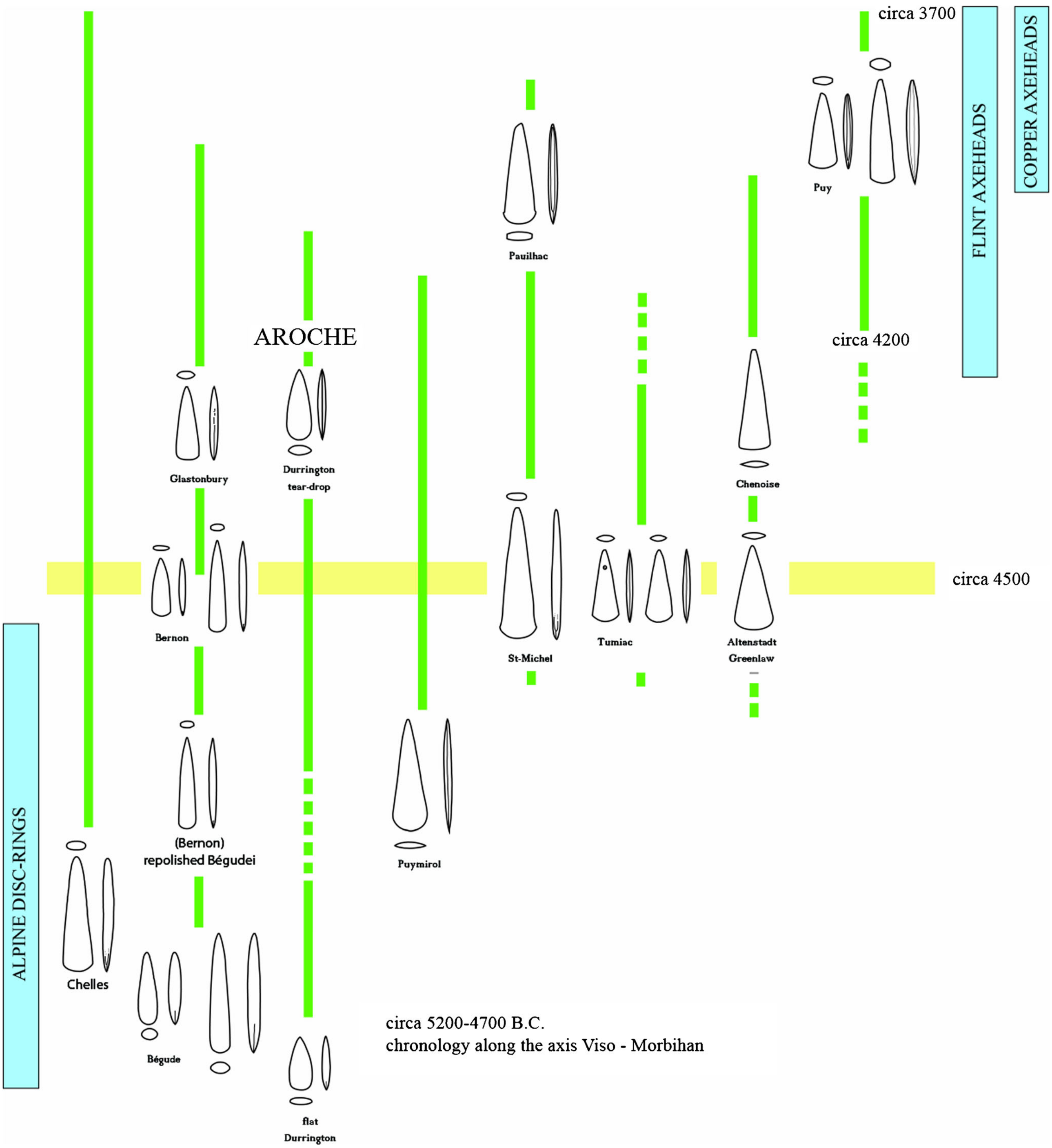


Fig. 3 Proposal for a chronological classification of large axes made of alpine jades, along the geographical axis Italy–Gulf of Morbihan. The Aroche axe belongs to the Durrington type towards 4600–4000 B.C. DAO: P. Pétrequin

shock as an exploitation technique (which could also have been used in Europe for other types of hard, fine-grained rocks). On their own, however, these arguments are not enough; we must now comment on the raw material of the Aroche axehead itself.

The macroscopic examination—both on the polished surface and on the flaked cutting-edge— reveals a fine-grained rock, slightly saccharoidal and a little laminated with its structure parallel to the cutting-edge. The polished surface is dark green with a light blue patina; however, in flaked areas, the color is of a brighter medium green than that of the surface of the axe. The presence should also be noted of very rare microgarnets with a hollow center (ancient garnet altered in atoll, whose center has disappeared), found on only one side

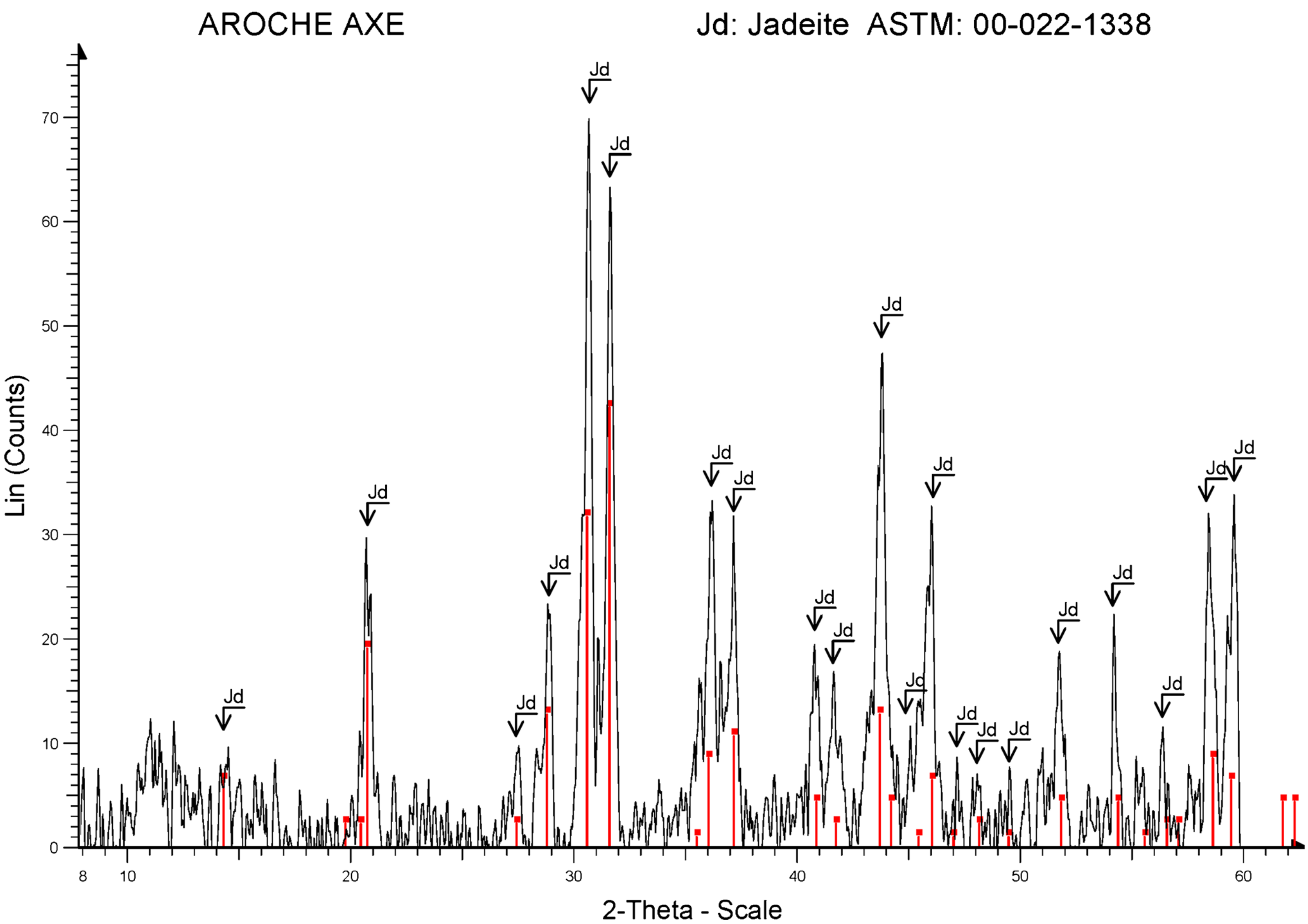


Fig. 4 X-ray diffractogram of the Aroche axehead. The mineralogical identification has shown the presence of jadeite as the principal component. S. Domínguez-Bella and J. Martínez

of the axe (Fig. 2, circles) as well as discrete areas with small white crystals (Fig. 2, squares), which could correspond to a phenomenon of slight retromorphosis of the rock.

To the naked eye, the comparison with reference JADE, which consists of almost 400 polished rock samples and has been the subject of determinations by petrographic thin section, X-ray diffraction and spectroradiometry (Pétrequin et al. 2012f), allows us to guide our diagnosis towards the Alpine jades of Mont Viso, specifically its southern foothills (Oncino, upper Vallon Bulè). Considering the characteristics described above, the Aroche axe could be made from a jadeitite or a mixed jade (jadeite associated with omphacite; as defined by D'Amico et al. 2003; D'Amico 2012), or even a slightly retromorphosed omphacitite. Of course, examination with the naked eye must be corroborated using complementary analyses.

The specific gravity of the Aroche axehead is between 3.33 and 3.34. This value is a little too high for Alpine jadeitites (around 3.32) that are scarcely or not retromorphosed (Errera 2014). However, it could also be easily included within the range of variation of specific gravity among the Mont Viso omphacitites, between 3.36 and 3.39 (Pétrequin et al. 2012f). The density, therefore does not allow us—in this particular case—to decide between a jadeitite and an omphacitite or even a form of association of the two minerals.

An approximate comparison can be given with the results of the two sets of analyses:

- First, the averages obtained on axes from northern Italy, where different types of jadeitites and omphacitites are represented (D'Amico et al. 2003) (Table 1, center).
- Secondly, spot analysis on the outer fringe (jadeitite) of a boudin fragment from Mont Viso/Oncino/Vallon du Bulè supérieur (OF3039) also appear (Compagnoni et al. 2012) (Fig. 5; Table 1, right). Here the extreme values of each main component are illustrated, showing the well-known variations from the outer fringe to the core of the pyroxenite boudins (Pétrequin et al. 2012f: 299–302). The most convincing comparisons indicate jadeitite.

In thin section, the rock has a granoblastic texture of monomineral character (Fig. 6). The absolutely prevailing pyroxene grains are colorless, subhedral and elongated up to 0.3–0.4 mm. Their radial arrangement is visible in places.

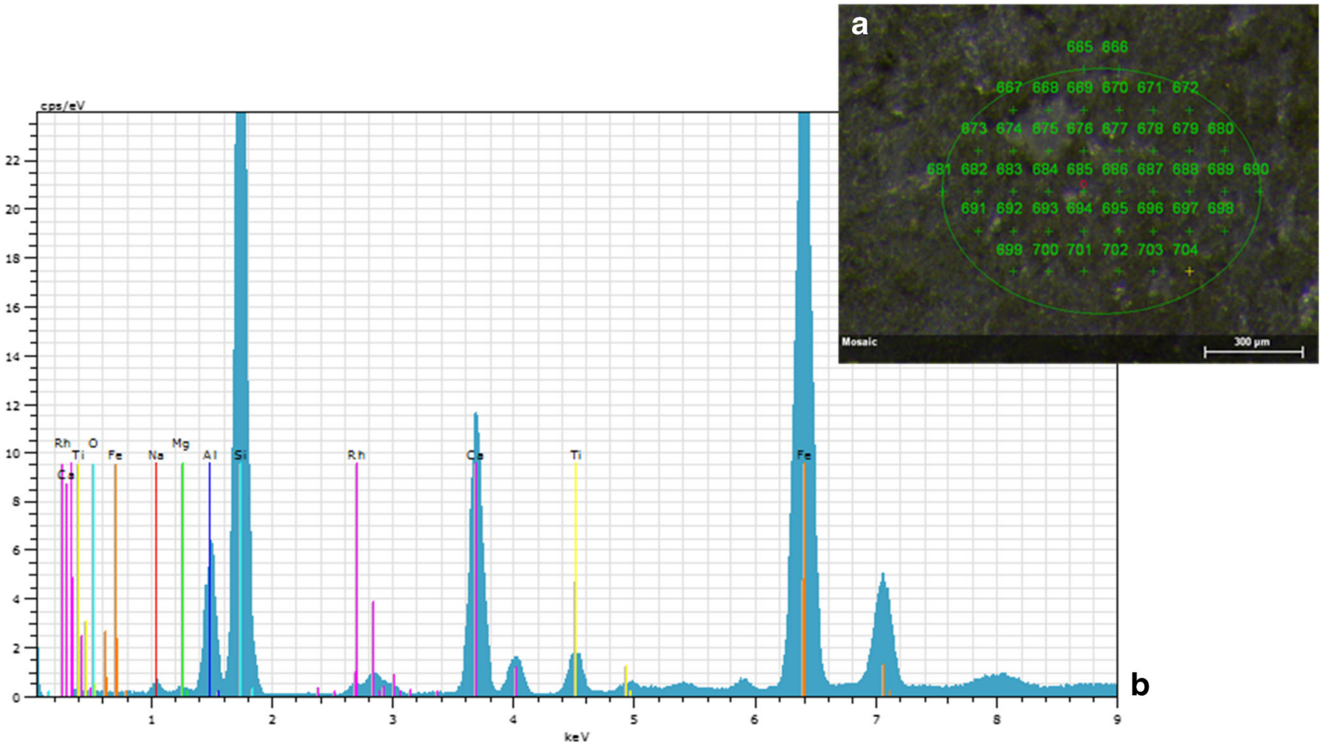


Fig. 5 Micro-XRF of the Aroche axe surface. **a** Multipoint chemical analyses (70 analyzed points) on the rock surface and **b** XRF spectra. S. Domínguez-Bella and J. Martínez

Some pyroxene grains exhibit a zonal pattern with a large core and a narrow rim. The core is often clouded with brownish inclusions. The extinction angle of cleavage, parallel with the elongation of pyroxenes, varies around 33°.

Back-scattered electron imaging shows three different parts of pyroxene grains (light, gray and dark). To determine their chemical composition, we used a microprobe Cameca SX100 at the Department of Geological Sciences, Masaryk

Table 1 Semiquantitative chemical analysis of Aroche axe (obtained by micro-XRF), and different analyses of jadeitites and omphacitites from the Alps. Left: Aroche axe; center: Neolithic axeheads; right: boudin from Mont Viso/Vallon du Bulè supérieur

		concentration								
compound formula	nZ	Aroche axe	jadeitite 16 ex	Fe-jadeitite 15 ex	mixed jades 12 ex	Fe-mixed jades 7 ex	omphacitite 5 ex	Fe-omphacitite 2 ex	omphacitic schist 9 ex	Viso Bulè OF3039 jadeitite outer rim
SiO_2	14	55,65	58,37	55,99	56,76	54,82	54,63	54,86	48,38	57,52 à 58,82
TiO_2	22	0,46	0,61	1,07	0,6	1,5	0,93	1,18	1,24	0
Al_2O_3	13	19,15	19,34	15,69	15,19	13,88	10,1	14,3	15,27	10,76 à 19,35
Fe_2O_3	26	3,88	2,61	9,13	5,03	9,38	7,84	13,09	8,23	3,89 à 3,99
MgO	12	1,22	2,74	2,16	5,35	3,42	8,29	1,96	10,8	2,19 à 5,39
CaO	20	4,22	2,79	3,19	5,88	5,58	9,96	5,92	8,37	0,33 à 11,90
Na_2O	11	15,42	11,9	11,45	9,79	9,54	6,89	6,47	4,96	8,26 à 15,15
Total		100	98,36	98,68	98,6	98,12	98,64	99,78	97,25	
			D'Amico, Starnini *et al.* 2003							Compagnoni *et al.* 2012

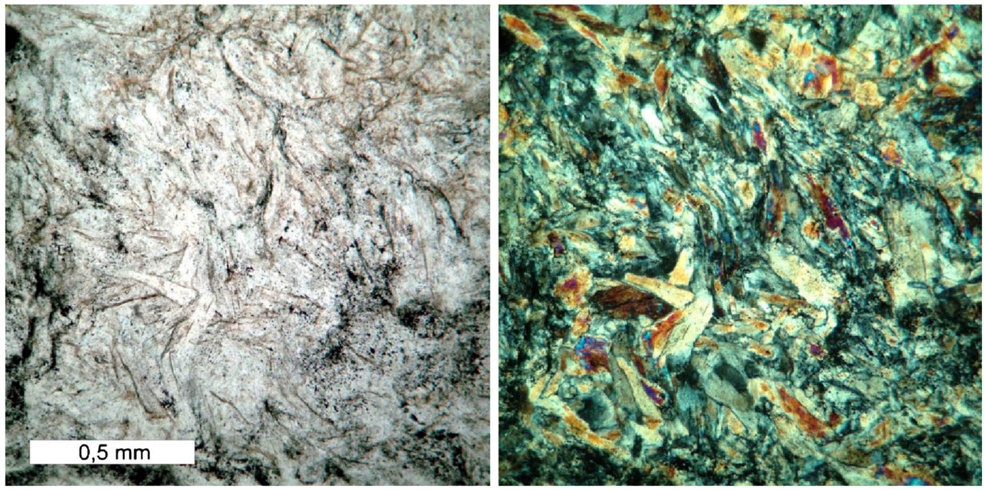


Fig. 6 Thin section of a small chip of the fractured zone of the axehead. *Left* parallel Nicols XP, ×100; *right* crossed Nicols XN, ×100. Photo: S. Domínguez-Bella

University, Brno. Analyzed points 1–9 are shown in Fig. 7. Light thin margins (analyses nos. 1, 2, 3) have the lowest contents of Na_2O (6.85–8.34 weight %) but a relatively high presence of total Fe as FeO (8.9–10.0 %). This means they have only 33–42 % jadeite component and their composition corresponds to omphacite, or some of them are even plotted just at the limit of omphacite/aegirine. The gray parts of the pyroxenes (analyses nos. 4, 5, 6) have a higher presence of Na_2O (9–10 %) and, after recalculation, the jadeite component represents 60–65 %. The dark pyroxene cores (analyses nos. 7, 8, 9) contain between 12 and 14.07 % Na_2O, meaning 81–98 % jadeite component. In total, we have analyzed 20 points of all three mentioned parts over the whole thin section area. When plotted in the diagram after Morimoto et al. (1988), 9 of them are situated in the range of jadeite and 12 in the range of omphacite. In addition, 3 of them lie just at the border with aegirine, 1 even from the aegirine side.

With regards accessory minerals, the presence of very small grains of apatite and also, rarely, zircon (both less than 10 μm) were confirmed using a microprobe. Apatite also occurs inside some pyroxene grains and zircon is usually arranged in the form of short elongated crystal aggregates.

The studied rock is similar to the jadeitite associated with omphacite described by Compagnoni et al. (2007, 2012) from the Mont Viso meta-ophiolite. According to them, zoning pyroxenes in the Mont Viso jadeitite may have a jadeite-rich core ($Jd_{95–98}$) and an overall omphacitic rim ($Jd_{45–60}$). The authors also mentioned large accessory zircons of a few micrometers. Our microprobe study of the Aroche axe thin section confirms the same situation. All the mentioned analyses discard a possible Iberian provenance of the only until now cited geological outcrop with jadeite in Spain, placed in Malpica-Tuy materials (Galice, NW Spain) (Gil Ibarguchi 1995).

The comparison between the thin section of the Aroche axe and those of the JADE reference collection of natural samples (Pétrequin et al. 2012f) allows us to show that only the deposits of the Mont Viso southern foothills seem to possess these particular characters: a very meshed pyroxene structure, clean crystals and sharp boundaries, with randomly oriented bars (or in a fan), and some small grains of light green cores (jadeite) and dark green borders (omphacite). As we know, no sample from the Mont Beigua massif presents these particularities.

The magnetic susceptibility of the axe measured using the portable kappameter is about 0.15×10^{-3} SI (mean value based on six measurements oscillated between 0.14 and 0.16×10^{-3} SI). This magnetic susceptibility measurement compares well with samples of jadeitite chips of similar dimensions and weight from the Mont Viso region, for which we have recorded values from 0.14 to 0.25×10^{-3} SI (Oncino, Vallon de Porco, Abri Jadéite) up to $0.22–0.27\times10^{-3}$ SI (Oncino, Porco supérieur, sous Rasciassa, bloc "Peyronel", jadeitite boudin destructed by mineral collectors) (Compagnoni et al. 2007; Pétrequin et al. 2012f, g).

Raw materials and production techniques

The Mont Viso massif must be pointed to as the origin of this polished blade. This is even in the absence of strict global comparisons that would have allowed a spectroradiometric analysis (Errera et al. 2012) between the raw material of the Aroche axe and all samples of collected jades from the internal Alps (Pétrequin et al. 2012f). The transfer distance from Mont Viso to Aroche is around 1420 km as the crow flies (Fig. 1).

To be more geographically specific, the omphacitic jadeitite exploited was probably extracted from "boudins" at Oncino/Vallon du Bulè supérieur area, between Alp Bulè and Col Luca. Here there are still on-site layers of abandoned flakes and hammer-stones (Pétrequin et al. 2012g: 130–149), particularly on the slope at the foot of the 'Pyramid' (op. cit.: 131–132, figs. 63, 64).

The observation of scars on the flakes, preforms and polished axes, combined with results from an experimental approach (Pétrequin et al. 2012a) allows us to specify the

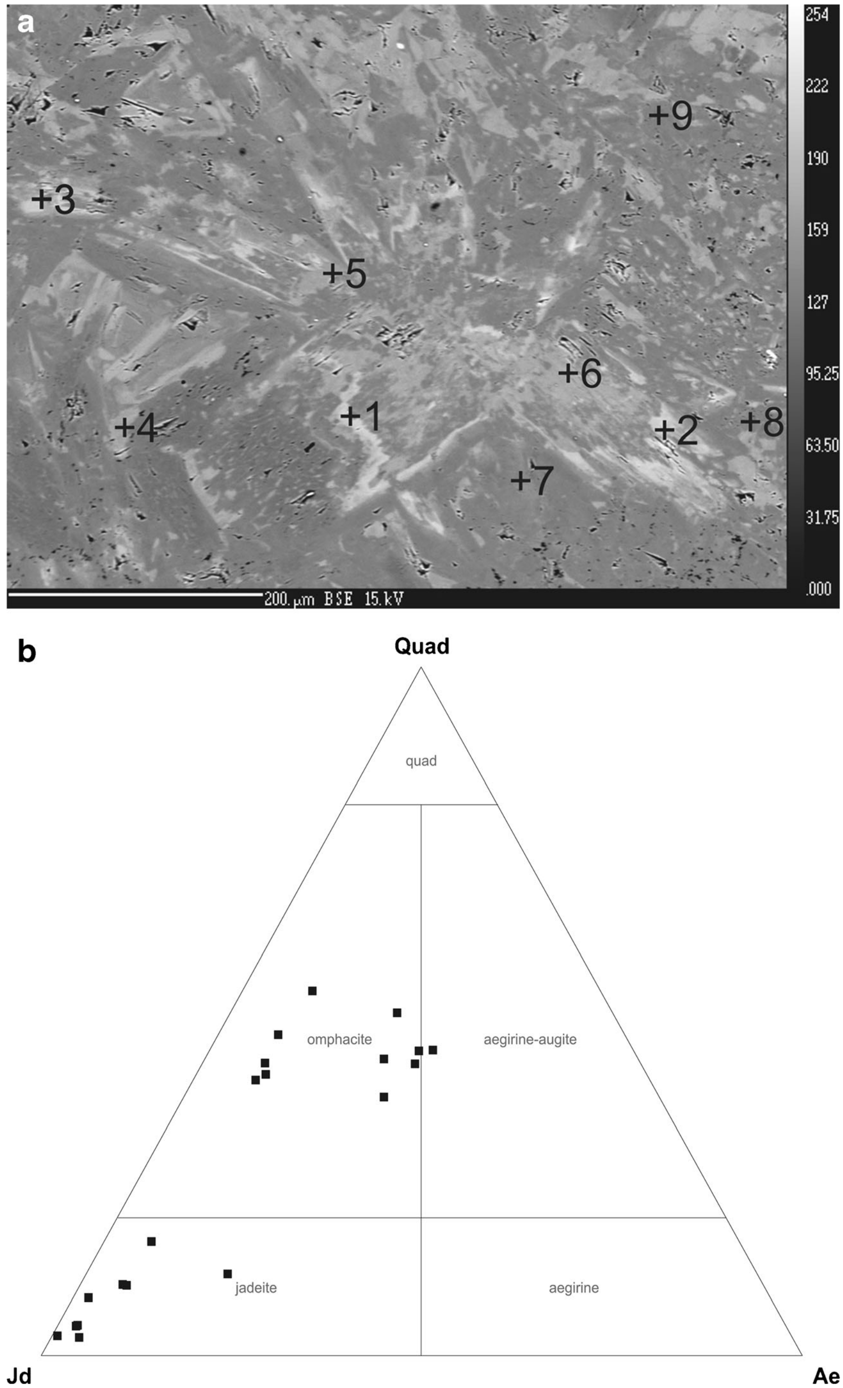


Fig. 7 **a** Back-scattered image of radial arrangement of zoning pyroxene grains in thin section of the Aroche axehead. *Crosses with numbers* show points of analyses mentioned in the text. **b** Twenty microprobe analyses showing clinopyroxene compositions of the Aroche axeheads in the jadeite-aegirine-Quad (normalized wollastonite + enstatite + ferrosilite) triangular diagram of Morimoto et al. (1989). P. Gadas and A. Prichystal

extraction methods of the raw material of the Aroche axe, which present narrow fissures of thermal origin (see Materials). The 'boudins' were slowly heated with a moderate amount of combustible material (Pétrequin et al. 2008) to create curved break-lines parallel to the exploitation surface (Fig. 8, top and middle). The process can be renewed until the total exhaustion of the block, some of which originally weighed several tons. At the end of this exploitation by Neolithic people, only a circular depression remains, with a layer of flakes produced by a thermal process or by percussion, and sometimes with the cracked residual base from the original boudin (Fig. 8).

Large thermal flakes—frequently curved—were created in the fire (Fig. 9, top), or thick flakes, detached using a heavy hammer-stone, were then flaked into shape. The Durrington type (that is to say the Aroche axehead) is represented by hundreds of specimens in the Vallon du Bulè supérieur valley (Fig. 9, bottom left), found among

Fig. 8 Mont Viso Massif: experimental approach to fragmentation process by fire (*top* jadeitite with garnets, and center saccharoidal jadeitite) and layer of flakes at the site of a former jadeitite boudin exploited just to exhaustion (jadeitite and omphacitite). Photos: A.M. and P. Pétrequin, M. Bailly

the flakes, rough-outs and preforms abandoned in place because they had cracks, breaks or were nodules considered as irreducible.

Extraction and shaping with a hammer-stone require a good level of specialization, but do not require a very long process, at the most 50 hours for an axe 20–25 cm long. In contrast, however, the final episode of polishing to obtain a very regular shape and a glossy or shiny surface (Fig. 9, bottom right) would have taken a considerable amount of time. We know that the average material loss in the polishing process of a jadeitite axe was of the order of 2–3 g per h, we can therefore assume that at least 80–120 h is the minimum time needed to polish a preform of 25 cm long to get an axe such as the Aroche (Pétrequin et al. 2012a) (Fig. 2).

The investment of this amount of time also had an impact on the social value of these axes, which were made out of a particularly rare polished rock that was difficult to access in a high mountain environment.

Fig. 9 Some stages of the shaping of axes made of Alpine jades in the southern foothills of Mont Viso: top thermal flake (eclogite); *bottom left* abandoned preform of Durrington type obtained by hard percutor/hammer–shaped (eclogite); *bottom right* Durrington-type polished axe from the Gulf of Morbihan (jadeitite similar to that of the Aroche axe). Photos and DAO: A.M. and P. Pétrequin ▶

Aroche and the circulation of Alpine jades

A distance of 1420 km in a straight line from the Mont Viso to Aroche is not unusual for a jade Alpine axe; many found elsewhere in Europe attest to distances of up to 1700 km as the crow flies (Fig. 1; Pétrequin et al. 2012c). It is therefore interesting to ask what the true route of this Durrington axe could have been between the Italian Alps and southwestern Spain.

Concerning the Durrington type, first it may be noted that the distribution of this typological model is completely asymmetrical with respect to the epicenter of exploitations, Mont Viso (Fig. 10, red dots). If the preforms and axes are well represented in the production area (Piedmont) and more widely in northern Italy up to 500 km from the source of raw materials, most of the Durrington-type axes crossed the Alps and were diffused towards the Atlantic European fringes.

In fact, these objects-signs of the Europe of jade (see Fig. 1) circulated from east to west, while northern Italy already had eastern influences from the Balkan Chalcolithic, at least from the middle of 5th millennium. At this time; Alpine jades were reaching Carnac and the Gulf of Morbihan (Fig. 1, left, green dots, Carnac), a social center of attraction for a lot of the polished blades coming from the Alps. This was predominantly via the main circulation axis of the Bourgogne and the Val de Loire or by the Limagne.

From 4300 B.C., a second axis in the distribution process was established, from the Paris Basin in the direction to Germany, coinciding with the expansion of the Michelsberg culture in this region of Europe. The establishment of a third diffusion axis corresponds to the Neolithic colonization of Britain, which reached Scotland and Ireland, towards the end of 5th and early 4th millennia.

ONCINO Upper Bulè, Pyramide

ONCINO / SAMPEYRE, Milanese valley

ONCINO Cercle of the Blocks, rockshelter B

JADE 2008_0526 Carnac

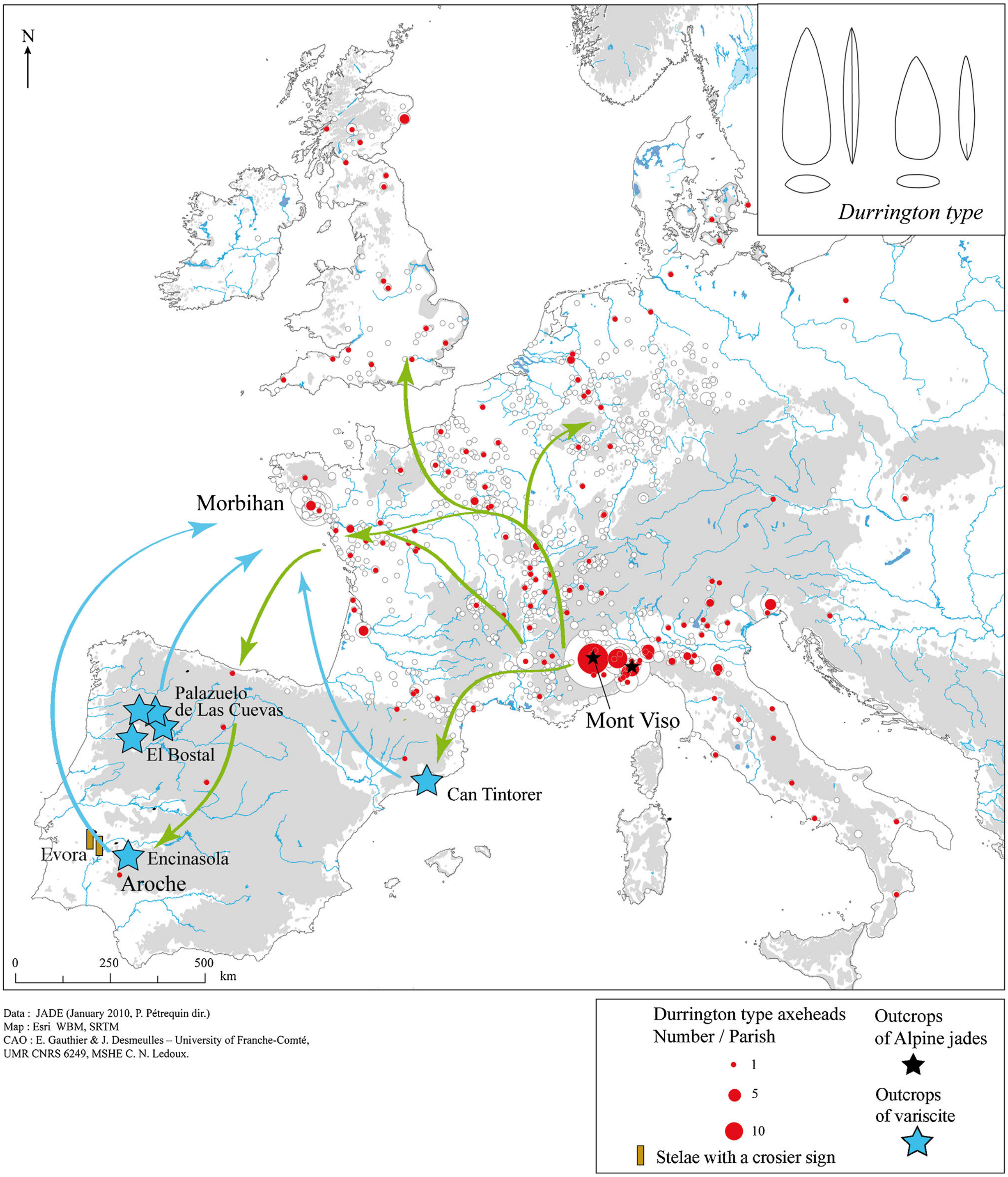


Fig. 10 Distribution of Durrington-type polished axes in Alpine jades compared with the circulation of the variscite from the Iberian Peninsula in direction to the Gulf of Morbihan. *Red dots* Durrington-type axes; *blue stars* mines of variscite; *green rectangles* steles with the throwing sticks sign. DAO: E. Gauthier, J. Desmeulles, P. Pétrequin and S. Cassen

A fourth axis, from the Italian Alps, that reached the region of Toulouse and Bordeaux by the southern Massif Central, was of secondary importance, except in the transition from the 5th to the 4th millennia. At this point, alpine axes arrived in Catalonia simultaneously with the Chassey production of cores and blades of heated flint, detached by pressure and attracted by the wealth of the variscite mines—other socially valued objects—were exploited in Gavá (Fig. 10, blue star, Can Tintorer) (Vaquer et al. 2012).

Apart from the Catalonian enclave, the Iberian Peninsula was scarcely affected by the movement of the Alpine jade axes; its eastern half seems almost devoid of any significant examples. This is not the case in western Spain, where three Durrington type axes—like those of Aroche—have already been identified in Diego Alvaro (Castilla y León, JADE 2008_1595), Palencia (Castilla y Leon, JADE 2008_1604) and Penamellera Baja (Asturias, JADE 2008_1605), among a few others of a carnacean typological model (Fábregas Valcarce et al. 2012) (Fig. 10, bottom left, red dots).

In western Spain, we suggest that the movement of the four axes of the Durrington type (including the Aroche axe) was not a terrestrial route through the Pyrenees, but an Atlantic sea route, in connection with the imports of Iberian variscite by the elites of the Gulf of Morbihan. The place of discovery of the Aroche axe would thus be very significant if we consider that it was not far from the Encinasola variscite open air mines (Fig. 10, bottom left, blue star), but 1130 km from the Gulf of Morbihan.

Perhaps it is also not a coincidence that the axes of the Durrington type found in western Spain are made of a dark jade (dark green), a material not very popular in the Gulf of Morbihan, where the preference is for light jades (Pétrequin et al. 2011). These were re-polished and re-shaped to obtain the incomparable and inimitable objects-signs of the carnacean type (Pétrequin et al. 2012d), of which an imported specimen is known in Vilapedre, Spain (Galicia, JADE 2008_1622).

The Gulf of Morbihan and the Iberian variscite

In 1864, A. Damour, studying the archaeological artefacts found in a carnacean tumulus (Locmariaquer/Mané-er-Hroëck), identified by means of chemical analysis a soft green mineral which he called "callaïs" in reference to the famous material mentioned by Pliny the Elder. Subsequently, A. Lacroix corrected the vocabulary and determined the variscite as the main component of the objects from the same graves, without commenting on the German origin (Variscia, district of Vogtland in Saxony) of the mineral proposed by Damour (Lacroix 1893).

The discovery of the Catalonian source of variscite from the 1960s (Muñoz 1965) indicated a distant origin for Morbihan ornaments which was assumed for some time. However, the discovery of variscite in phtanites of Pannecé, near Nantes (Loire-Atlantique), led many authors to consider a possible regional provenance, as had happened with the Alpine jades (Forestier et al. 1973: 178), and a more "economic" hypothesis was formed (Cassen et al. 2012: 973). But with the use of new methods (X-ray diffraction, scanning electron microscopy, electron microprobe, optical spectrometry), this more regional, Armorican origin was ultimately dismissed, with no other source proposed (Kiratisin and Demaille 2006). The exceptional Aroche polished blade found so close to the outcrops of variscite, and the probable Neolithic chronology of the Encinasola mines, must therefore be seen in the context of socio-economic transfers and geographic relationships over very long distances. We can also strengthen Morbihan's connection with the symbolic representations that accompany the phenomenon of "Alpine jades" during the 5th millennium (Cassen 2012).

It is important to point out the aforementioned concentration of stelae and stone rows in the Portuguese geographic areas of Evora and Reguengos de Monsaraz, containing the engraved sign "crook" (Fig. 10, green rectangles, bottom left), the only known concentration to date in the Iberian Peninsula (Cassen 2007; fig. 18 in Pétrequin et al. 2012d). This "crosse" sign has been abundantly recorded in Morbihan, alongside the representations of hafted axes (Cassen 2012). To this geocultural singularity, we must now add the essential structural association, recognized on a stele of the standing stones complex of Vale Maria do Meio, Evora (Cassen et al. 2015).

On stele No. 10, the cross+quadrangular+crescent+arc signs are found. The first three signs are juxtaposed on the morbihannais stelae; the presence of the arc is a particularity of this Portuguese site. Its singular design, unique to-date in the Iberian Peninsula, is, however, known in Morbihan, inscribed on a reused covering slab in the middle of the I'lle Longue passage tomb (Larmor-Baden). In the world of representations, the repetition and correlation of very specific signs on steles of European regions as far away as this can hardly be regarded as the result of a simple coincidence.

The authors also note with interest that the geological variscite deposit of Pico Centeno, located only 2 km from the border with Portugal (Picos de Aroche at the western end of the Sierra Morena), has a natural outlet on the Ribeira do Murtiga river which flows into the Ardila river. This river in turn flows into the Guadiana, precisely at the confluence of the Degebe river, whose source is located very close to Evora.

This set of geographical and hydrographic connections over a few tens of kilometers from east to west, although observable connections today, were certainly also valid in the 5th millennium. They can contribute to the general interpretation of the ancient megalith concentration in Alentejo, especially in this unique area of communication involving the territories of Evora and Reguengos de

Monsaraz, at the confluence of three major basins of the Tagus and Sado rivers (to the Atlantic) and Guadiana river (to the Gulf of Cádiz).

Conclusions

After the typological and archaeometrical study carried out at macroscopic and microscopic level on the Aroche axehead, it turns out that it can clearly be classified as an Alpine jade object. These petrological and geochemical results show great compositional similarities with Mont Viso omphacitic jadeitite, Oncino, in the Italian Alps, one of the main source-areas of jades used in the elaboration of Neolithic prestige axeheads. The appearance of a jade axehead in this geographical area is of great interest because of its novelty and the scarcity of finds in the south of the Iberian Peninsula for these precious materials.

A remarkable fact is the proximity to Aroche of one of the largest geological deposits of variscite in Europe, with a demonstrated record of prehistoric exploitation, such as Encinasola (Huelva), and the clear and confirmed relationships between the two Neolithic raw materials in the grave goods of the Atlantic coast of Western Europe, which suggest a possible relationship between the trade routes of both materials, with a long-distance distribution network, up to several thousand kilometers, in Neolithic times.

We can also point to a possible connection between the Atlantic seaboard in SW Europe and the coast of Morbihan in Brittany, from the undoubted coincidence in some of the symbolic representations that appears in the 5th millennium B.C. megaliths of both regions.

These relationships with the Italian Alps and the megalithic sites of the Atlantic seaboard, such as Carnac (Brittany), Galicia (NW Spain) and Alentejo (SW Portugal), with the presence of rare and precious raw materials such as omphacitic jadeitite, variscite and sillimanite, suggest possible routes, terrestrial or maritime, for the exchange of these products, throughout thousands of kilometers, during the Neolithic in southwest Europe, matters certainly encouraging for future studies.

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