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The Neolithic greenstone industry of Chiomonte (northwestern Italy): mineralogy, petrography and archaeometric implications

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The Neolithic greenstone industry from Chiomonte (northwestern Italy): mineralogy, petrography and archaeometric implications

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Abstract. The polished stone industry of Chiomonte (Piedmont region, northwestern Italy), dating back to the Middle-to-Late Neolithic, was studied with a multi-analytical approach, including mineralogical, petrographic and morpho-typological issues, with the aim of providing information about the supply sources of the raw materials and determining the function of the

- 15 settlement in the prehistoric Western Alps setting. Most of the lithic tools are made of stricto sensu greenstones (i.e., 'Napyroxene rocks' and 'Na-pyroxene + garnet rocks'), though a large amount of serpentinites (25 %) also exists. The combined application of XRPD, polarizing microscopy and SEM-EDS led to the detection of specific mineral/chemical 'markers', pointing to a likely provenance of the Chiomonte tools from the Monviso area. However, other closer supply sources – e.g., small meta-ophiolite units in the Orsiera-Rocciavré mountain range or in the lower Susa valley – cannot be ruled out. The
- 20 presence, on the many retrieved roughouts and broken tools, of raw, yet unpolished surfaces ascribable to pebbles and cobbles from alluvial or glacial deposits, suggests that these rocks had been picked up from local 'secondary' sources. The abundance of roughouts and broken tools identifies Chiomonte as a second-order/manufacturing site, although it is still unclear whether such an activity was restricted to the local needs or rather contributed to the circulation of greenstone implements on a wider scale.

25 1 Introduction

In the Neolithic, mankind abandoned nomadism and settled permanently in flat lands, dedicating to agriculture and stock raising and passing from the use of the splintered to the polished stone. Most lithic implements (axes, chisels and hatchets) have been found in archaeological sites spread all over Europe – and especially in the Po plain and Western Alps. These tools underwent a vast circulation – as similar relics have been found in southern France, southern Italy, Great Britain (Pétrequin et

30 al., 2002), Slovakia, Czech Republic, Hungary, (Spišiak and Hovorka, 2005; Pétrequin et al., 2011; Bendő et al., 2014; 2019), Austria, Bulgaria, Denmark, Germany, Spain (Tsonchev, 1946; Přichystal and Trnka, 2001; Errera et al., 2006; Pétrequin et al., 2008) and Malta (Mancusi, 2017). They are mostly made of stricto sensu greenstones, i.e. high-pressure (HP) metaophiolites marked by toughness and high density (Ricq-de-Bouard, 1993; Giustetto et al., 2008; D'Amico and Starnini, 2009; 2011), mostly consisting of Na/Ca-pyroxenes, i.e. solid solutions of jadeite (Jd), omphacite and aegirine (Ae). Giustetto

- 35 and Compagnoni (2014) divided these rocks in two groups: 1) 'Na-pyroxene rocks', commonly referred to as 'jades', including jadeitite (with 95-100 vol% jadeite), omphacitite (with 95-100 vol% omphacite) and mixed Na-pyroxenite (with intermediate amounts of jadeite and omphacite); 2) 'Na-pyroxene + garnet rocks', made of omphacite plus garnet, including eclogite (with omphacite and garnet in 25 to 75 % mutual amounts), garnet-omphacitite (with 5-25 vol% garnet) and omphacite-garnetite (with 5-25 vol% omphacite). Actually, the term 'jade' includes 'jadeite jade' (made of jadeite, NaAlSi2O6) and 'nephrite jade'
- 40 [made of an amphibole of the tremolite–ferro-actinolite series: Ca2(Mg,Fe)5Si8O22(OH)2]. Only the former will be treated here, though 'omphacite jade' [made of omphacite, (Ca,Na)(Mg,Fe2+,Al)Si2O6] will be considered too (D'Amico et al., 2004; Ou Yang, 2006; Ou Yang et al., 2011; McClure, 2012).

These greenstones occur in the alpine geological context as rare and small 'primary' outcrops (few m3) at high altitude, mainly in the Monviso and Voltri massifs (D'Amico, 2005; Pétrequin et al., 2005a, 2005b, 2006; Compagnoni et al., 2007; 2012), or

- 45 as boulders and pebbles/cobbles in 'secondary' alluvial deposits, derived from the dismantlement in the neighboring downhill regions (Compagnoni et al., 2006; D'Amico and Starnini, 2006; D'Amico and De Angelis, 2009). The pioneering studies of Gastaldi (1871), Damour (1846) and Franchi (1900) have shown that these greenstones belong to the Internal Piemonte Zone, which includes meta-ophiolite units derived from the Liguria–Piemonte oceanic domain, characterized by alpine metamorphism under eclogite-facies conditions (Compagnoni, 2003). Moreover, jadeitites and omphacitites are also found in
- 50 Queyras, a typical blueschist facies area located in the External Piemonte Zone (Caron and Saliot, 1969; Harlow et al., 2014). Locating the supply sources of the raw materials used to produce these artifacts (whether from the Monviso or Voltri 'massifs') and their nature (whether from 'primary' outcrops or 'secondary' deposits) represent important issues, as they might allow reconstructing the manufacturing techniques and ancient migratory fluxes or trade routes (Chiarenza and Giustetto, 2010; D'Amico et al., 1992, 1997, 2013; Pétrequin et al., 2017b). Such a goal can be pursued only by comparing the distinctive
- 55 mineralogical and petrographic features of these tools with those of analogous geological samples of known origin, searching for common traits that may hint the same provenance. Other lithotypes – such as serpentinites, prasinites and chloritites (occasionally also termed as greenstones, due to their hue) – were seldom used to produce these tools. However, due to their ubiquitous distribution in the Western Alps, they have limited archaeometric relevance. This study deals with the characterization of the polished greenstone industry from the archaeological site of Chiomonte – La Maddalena, near Torino,
- 60 northwestern Italy (Figs. 1.a, b). Over 130 stone implements were investigated with a well-established analytical protocol, thus allowing archaeometric considerations.

2 Materials and methods

2.1 Archaeological case study and materials

The archaeological site of Chiomonte – La Maddalena (The Magdalene) was discovered in 1985, while excavating for the Fréjus highway, and explored by the local Archaeological Superintendence during three campaigns. The site, inhabited from the Middle Neolithic until the Medieval age, is positioned in the high Susa valley (718 m a.s.l.) at the base of a slope on the left side of the Dora Riparia river (Fig. 1.b), sheltered by big boulders of an ancient landslide deposit. The so-called 'La Maddalena' site corresponds to a terraced surface on fluvioglacial deposits close to the Clarea stream, which flows 60-80 m downstream. The archaeological materials (ceramics, splintered and polished stone) lay directly on landslide and fluvioglacial

- 70 deposits, showing two separate colluvial layers: i) a lower, muddy/sandy level, conserving traces of anthropic activity; ii) a superficial, gravelly/pebbly layer, with landslide blocks in the upper portion and strongly muddled up archaeological goods. An area of about 12500 m2 at the base of the slope was stratigraphically investigated, thus uncovering a significant number of structures and artifacts, pertinent to a multiphase settlement dating back to the Middle/Late-Final Neolithic. The importance of the site is due to the frequent relationships that occurred between the end of the 5th/first half of the 4th millennium BC with
- other cultures on the French and Swiss sides of the Western Alps, especially in the high and medium Rhône valley (Padovan, 2017). The polished stone industry of Chiomonte consists of 132 objects, mostly in greenstone, mainly represented by instruments for cutting (i.e., axeheads, with some hatchets and scalpels). All different steps of the manufacturing chain are represented, including several tool fragments and/or roughouts. Few are the finished objects, whilst some pebbles are also present. The collection was held in the archaeological museum of 'La Maddalena Chiomonte', recently closed due to the
- 80 turmoil connected with the construction of the high-speed train line from Turin to Lyon. Since then, it has been transferred to the deposits of the Antiquity Museum in Turin.

2.2 Methods

All 132 retrieved implements were analyzed with a well-established protocol, involving archaeological (morpho-typological exam) and archaeometric (non-invasive mineralogical-petrographic analyses) methods, aimed at obtaining a statistical screening about their functionality and lithology. Furthermore, a more restricted number of tools – basing on their lithotype and mineral-petrographic features – was selected for micro-invasive mineral-petrographic analyses. Although alternative non-destructive approaches have been recently used (e.g., SEM-EDX to infer the chemistry from the tools surface and prompt-gamma activation to obtain their bulk elemental composition without any sampling: Bendő et al, 2014; 2019; Váczi et al., 2019), a micro-invasive protocol was preferred, so as to avoid severe limitations on the area of analysis and dispose of unbiased data. This sacrifice was counterbalanced by restricting such exams, which include X-ray powder diffraction (22 specimens), optical polarizing and scanning electron microscopy (12 specimens, representative of the previous ones; Chiari et al., 1996; Compagnoni et al., 2006; Giustetto et al., 2008), only to roughouts and broken/fragmented artifacts, in order to preserve the integrity of the few finished tools. Small cores (10 mm diameter) – representative at best of the rock composition – were extracted with a diamond crown drill and used to prepare powders and 30 µm polished thin sections. These analyses were

95 aimed at pointing out typical mineral-petrographic 'markers', to be compared with those already described in the literature for analogous geological samples of known origin. X-ray powder diffraction (XRPD) data were collected in the 3-70° 2 θ range, using an automated Siemens D-5000 diffractometer with $\theta/2\theta$ setup in Bragg-Brentano geometry, CuK α radiation and zero-background, flat sample holder. Data were processed with the Diffrac Plus (2005) software (EVA 11,00,3).

100 Polarizing microscopy was performed on a Zeiss WL Pol optical instrument. Scanning electron microscopy (SEM) was performed with a SEM Stereoscan 360, Cambridge Instrument, on carbon-coated thin sections. Chemical characterization was performed by an EDS Link Pentafet, Oxford Instrument (operating conditions: 50 s counting time, 15 kV accelerating voltage, 25 mm working distance, 300 pA beam current). The collected data were processed with the INCA 200 Microanalysis Suite Software, version 4.08, calibrated on natural mineral standards using the ZAF correction method.

105 3 Results

3.1 Morpho-typological examination

The raw processing state and fragmentary conditions of the Chiomonte tools (especially axes and hatchets) allow only preliminary typological considerations, due to difficulties in checking their effective dimensions (length, width and thickness), upon which the existing classifications are based (Pedrotti, 1996). However, the studied tools and roughouts (132, some of

- 110 which are shown in Fig. 2a) can be classified, basing upon their functionality and traces of manufacture/use, mostly as implements for cutting (axes, 52 % but also hatchets and chisels, 10 %), with a few apt for striking (percussors, 5 %) or abrading (grindstones and millstones, 3 %). Some instruments with ornamental or playing purposes (pendants and taws, 5 %) have also been found. Finally, numerous splinters, unspecified fragments and/or pebbles (22 %) and a few residual samples with no plausible function (3 %) are found (Fig. 2b). As far as instruments for cutting are concerned, few complete and finished
- 115 artifacts exist (8 out of 82 total), with small to moderate dimensions, whilst the number of roughouts and fragmented tools (probably broken during manufacture and/or after use) is significant (58). Table S1 (freely available online in the Supplementary Material linked to this article at <u>https://pubs.geoscienceword.org/eurjmin</u>) lists, for each implement, the inventory label(s) and presumed typological function.

3.2 Density measurements and stereomicroscopy examination

- 120 Density values were determined with a precision balance (weighing each tool in air and in water; Compagnoni et al., 2006) for 119 (out of 132) artifacts, by excluding those too small to obtain reliable measurements. All implements were also examined with a stereomicroscope in reflected light, on wet and polished surfaces (if present), in order to evaluate their mineral grainsize, heterogeneities and microstructural features. A preliminary lithotype determination was thus achieved (see Supplementary Material, Table S1).
- 125 The density histogram for greenstones (Fig. 3.a) shows a sharp distinction between HP-metaophiolites stricto sensu (i.e., 'Napyroxenites' and 'Na-pyroxene + garnet rocks', usually > 3 g/cm3) and other lithotypes – similar to the naked eye (i.e., serpentinites and prasinites, with densities usually \square 3 g/cm3). Eclogites show higher densities (mostly between 3.4 and 3.6

g/cm3), partially overlapping the slightly lower ones for jadeitites, omphacitites and mixed Na-pyroxenites (varying between 3.2 and 3.5 g/cm3). The lithotype distribution (Fig. 3.b) is rather heterogeneous, with serpentinite as the most abundant rock

130 (25 %). Globally, stricto sensu greenstones represent 50 % of the tools; among them, mixed Na-pyroxenite (almost 24 %) is the most abundant rock, followed by eclogite (19 %). Jadeitite and omphacitite are scarce (2 and 3 %, respectively), as well as garnet-bearing omphacitite (2 %). Basing on the average distribution, 22 samples were selected among the roughouts and broken/fragmented tools for micro-invasive analyses (Table 1).

3.3 X-ray powder diffraction

135 With this technique, the mineralogical composition of the 22 selected samples was determined and confirmed their lithotypes. A rough measurement of the reflections intensities for the crystalline phases is also reported, prompting semi-quantitative evaluations (Table 2).

Sixteen samples are made of stricto sensu "greenstones", the rest being related to other less representative (e.g., chloritites and serpentinites) or peculiar lithologies. 'Na-pyroxene rocks' are made of a single pyroxene with a well-defined composition

- (jadeitite and omphacitite), or two pyroxenes in almost equal amounts (mixed Na-pyroxenite), with scarce or no minor phases. The three main pyroxene reflections – -221, 310 and 002 – are well defined in jadeitite (Fig. 4a) and omphacitite (Fig. 4b), while in mixed Na-pyroxenite they are split due to presence of both jadeite and omphacite, each with a complex zoning (Fig. 4c). In 'Na-pyroxene + garnet rocks', the reflections of garnet also appear – evident in eclogite (Fig. 4d) but hardly visible in garnet-bearing omphacitite (Table 2). In sample 5747, the reflections of garnet prevail over those of other phases (omphacite, each with a complex source).
- 145 plagioclase and minor clinochlore and amphibole) thus suggesting a peculiar composition. The chemistry of Na-pyroxene solid solutions may be estimated from the dhkl values of their main reflections (-221, 310, 002). When transferred on the grid proposed by Giustetto et al. (2008), superposed to the Jd-Q-Ae diagram of Morimoto et al. (1988), these values lead to an average composition affected by a mostly restricted error (Fig. 5a, b and c).

3.4 Polarizing microscopy and SEM-EDS

- 150 The petrographic approach, despite its micro-destructivity, is fundamental to identify compositional mineral zoning and microstructural heterogeneities of these rocks, together with the chronological relationships among different pyroxene (and garnet) generations. Moreover, the petrographic study allows identifying minor phases, undetected by XRPD. All these features are essential for the comparison between data collected on prehistoric tools and geological specimens of known provenance, in order to trace the origin of the raw materials (Giustetto et al., 2017). Twelve thin sections were obtained from as many tools
- 155 in stricto sensu greenstone already inspected by XRPD, namely:
 - 5 'Na-pyroxene rocks' [2 jadeitites, 1 omphacitite and 2 mixed Na-pyroxenite];

• 7 'Na-pyroxene + garnet rocks' (4 eclogites and 3 garnet-omphacitites).

The chemistry and zoning of pyroxene and garnet were studied by plotting EDS data in the ternary diagrams of Morimoto et al. (1988) (Fig. 5a, b and c) and almandine (Alm) + spessartine (Sps) – grossular (Grs) – pyrope (Prp), respectively (Fig. 6).

160 Table 3 provides the semi-quantitative mineralogical composition obtained for each sample by combining XRPD, polarizing microscopy and SEM-EDS. Selected EDS analyses for pyroxene and garnet are reported in the Supplementary Material (Tables S2 to S20).

3.4.1 Na-pyroxene rocks: jadeitites

The 3788 axehead fragment is a typical jadeitite with granoblastic structure and faint foliation, marked by jadeite crystals with a complex zoning and including greener omphacite domains. Locally, the Jd crystals show 'dusty' cores or small, iso-oriented linear exsolutions of omphacitic nature (Fig. 7a), together with scarce opaque ores. The SEM-EDS analyses proved that these omphacitic domains have a rather low Ae content (< 20 %; Table S2). Green-to-bluish amphibole coupled to apatite, titanite, zircon and biotite occur as minor or accessory phases. The other sample (CMIX/81; axe heel) is marked by crumbled Jd crystals (hundreds of µm across), partly retrogressed with a 'dusky' aspect (Fig. 7.b), and albite. SEM-EDS investigations indicated that the jadeitic matrix includes tiny and irregular omphacite exsolutions, with no (or little) Ae. White mica (paragonite), together with clinozoisite, nepheline and titanite also occur.

3.4.2 Na-pyroxene rocks: omphacitites

The studied artifact (4360; axehead fragment) is quite homogenous and fine-grained, with an incipient mylonitic microstructure. Small green and zoned omphacite crystals (\approx 50 µm) locally have tiny, iso-oriented darker inclusions (Fig.

175 8.a). The SEM images show a complex pyroxene zoning, with older Ca/Mg richer domains (brighter in BSE) being surrounded by a younger, Na/Al richer matrix (darker; Fig. 8.b). Spot analyses clearly indicate an omphacitic composition, with a wide range of Ae content (10 to even 40 %; Table S4). Zircon is the only accessory phase.

3.4.3 Na-pyroxene rocks: Mixed Na-pyroxenites

The two studied specimens are similar. The 6636 axe heel exhibits an evident foliation, defined by the alignment of abundant rutile, commonly forming aggregates. The very fine grained pyroxene matrix shows a complex zoning, appreciable only at high magnifications, with a dual distribution of colourless jadeite and greenish omphacite (Fig. 9.a). At SEM, such a zoning shows in some areas the presence of darker jadeite 'relics', corroded by a younger omphacite (Fig. 9.b).

The 7179 axehead fragment is also fine-grained, though some stumpy pyroxene crystals locally occur, commonly wrapped out by shear zones marked by the preferred orientation of finer-grained, iso-dimensional crystals. The only accessory minerals are

185 rutile and zircon. The distribution of EDS spot analyses covers an almost continuous range between the jadeite and omphacite fields. The aegirine content is usually less than 20 % (Table S6).

3.4.4 Na-pyroxene + garnet rocks: eclogites

Three (out of the four) analyzed eclogites (3088, 5653 and 67142/8936) show fine to very fine-grained omphacite matrix, commonly with mylonitic structure. When observed at the polarizing microscope, pyroxenes show a strong zoning – their

- 190 colours varying from pale to deep green (Fig. 10.a). The EDS data confirm this heterogeneity, the related spot analyses being scattered in the omphacite field (Wo + En + Fs20-50 with Ae10-40; Tables S7, S9 and S13). Jadeite is rare: only in sample 3088, small domains of impure Jd, including small 'blebs' of exsolved omphacite, are surrounded by an omphacite matrix. Locally, pyroxene crystals show a peculiar yellowish to green/bluish pleochroism. A foliation is evident, marked by the abundant rutile (or pyroxene) crystals. Garnet (≈ 100 µm across) forms packed aggregates and show a typical atoll-like aspect;
- 195 a greener pyroxene is locally observed inside the atoll (Fig. 10.a, b). The garnet chemistry is quite constant, with higher Alm + Sps content (70-80 %) and minor pyrope (20-30%) and grossular (< 10 %; Tables S8, S10 and S14). Occasionally, retrogression zones are observed converting both omphacite and garnet into green amphibole. White mica, ilmenite, (rare) sulfides and apatite occur as minor or accessory phases.

The last sample (7144; axehead fragment) differs from the others due to the larger pyroxene grain-size (hundreds of μ m across),

- including both omphacite and jadeite. Fractured garnet crystals, with no atoll-like habit, form scattered aggregates; large and scattered rutile crystals (hundreds of µm across) occur as an accessory phase (Fig. 10c). SEM-EDS analyses showed that relict Jd crystals, including tiny exsolved omphacitic 'blebs', are corroded by younger zoned omphacite (Fig. 10d). Jadeite is rather pure (≈ Jd90), with no or very small Fe-content. The distribution of omphacite analyses is quite scattered (Ae10-20), confirming its marked zoning; garnets are almandine (Alm-Sps80), with minor pyrope (around 10-20 %) and grossular (< 10
- 205 %; Tables S11 and S12).

3.4.5 Na-pyroxene + garnet rocks: garnet-omphacitites

All findings of this lithology – a broken axe heel (3975) and two fragments (5319, 7736) – were analyzed. The 3975 sample has granoblastic structure with mylonitic portions, in which porphyroclasts (hundreds of μm across) of a relict magmatic pyroxene exhibit dusky cores and contain deformed ilmenite inclusions (Fig. 11.a). The matrix, rather homogeneous, has omphacitic composition with Ae10-20 (Table S15). In the mylonitic domains, a moderate zoning occurs with scattered spots in the aegirine-augite field. Single, fractured Alm+Sps rich (70-80 %) garnets with relict appearance, possibly developed after the mylonitic fabric, occasionally overgrow the porphyroclasts. Pyrite, rutile and ilmenite are the only accessory phases. In sample 5319, the microstructure is isotropic, with fragmented and irregularly shaped omphacite crystals (hundreds of μm wide) having a rather homogeneous chemistry. Garnet is scarce and fractured. Apatite and titanite are accessory phases. In 7736, the fine-grained pyroxene matrix shows coexistence of both jadeitic and omphacitic domains, with complex mutual relationships. Locally, omphacite seems older than jadeite, because it appears in the core of larger crystals (Fig. 11.b) – in opposition to what observed elsewhere (e.g., in 6636 and 7144; Sections 3.4.1.3 and 3.4.2.1). The scattered distribution of EDS analyses confirms the observed zoning, with Ae up to 30 %. Scarce and isolated garnets are rich in Alm-Sps (up to 90 %) and poor in Grs (< 5 %; Tables S19 and S20). Rutile and interstitial ilmenite occur as accessory phases.

220 4 Discussion

4.1 Mineralogical/petrographic considerations and provenance issues

In the Chiomonte lithic industry, the fraction made of stricto sensu greenstones ('Na-pyroxene rocks' and 'Na-pyroxene + garnet rocks') is large (around 50%) though less conspicuous than elsewhere (e.g., in Brignano Frascata; Giustetto et al., 2017). Serpentinites are quite abundant. This is an uncommon occurence, rarely observed in other sites (e.g., Villaromagnano;

- 225 Giustetto et al., 2017), and may suggest a certain scarceness of HP-greenstones in the areas surveyed for the retrieval of raw materials. Such a possibility has been suggested by Mancusi (2016) and contextualized by D'Amico (2012), who pointed out the scarcity of these tougher lithotypes in the northern Monviso 'massif' (close to the inspected site; Fig. 1.b). An alternative explanation might be a reduced skill of the local gatherers in tracing those rocks apt to produce better tools. A further oddity in Chiomonte is represented by the assorted fraction of tools made of rocks other than greenstones (25%, including quartzite
- 230 and marble, hardly found in other sites), which may further support the inference about the local scarcity of more suitable lithotypes.

'Na-pyroxene rocks' prevail on 'Na-pyroxene + garnet rocks' (29 vs. 21 %). Such a trend, though locally seen elsewhere (e.g., Brignano Frascata; Giustetto et al., 2017), is opposite to what observed in most sites (i.e., Alba, Castello di Annone, Gaione, Ponte Ghiara, Rivanazzano, Rocca di Cavour, Sammardenchia and San Lazzaro di Savena; Mannoni and Starnini, 1994;

- D'Amico et al., 1995; 1997; 2013; D'Amico and Ghedini, 1996; D'Amico and Starnini, 2000, 2012b; Andò, 1998; Bernabò Brea et al., 2000; Borgogno, 2000; Giustetto et al., 2016) in which eclogites dominate, even reaching 66 %. 'Na-pyroxene rocks' (with 'mixed Na-pyroxenite' being the prevailing rock) are quite abundant with respect to other sites (e.g., Sammardenchia and Rivanazzano), where these 'jades' are □ 10 %.
- From a mineral/petrographic point of view, accurate comparison can be done between the Chiomonte tools and those from other coeval sites. Besides, the same data can also be related to analogous geologic material of known provenance, in order to infer analogies or differences and retrieve information about the location of the raw material supply sources. Of course, the reliability of such a survey increases if samples analyzed with analogous protocols are compared. This is the reason why, in the following, studies that followed analytical procedures similar to those adopted here (e.g., D'Amico, 2012; Giustetto et al., 2016; 2018) will be kept into account more than others, based on different approaches (i.e., visual appearances to the naked
- 245 eye or non-invasive analytical methods, such as spectroradiometry; Errera et al., 2012, Pétrequin and Errera, 2017). The latter studies, although providing databases with hundreds of entries (Pétrequin et al., 2012b), offer less reliable mineral/petrographic information. Also, it is known that, on average, jadeitites, omphacitites and mixed Na-pyroxenites are hard to discriminate with no instrumental support (XRD, at least) and virtually indistinguishable by visual methods alone (D'Amico, 2012). Similar difficulties arise for eclogites, their garnet often being fine grained (especially in greenstone tools). Moreover, eclogites are
- 250 hardly recognizable from omphacitites with spectroradiometry, their spectra not being distinctive enough (Errera et al., 2012; Pétrequin et al., 2012b; Pétrequin and Errera, 2017). In this perspective, the high number of roughouts and broken implements becomes an important issue, as micro-invasive mineral/petrographic analyses might be restricted to these 'unfinished' or

incomplete tools – more 'expendable' than their complete counterparts. This might allow the detection of distinctive (albeit not easily traceable) 'markers', essential to provide hints about a possible provenance – hardly attainable otherwise.

- 255 A remarkable feature of the Chiomonte greenstone tools concerns the scarcity of white mica(s), almost absent in all studied samples (with the exception of CMIX/81, in which paragonite occurs in moderate amounts) albeit regularly detected (by XRPD and SEM-EDS) in tools from the sites of southern and southeastern Piedmont (Castello d'Annone, Brignano Frascata, Momperone and Villaromagnano; Giustetto et al., 2016; 2017). The systematic presence of white mica has also been ascertained in most greenstone geologic specimens from the 'secondary' deposits of the Beigua 'massif' (feasible supply)
- 260 sources for the southeastern Piedmont sites; Giustetto et al., 2018). Also, such a mineral has been hardly reported in samples from 'primary' and/or 'secondary' deposits in the Monviso 'massif' and Po valley (Váczy et al., 2019) i.e., the areas that might better suit, geographically, the reservoir for the supply of raw materials by the local gatherers; only in the southern Monviso 'massif' (i.e., opposite to Chiomonte), K-micas (such as phengite and muscovite) were seldom observed (D'Amico, 2012). Hence, the absence of white mica(s) might support an origin of the Chiomonte tools from the Monviso. In this respect,
- 265 detection of white micas (even by XRPD) might indeed represent a general 'marker' in order to preliminarily infer the provenance of a given implement from a certain supply area i.e., the Beigua (Voltri) or Monviso 'massifs' where they are either abundant or rare, respectively. However, such an opinion is not shared by others, according to which this issue (especially when muscovite is concerned) should not be considered discriminant (Pétrequin et al., 2012b). Similarly, chlorite is frequently observed in geological samples and artifacts of Beigua origin (Giustetto et al., 2017; 2018), but rare in the Chiomonte tools
- 270 (Tables 2 and 3). Even then, detection of chlorite as a 'marker' for an origin from Monviso is debated (Pétrequin et al., 2012b). The mineralogy of CMIX/81 (axe heel) is intriguing: in addition to tiny omphacitic exsolutions (reminiscent of those described by Schertl et al., 2012) and paragonite, discrete amounts of albite also appear. Its marked alteration and low density (3.18 g/cm3) is consistent with those of a 'retromorphosed jadeitite' (D'Amico, 2012) an issue typical of geological samples from the southern Monviso or the central Voltri 'massifs'. Similar features occur also in 67138/4148 [Fig. 2a, (iii), Table S1], not
- analyzed in depth being one of the few complete artifacts.
 - Another 'marker' might be represented by the pseudomorphs of (white mica + epidote) after lawsonite, systematically observed in greenstone tools from the lower Piedmont and Lombardy sites (e.g., Castello di Annone, Brignano Frascata and Rivanazzano: D'Amico and Starnini, 2012a; Giustetto et al., 2016, 2017) as well as in geologic samples from the areas of presumed supply (Giustetto et al., 2018), but apparently lacking in the Chiomonte artifacts. Presence of these pseudomorphs
- 280 in greenstone rocks from the Monviso 'massif' is disputed: according to some authors, they should be typical of this area (especially in omphacitites and eclogites; Pétrequin et al., 2012b), whereas others do not report them neither in the Monviso nor from 'secondary' deposits in the Po valley (Váczi et al., 2019). Moreover, the presence of rutile and apatite in the Chiomonte greenstone tools (Table 3) is open to interpretation: the former, considered as a 'marker' of Monviso provenance (D'Amico, 2012), is also observed in most Brignano Frascata tools of presumed Voltri (Beigua) origin (Giustetto et al., 2017);
- 285 the latter, believed as symptomatic of a Beigua source (Pétrequin et al., 2012b), was also detected in greenstone pebbles from alluvial sediments of the Po valley (Váczi et al., 2019). Green-to-bluish pyroxene crystals, similar to those observed in

Chiomonte, have also been reported in the Castello di Annone tools (Giustetto et al., 2016). This may suggest either a common source for the raw materials or that trade relationships occurred between these sites, which is consistent with their coeval dating (from the Middle Neolithic on). However, similar pleochroic crystals appear also in the tools of other sites located eastwards

290 (Giustetto et al., 2017). Moreover, the bluish hue of the Castello di Annone pyroxenes is justified by relatively high Ti-contents (TiO2 up to 5 wt%), whereas lower ones (TiO2 < 1 wt%) appear in the Chiomonte artifacts.

Garnets with an atoll-like habit similar to the eclogite tools from Chiomonte are also described in the Castello di Annone artifacts, further supporting the hypothesis of a common origin or occurred trade/exchanges. Such a habit is quite common in garnets from the Monviso, albeit rarer in those from Beigua. Moreover, lack in the Chiomonte tools of Qtz-Ab-jadeitites and omphacite schists – rocks found only in the Voltri massif (D'Amico and Starnini, 2006; D'amico, 2012; Pétrequin et al.,

- 2012b) corroborate a possible origin from the Monviso. The most compelling evidence about the provenance of the Chiomonte artifacts is the total absence of glaucophanite in the many heterogeneous artifacts made of rocks other than greenstones (Fig. 3.b). As inferred by Pétrequin et al. (2012a), the lack of this lithotype, which is found only in the Voltri 'massif' (D'amico, 2012), strongly supports an origin from the Monviso area.
- 300 Most mineral/petrographic features of the Chiomonte tools indicate therefore the nearby Monviso 'massif' as the feasible area of provenance. However, some closer areas cannot be ruled out a priori, such as the Rocciavré and the lower Susa-Lanzo valleys-Orsiera (SLO) meta-ophiolite units (e.g. Cadoppi et al., 2002), cropping out on the left (northern) side of the middle and lower Susa Valley and in the Orsiera-Rocciavré mountain range, between the Susa and Sangone valleys – within 20 km as the crow flies from Chiomonte (Fig. 1b). These units were also affected by eclogite-facies metamorphism during the Alpine
- 305 orogeny. 'Primary' outcrops of Na-pyroxene rocks are rarely reported there: a dm-thick omphacitite layer occurs at Balangero mine, at the contact between the gneisses of the Sesia–Lanzo Zone and the serpentinites of the northern part of the Lanzo ultramafic 'massif', belonging to the SLO Unit (Compagnoni and Sandrone, 1986); there is no known occurrence of jadeitite. Nonetheless, scarce and small 'jade' boulders have been reported from the alluvial and glacial deposits of the Susa Valley and of the Rivoli-Avigliana end moraine system at the outlet of the same valley (Piolti, 1898-1899; 1901-1902; Franchi, 1903;
- 310 Pétrequin et al., 2012a, 2012b).

A peculiarity of Chiomonte is the retrieval of ornamental and playing objects, hardly found in other sites, made of chloritite [pendants; Fig. 2.a, (v) and (x)] and serpentinite [taws; Fig. 2.a, (ix)] – 'softer' lithotypes easier to model. A careful selection of raw materials might thus have been operated by the Chiomonte craftsmen, depending on their purposes: probably, stricto sensu greenstones were intended for instruments for cutting, because of their particular toughness (still, the abundance of

315 serpentinite in these tools suggests that this interpretation should be taken cautiously). Finally, the 5747 axehead fragment shows a peculiar mineralogical composition with abundant garnet, predominant over plagioclase, chlorite and amphibole, with only few omphacite. Such a composition may be ascribed to an 'omphacite-garnetite' (see Table 2) – a peculiar lithology actually considered by Giustetto and Compagnoni (2014) in their petrographic classification of HP-metaophiolites, but never found before in a greenstone archaeological implement (Giustetto et al., 2018).

320 **4.2** Archaeological issues and archaeometric implications

The Piedmont region represents an important area for analyzing the trade and exchange circuits of greenstone artifacts that spread over Europe during Neolithic, being bordered at the West and South by the Monviso and Voltri 'massifs', respectively (the two main sources of supply in the Western Alps; Pétrequin et al., 2005a; 2006; Lunardi, 2008a; Pétrequin and Pétrequin, 2012; Pétrequin et al., 2012b; 2012a; 2012c; Forno et al., 2015). The relatively small set of polished tools from Chiomonte is considered to have utilitarian purposes in a sort of 'habitat' environment (Pétrequin and Pétrequin, 2017). A peculiarity is represented by the absence of disc-rings, retrieved instead elsewhere (e.g., Brignano Frascata, Villaromagnano, Momperone; Giustetto et al., 2017), coupled to the recovery of playing objects (taws) in serpentinite, seemingly exclusive of this settlement. Unfortunately, little can be inferred about their provenance, due to the ubiquitous distribution of this rock in the Western Alps (D'Amico et al., 2004; D'Amico and Starnini, 2006). Recently, most attention was devoted to the bigger (15-36 cm long), ultra-polished jade axes, used for trade and ceremonial purposes in the Western and Northern Europe (France, Germany, Benelux, and Great Britain; Pétrequin et al. 2005a, 2005b; 2017a; Zamagni, 1996, Lunardi, 2008b, Lunardi and Starnini,

- 2010/2011). Another important factor is the examination of the roughouts, essential in those sites where a consistent record exists (Mancusi, 2016), which may retain clues about the nature and shape of the raw materials, providing information about their origin (whether detached by thermal shocks from 'primary' outcrops at high altitude or moulded from pebbles/cobbles
- from 'secondary' alluvial deposits; D'Amico and Starnini, 2012b; Pétrequin et al., 2017b). The morpho-typological examination of the roughouts, splinters and broken blades marks Chiomonte as a manufacturing site. The presence of elongated chisels with parallel sides and narrow blades (mostly in eclogite) is symptomatic of an economy aimed at production purposes. On some roughouts, superficial portions (untouched by moulding and shaping) show raw surfaces, reminiscent of the cobbles or pebbles from which they had been obtained. Moreover, greenstone pebbles raw material to be destined to further
- 340 production were found among the artifacts. Such lines of evidence indicate that most (if not all) of the materials used for these artifacts was collected from 'secondary' deposits. Their small-to-modest size further supports this assumption, also backed by chronological issues, as from the late Neolithic onwards the exploitation at high altitudes of these lithologies apparently started to decline (Mancusi, 2016). The Chiomonte site must be contextualized in the Western Alps setting, where shaping of the roughouts was carried out in areas close to the supply sources (Thirault, 2005), once collected from 'secondary'
- 345 deposits in the nearby geological units. Reasonably, the period testifying the bigger expansion of the Chiomonte site stands between 4200 and 3500 B.C., similarly to what was observed in other close long-occupation settlements in France (Savoy, Tarantaise and Maurienne; Padovan, 2017).

5 Concluding summary

A thorough study was performed on the polished stone industry from the archaeological site of Chiomonte – La Maddalena, dating back to the Middle-to-Late Neolithic, with both archaeometric and morpho-typological issues. Particular care was devoted in studying the greenstone artifacts, which represent by far the most significant rock types used in the Po plain in prehistory for the production of tools – distributed even in areas very far from their sources.

A theory has been raised by archaeologists, according to which the exploitation of supply sources (from the Monviso and Voltri 'massifs') and production of greenstone tools might have induced, from the early Neolithic on, a sort of hierarchical

- 355 organization. First-order sites (e.g., Alba; Venturino-Gambari and Zamagni, 1996; D'Amico and Ghedini, 1996) were meant to be important centres of supply (from both 'primary' and 'secondary' sources) and distribution, with an intense and refined production that exceeded the local needs. In Second-order sites, instead (e.g., Brignano Frascata, Giustetto et al., 2017), all the production steps (splintering, shaping and bush-hammering) were carried out, but the supplies were limited by their own needs, stocked up from local 'secondary' deposits – as testified by the moderate dimensions of the tools and roughouts derived from
- 360 pebbles (the surfaces of which are somewhat preserved; Mancusi, 2016). The abundance of roughouts and broken tools indicates that Chiomonte was a second-order/manufacturing site, although it is hard to assess whether such an activity was confined to the local needs or involved in the trade, circulation and diffusion on a wider scale.

Most mineralogical and petrographic 'markers' of the Chiomonte tools suggest that the raw materials might originate from the Monviso 'massif' – though other 'local' areas cannot be ruled out. The presence of many roughouts with unmanufactured, raw surfaces and even pebbles, suggests that these rocks might have been picked up from 'secondary' sources, represented by the glacial and alluvial deposits of the adjoining valleys.

6 Author contribution

R. Giustetto and R. Compagnoni performed the mineral/petrographic analyses; S. Padovan took care of all morpho-typological descriptions; L. Barale provided an accurate characterization of the inspected geological contexts. R.Giustetto also assembled the manuscript, with contributions from all co-authors.

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References

Andò, M.C.: La pietra levigata neolitica di Gaione (PR). Studio petroarcheometrico dei litotipi. Unpublished Thesis, Università di Bologna, 1996-97, 1998.

380

Bendő, Z., Szakmány, G., Kasztovszky, Maróti, B., Szilágyi, S. Szilágyi, V., and Biró, K.T.: Results of non-destructive SEM-EDX and PGAA analyses of jade and eclogite polished stone tools in Hungary. Archeometriai Műhely, Archaeometry Workshop XI., 187-205, 2014.

385 Bendő, Z., Szakmány, G., Kasztovszky, Z., Biró, K.T., Olah, I., Osztás, A., Harsányi, I., and Szilágyi, V.: High pressure metaophiolite polished stone implements found in Hungary. Archaeological and Anthropological Sciences, 11(5), 1-25, DOI: 10.1007/s12520-018-0618-6, 2019.

Bernabò Brea, M., Battiston, C., Mazzieri, P., and Ottomano, C.: Un gruppo di figurine fittili dal sito di Ponte Ghiara (Parma).
Atti del Convegno "La Neolitizzazione tra Oriente e Occidente", vol. 29 II, Udine, pp. 271-289, 2000.

Borgogno, M.: Petrografia delle asce neolitiche della Rocca di Cavour (TO) e di analoghi litotipi affioranti nel Massiccio Ofiolitico del Monviso (Alpi Cozie). Unpublished Thesis, Università degli Studi di Torino, 178 p., 2000.

395 Cadoppi, P., Castelletto, M., Sacchi, R., Baggio, P., Carraro, F., Giraud, V., and Bellardone, G.: Note illustrative della Carta Geologica d'Italia alla scala 1:50.000. Foglio 154 Susa. Regione Piemonte, Direzione Regionale Servizi Tecnici di Prevenzione, Torino, 123 p., 2002.

Caron J.M and Saliot P.: Nouveaux gisements de lawsonite and jadéite dans les Alpes franco-italiennes. C.R. Acad. Sci. Paris,
268, 3153-3156, 1969.

Chiarenza, N. and Giustetto, R.: L'officina litica di Pertus (Paesana, CN): testimonianze di lavorazione ed analisi mineropetrografiche. Quaderni della Soprintendenza Archeologica del Piemonte, 25, 13-29, 2010.

405 Chiari, G., Compagnoni, R., Giustetto, R., and Ricq de Bouard, M.: Metodi archeometrici per lo studio dei manufatti in pietra levigata. In: "Le vie della pietra verde. L'industria litica levigata nella preistoria dell'Italia settentrionale", M. Venturino Gambari, Omega Ed., Torino, pp. 5-52, 1996.

Compagnoni R.: HP metamorphic belt of the western Alps. Episodes, 26 (3), 200-204, 2003.

410

Compagnoni, R., Giustetto, R., Ricq-de-Bouard, M., and Venturino Gambari, M.: Studio archeometrico di reperti neolitici e dell'età del rame in pietra verde levigata: discussione sulle tecniche analitiche ed interpretazione dei risultati. Atti della XXXIX Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria, Firenze, 25-27 Novembre 2004, 655-682, 2006.

415 Compagnoni, R., Rolfo, F., and Castelli, D.: Jadeitite from the Monviso meta-ophiolite, western Alps: occurrence and genesis from an oceanic plagiogranite. Eur. J. Mineral. 24, 333-343, 2012.

Compagnoni, R., Rolfo, F., Manavella, F., and Salusso, F.: Jadeitite in the Monviso meta-ophiolite, Piemonte Zone, Italian western Alps. Per. Mineral., 76, 79–89, 2007.

420

Compagnoni, R. and Sandrone, R.: Omphacite/diopside composite metasomatic reaction rims between Sesia gneisses and Lanzo ultramafics at Balangero near Lanzo (western Alps). International IGCP Meeting on "Ophiolites from Serra Nevada and Cost Range complexes", Davis, California (USA), June 1986, 5-16, 1986.

425 D'Amico, C.: Neolithic 'greenstone' axe blades from North-western Italy across Europe: a first petrographic comparison. Archaeometry, 47(2), 235-252, 2005.

D'Amico, C.: Jades and other greenstones from the Western Alps. A petrographic study of the geological sampling Jade. In: "Jade. Grandes haches alpines du Néolithique européen", P. Pétrequin, S. Cassen, M. Errera, L. Klassen, A. Sheridan, A.M.

430 Pétrequin (Sous la direction de), Chapitre 7, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 420-439, 2012.

D'Amico, C. and De Angelis, M.C.: Neolithic greenstone in Umbria, from the Bellucci Collection. Petrography, provenance, interpretation. Rend. Fis. Acc. Lincei, 20, 61-76, 2009.

435 D'Amico C. and Ghedini M.: La pietra levigata della Collezione Traverso di Alba nel Museo Etnografico "L. Pigorini" di Roma. Atti 10° Congresso A.N.M.S., Bologna 1994, Museologia Scientifica 13, Supplemento, 292-312, 1996.

D'Amico C. and Starnini E.: Eclogites, jades and other HP metaophiolites of the Neolithic polished stone tools from Northern Italy. Kristallinikum, 26, 11-20, 2000.

440

D'Amico, C. and Starnini, E.: L'atelier di Rivanazzano (PV): un'associazione litologica insolita nel quadro della "pietra verde" levigata in Italia. In: "Preistoria dell'Italia settentrionale. Studi in ricordo di Bernardino Bagolini", A. Pessina and P. Visentini, eds.. Atti del Convegno, Udine, settembre 2005, Udine, Edizioni del Museo Friulano di Storia Naturale, pp. 37-54, 2006.

445 D'Amico, C. and Starnini, E.: Circulation et provenance des « roches vertes » néolithiques d'Italie du Nord. In: "Jade, aspects of social inequality in Neolithic Europe, the circulation of large axeheads made from Alpine jades", Book of abstracts, Colloque International, Besançon, Septembre 24-26, 2009, pp. 9-12, 2009. D'Amico, C. and Starnini, E.: Les "Roches Vertes" Alpines. Productions et circulations Néolithique en Italie Septentrionales.

450 In: "Les Hommes Préhistorique et les Alpes. Document du Département de géographie et environnement de l'Université de Genève", M. Borrello (sous la direction de), pp. 125-134. British Archaeological Reports, International Series 2476, 2013, 2011.

D'Amico, C. and Starnini, E.: La production d'outils de pierre en Italie du nord vue depuis l'atelier de Rivanazzano (province
de Pavie, Lombardie): matières premières et chaîne opératoire. In: "Actes de la Table Ronde de Saint-Germain-en-Laye", P.A. De Labriffe, É. Thirault (sous la direction de), 16 et 17 Mars 2007, Musée d'Archéologie Nationale, Paris, Société préhistorique francaise, 2012, 235-243, ISBN : 2-913745-47-4, 2012a.

D'Amico, C. and Starnini, E.: Circulation and provenance of the Neolithic "greenstone" in Italy. In: "Jade. Grandes haches
alpines du Néolithique européen", P. Pétrequin, S. Cassen, M. Errera, , L. Klassen, A. Sheridan, A.M. Pétrequin (Sous la direction de), Chapitre 12, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 728-743, 2012b.

D'Amico, C., Campana, R., Felice, G., and Ghedini, M.: Eclogites and jades as prehistoric implements in Europe. A case of petrology applied to Cultural Heritage. Eur. J. Mineral. 7, 29-41, 1995.

465

D'Amico, C., Felice, G., Gasparotto, G., Ghedini, M., Nannetti, M.C., and Trentini, P.: La pietra neolitica di Sammardenchia (Friuli). Catalogo petrografico. Mineralogica et Petrografica Acta, 40, 385-42, 1997.

D'Amico, C., Felice, G., and Ghedini, M.: Lithic supplies in the early Neolithic to Sammardenchia (Friuli), Northern Italy. 470 Science and Technology for Cultural Heritage, 1, 159-176, 1992.

D'Amico, C., Nenzioni, G., Fabris, S., Ronchi, S., and Lenzi, F.: Neolithic tools in S. Lazzaro di Savena (Bologna). A petroarchaeometric study. Rendic. Lincei, 24(1), 23-38, 2013.

475 D'amico C., Starnini E., Gasparotto G., and Ghedini M.: Eclogites, jades and other HP-metaophiolites employed for prehistoric polished stone implements in Italy and Europe. Periodico di Mineralogia, 73, Special Issue (3), 17-42, 2004.

Damour, M.A.: Analyse du jade oriental: réunion de cette substance à la tremolite. Ann.Chim. Phys., 3rd ser., 17, 469-474, 1846.

480

Debelmas, J.: Carte géologique de la France à 1/250 000, Feuille 30, Annecy. Editions du BRGM, Orléans, 1980.

Errera, M., Hauzeur, A., Pétrequin, P., and Tsonev, T.: Etude spectroradiométrique d'une lame de hache trouvée dans le district de Chirpan (Bulgarie). in: Interdisciplinary Studies, XIX, Sofia, Archaeological Institute and Museum – Bas, 7-24, 2006.

485

Errera, M., Pétrequin, P., and Pétrequin, A.M.: Spectroradiométrie, référentiel naturel et étude de la diffusion des haches alpines (Spectroradiometry, raw material reference samples and the diffusion of Alpine axeheads). In: "Jade. Grandes haches alpines du Néolithique européen", P. Pétrequin, S. Cassen, M. Errera, L. Klassen, A. Sheridan, A.M. Pétrequin (Sous la direction de), Chapitre 8, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 440-533, 2012.

490

Forno, M.G., Avondetto, S., Groppo, C.T., and Rolfo, F.: The Quaternary succession of the Bulé and Alpetto valleys (Monviso Massif, Piedmont) as possible supply for prehistoric jade axes raw material. Rend. Fis. Acc. Lincei, 26, 13-20, 2015.

Franchi, S.: Sopra alcuni giacimenti di rocce giadeitiche nelle Alpi Occidentali e nell'Appennino Ligure. Boll. R. Comit. Geol. 495 It., 4, 119-158, 1900.

Franchi, S.: Sul rinvenimento di nuovi giacimenti di roccie giadeitiche nelle Alpi Occidentali e nell'Appennino Ligure. Boll. Soc. Geol. It., 22, 130–134, 1903.

500 Gastaldi, B.: Studi geologici sulle Alpi Occidentali. Mem. Descr. Carta Geol. Italia, 1, 1-36, 1871.

Giustetto R. and Compagnoni R.: Petrographic classification of unusual high-pressure metamorphic rocks of archaeometric interest. Eur. J. Mineral., 26, 635-642, 2014.

505 Giustetto R., Barale, L., and Compagnoni R.. 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, 2018.

Giustetto, R., Chiari, G., and Compagnoni, R.: An easy non-invasive X-ray diffraction method to determine the composition 510 of Na-pyroxenes from high-density 'greenstone' implements. Acta Crystallographica, A64, 161-168, 2008.

Giustetto, R., Perrone, U., and Compagnoni, R..: Neolithic polished greenstone industry from Castello di Annone (Italy): minero-petrographic study and archaeometric implications. Eur. J. Miner., 28, 889-905, 2016.

515 Giustetto, R., Venturino, M. Barale, L. d'Atri, A., and Compagnoni, R.: The Neolithic greenstone industry of Brignano Frascata (Italy): Archaeological and archaeometric study, implications and comparison with coeval sites in the Grue, Ossona and Curone valleys. Journal of Archaeological Science: Reports, 14, 662-691, 2017.

Harlow, G.E., Tsujimori, T., and Sorensen, S.S.: Jadeitites and Plate Tectonics. Annual Review of Earth and Planetary 520 Sciences, 43(1), 105-138, 2014.

Kerckhove, C., Barféty, J.C., Bogdanoff, S., and Lemoine M.: Carte géologique de la France à 1/250 000, Feuille 35, Gap. Editions du BRGM, Orléans, 1980.

525 Lunardi, A.: La selezione delle materie prime e il loro utilizzo durante l'Olocene. Un'applicazione ai siti neolitici di Quinzano e Rivoli nella Valle dell'Adige (Verona). Rivista di Scienze Preistoriche, LVIII, 59-74, 2008a.

Lunardi, A.: Experimental testing with polished greenstone axes and adzes: technology and use. In: "Prehistoric Technology 40 years later: functional studies and the Russian legacy", L. Longo and N. Skatun (a cura di). Proceedings of the International Congress, Verona (Italy), 20-23 April 2005, Oxford (BAR. International series, 1783), pp. 369-373, 2008b.

Lunardi, A. and Starnini, E.: Tipologia, uso e materie prime delle industrie in pietra non scheggiata della cultura dei VBQ: materiali dal Veneto e dalla Liguria a confronto. In: "Atti della Società per la Preistoria e la Protostoria della Regione Friuli-Venezia-Giulia", XVIII, pp. 53-86, 2010/2011.

535

530

Mancusi, V.G.: Produzione, funzione e circolazione degli abbozzi di asce in pietra verde nel territorio piemontese durante il Neolitico. Quaderni della Soprintendenza Archeologica del Piemonte, 31, 13-34, 2016.

Mancusi, V.G.: De l'Italie du Sud à Malta. In: "Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe
néolithique", P. Pétrequin, E. Gauthier, A.M. Pétrequin (Sous la direction de), Tome 3, Chapitre 16, Presses Universitaires de
Franche-Comté Ed., Besançon, pp. 395-418, 2017.

Mannoni, T. and Starnini, E.: Il contributo delle analisi petrografiche nello studio dell'officina litica di Rivanazzano (PV). In: "Le scienze della terra e l'archeometria", C. D'Amico and R. Campana (eds.), Università di Bologna, 21, 1994.

545

McClure, S.: Jadeite/omphacite nomenclature question. GIA News from Research, April 10, 2012: http://www.gia.edu/research-resources/news-from-research, 2012.

Morimoto, N., Fabries, J., Ferguson, A.K., Ginzburg, I.V., Ross, M., Seifert, S.A., Zussman, J., Aoki, K., and Gottardi, G.: 550 Nomenclature of pyroxenes. American Mineralogist, 73, 1123-1133, 1988.

Ou Yang, M.C.M.: The development of Fei Cui's study in China. Proceedings of the First International Gem and Jewelry Conference, Gemological Institute of Thailand, Bangkok, December 6-9, 2006, p. 44, 2006.

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

Padovan, S.: Il sito di Chiomonte La Maddalena nel quadro del Neolitico recente-finale dell'arco alpino occidentale. Aspetti cronologici e culturali. In: Pionieri delle Alpi. Il pieno Neolitico tra le Alpi Occidentali, F.M. Gambari, M. Ferrero, S. Padovan

560 (A cura di). Atti del Congresso, Chiomonte, Palazzo Levis, 16/17 Novembre 2007, Tipo Stampa Srl, Moncalieri (TO), pp. 49-56, 2017.

Pedrotti, A.: La pietra levigata nei corredi delle sepolture neolitiche dell'Italia Settentrionale. In: "Le vie della pietra verde. L'industria litica levigata nella preistoria dell'Italia settentrionale", M. Venturino Gambari, Omega Ed., Torino, pp. 150-164,
1996.

Pétrequin, P. and Errera, M.: 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, P. Pétrequin, E. Gauthier, A.M. Pétrequin (Sous la direction de), Tome 3, Chapitre 4, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 75-86, 2017.

570

Pétrequin, P. and Pétrequin, A.M.: Chronologie et organization de la production dans le massif du Mont Viso. In: Jade. Grandes haches alpines du Néolithique européen, P. Pétrequin, S. Cassen, M. Errera, L. Klassen, A. Sheridan, A.M. Pétrequin (Sous la direction de), Chapitre 4, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 214-257, 2012.

575 Pétrequin, P. and Pétrequin, A.M.: À l'origine des routes du jade alpin: specialisation régionale et premiers transferts. In: Jade. Objets-signes et interprétations sociales des jades alpins dans l'Europe néolithique, P. Pétrequin, E. Gauthier, A.M. Pétrequin (Sous la direction de), Tome 3, Chapitre 14, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 323-361, 2017.

Pétrequin, P., Errera, M., Cassen, S., and Croutsch, C.: Les Matières Premières Lithiques en Préhistoire, 253–275. Aurillac:
Table Ronde Internationale, 2002.

Pétrequin, P. Pétrequin, A.M, Errera, M., Cassen, S., Croutsch, C., Klassen, L., Rossy, M., Garibaldi, P., Isetti, E., Rossi, G., and Delcaro, D.: Beigua, Monviso e Valais. All'origine delle grandi asce levigate di origine alpina in Europa occidentale durante il V millennio. Rivista di Scienze Preistoriche, 55, 265-322, 2005a.

585

595

- Pétrequin, P., Errera, M., Cassen, S., Billand, G., Colas, C., Maréchal, D., Prodéo, F., and Vangele, F.: Des Alpes italiennes à l'Atlantique: les quatre grandes haches polies de Vendeuil et Maizy (Aisne), Brenouille (Oise). Hommage à Claudine Pommepuy. Revue archéologique de Picardie, 22 (numéro spécial), 75-104, 2005b.
- 590 Pétrequin, P., Errera, M., Pétrequin, A.M., and Allard, P.: The Neolithic quarries of Mont Viso, Piedmont, Italy: initial radiocarbon dates. European Journal of Archaeology, 9(1), 7-30, 2006.

Pétrequin, P., Sheridan, A., Cassen, S., Errera, M., Gauthier, E., Klassen, L., Le Maux, N., and Pailler, Y.: Neolithic Alpine axeheads, from the Continent to Great Britain, the Isle of Man and Ireland. In: Fokkens et al. (eds.): Between foraging and farming. APL 40, 262-279, 2008.

Pétrequin, P., Errera, M., Cassen, S., Gauthier, E., Hovorka, D., Klasen, L., and Sheridan A.: From Mont Viso to Slovakia: the two axeheads of Alpine jade from Golianovo. Acta Archaeologica Academiae Scientiarum Hungaricae, 62, 243-268, 2011.

- 600 Pétrequin, A.M., Pétrequin, P., Errera, M., and Prodéo, F.: Prospections alpines et sources de matières premières. Historique et résultats. In: Jade. Grandes haches alpines du Néolithique européen, P. Pétrequin, S. Cassen, M. Errera, L. Klassen, A. Sheridan, A.M. Pétrequin (Sous la direction de), Chapitre 2, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 46-183, 2012a.
- 605 Pétrequin, P., Errera, M., and Rossy, M. (avec la collaboration de C. D'Amico et M. Ghedini): Viso ou Beigua : approche pétrographique du référentiel des "jades alpins". In: Jade. Grandes haches alpines du Néolithique européen, P. Pétrequin, S. Cassen, M. Errera, L. Klassen, A. Sheridan, A.M. Pétrequin (Sous la direction de), Chapitre 6, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 292-419, 2012b.
- 610 Pétrequin, P., Cassen, S., Klassen, L., and Valcarce, R.F.. La circulation des haches carnacéennes en Europe occidentale. In: Jade. Grandes haches alpines du Néolithique européen, P. Pétrequin, S. Cassen, M. Errera, L. Klassen, A. Sheridan, A.M. Pétrequin (Sous la direction de), Chapitre 18, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 1015-1045, 2012c.

Pétrequin, P., Cinquetti, M., and Buthod-Ruffier, D.: Le choix des jades alpins. In: Jade. Objets-signes et interprétations

615 sociales des jades alpins dans l'Europe néolitique, P. Pétrequin, E. Gauthier, A.M. Pétrequin (Sous la direction de), Tome 3, Chapitre 2, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 47-67, 2017a.

Pétrequin, P., Pétrequin, A.M., Gauthier, E., and Sheridan, A.: Mécanismes sociaux: les interpretations idéelles des jades alpins. In: Jade. Objets-signes et interpretations sociales des jades alpins dans l'Europe néolitique, Pétrequin P., Gauthier E., Pétrequin A.M. (Sous la direction de), Tome 3, Chapitre 21, Presses Universitaires de Franche-Comté Ed., Besançon, pp. 521-

620 Pétrequin A.M. (Sous la direction de), Tome 3, Chapitre 21, Presses Universitaires de Franche-Comté 599, 2017b.

625

640

Piana, F., Fioraso, G., Irace, A., Mosca, P., d'Atri, A., Barale, L., Falletti, P., Monegato, G., Morelli, M., Tallone, S., and Vigna, G.B.: Geology of Piemonte region (NW Italy, Alps-Apennines interference zone). Journal of Maps, 13, 395–405, 2017.

Piolti, G.: Sulla presenza della jadeite nella valle di Susa. Atti Reale Academia delle Scienze di Torino, XXXIV, pp. 600-608, 1898-1899.

Piolti, G.: I manufatti litici del "Riparo sotto roccia" di Vayes (Val di Susa). Osservazioni petrografiche. Atti Reale Academia
delle Scienze di Torino, XXXVII, pp. 476-491, 1901-1902.

Přichystal, A. and Trnka, G.: Raw materials of polished artifacts from two Lengyel sites in Lower Austria. Slovak Geological Magazine 7, 337-339, 2001.

Ricq-de-Bouard, M.: Trade in Neolithic jadeite axes from the Alps: new data. In: "Trade and Exchange in Prehistoric Europe",
 C. Scarre and F. Healy (eds), Oxford Monographs 33, pp. 61-67, 1993.

Schertl, H.P., Maresch, W.V., Stanek, K.P., Hertwig, A., Krebs, M., Baese, R., and Sergeev, S.S.: New occurrences of jadeitite, jadeite quartzite and jadeite-lawsonite quartzite in the Dominican Republic, Hispaniola: petrological and geochronological overview. Eur. J. Mineral., 24, 199-216, 2012.

Spišiak, J. and Hovorka, D.: Jadeite and Eclogite: peculiar raw materials of Neolithic/Aeneolithic stone implements in Slovakia and their possible sources. Geoarcheology, 20(3), 229-242, 2005.

Thirault, E.: The politics of supply: the Neolithic axe industry in Alpine Europe. Antiquity, 79, 34-50, 2005.

Tsonchev, D.: New found antiquities in the Plovdiv region. Proceedings of the Archaeological Institute 15 pp. 209, 1946.

Váczi, B., Szakmány, G., Starnini, E., Kasztovszky, Z., Bendő, Z., Nebiacolombo, F., Giustetto, R., and Compagnoni, R.:
Characterization of HP meta-ophiolite blocks and cobbles from Northern Italy primary outcrops and secondary deposits, as possible raw material sources for the production of "greenstone" prehistoric tools: petrographic investigation and archaeological assessment. Eur. J. Mineral., 31, 905-917, 2019.

Venturino Gambari M. and Zamagni B.: Castello di Annone. In: "Le vie della pietra verde. L'industria litica levigata nella preistoria dell'Italia settentrionale", M. Venturino Gambari, Omega Ed., Torino, pp. 98-105, 1996.

Zamagni, B.: L'ascia come simbolo. Prestigio, distinzione sociale, accumulo di ricchezza. In: "Le vie della pietra verde. L'industria litica levigata nella preistoria dell'Italia settentrionale", M. Venturino Gambari, Omega Ed., Torino, pp. 144-145, 1996.

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685 Table captions

- **Table 1.** Characterization of the 22 polished stone implements from the Neolithic site of Chiomonte La Maddalena, analyzed by XRPD, optical polarizing microscopy (PM) and SEM-EDS.
- **Table 2.** Mineralogical composition of the 22 polished stone implements ('Na-pyroxene rocks', 'Na-pyroxene + garnet rocks' and 'other lithotypes') from the Neolithic site of Chiomonte *La Maddalena*, according to XRPD [XXX: very strong reflections; XX: strong reflections; X: weak reflections; X(?): dubious].
- 695 Table 3. Mineralogical composition (vol%) of 12 polished stone implements in HP-meta-ophiolites (5 'Na-pyroxene rocks' and 7 'Na-pyroxene + garnet rocks') from the archaeological site of Chiomonte La Maddalena, obtained by combining X-ray powder diffraction, polarizing microscopy and SEM-EDS on thin sections.

Na-PYRO	XENE ROCKS							
Inventory code	Excavation code (sample label)	Functional typology	Notes (from macroscopic and stereomicroscopy observations)	Density (g/cm ³)	XRD	P.M.	SEM -EDS	Picture (Fig.2a)
JADEITI	TE:							
=	3788	Axehead fragment	===	3.34	Х	Х	Х	=
CMIX	81	Axe heel	===	3.18	X	Х	X	=
ОМРНА	CITITE							
	4360	Axehead fragment	===	3.36	х	х	х	=
=	6602	Splinter	Too small to obtain a reliable density	=	X	=	=	=
=	6830	Axe cutting edge		3.37	X	=	=	=
MIXED	Na-PYROXENITI	R.						
=	6636	Axe heel	===	3.38	Х	х	х	=
=	1548	Splinter	===	3.48	X	=	=	=
=	7179	Axehead fragment	Approximate equal amounts of jadeite and omphacite	3.34	Х	Х	Х	=
Na-PYRO	XENE + GARN	IET ROCKS						
Inventory	Excavation code			Density	WDD		ar. (
code	(sample label)	Functional typology	Notes	(g/cm ³)	XRD	О.M.	SEMI	Acture
ECLOGI	TE:							
=	3088	Axehead fragment	Eclogitic portions with atoll-like garnets and sulfides	3.36	Х	Х	Х	=
=	4217	Small chisel	Presence of a small superficial groove (perhaps modern)	3.58	Х	=	=	=
=	5653	Hatchet	===	3.57	Х	Х	Х	=
=	7144	Axehead fragment	===	3.55	Х	Х	Х	=
67142	8936	Axehead fragment	===	3.57	Х	Х	Х	=
GARNET	C-OMPHACITITE	3						
=	3975	Axe heel	===	3.33	Х	Х	Х	=
=	5319	Unidentif. fragment	===	3.30	Х	Х	Х	=
=	7736	Axehead fragment	===	3.48	Х	Х	Х	=
OTHER	LITHOTYPES							
Inventory	Excavation code	E	N-t	Density	VDD	0.14	CEM	D'ataun
code	(sample label)	Functional typology	Notes	(g/cm ³)	AKD	0.M.	SEMI	Acture
SERPEN	TINITE:							
=	5515	Small chisel	Presence of fibrous antigorite	2.51	Х	=	=	=
CHLORI	TITE:		C					
86451	3256	Pendant	Showing a peculiar banding; exclusively chlorite-containing	2.71	Х	=	=	Х
86453	1000	Pendant	Exclusively chlorite-containing	2.56	Х	=	=	Х
META-D	IABASE:							
=	7645	Axehead fragment	With omphacite, garnet, chlorite, feldspar and amphibole	3.21	Х	=	=	=
ROCK W	ITH PREDOMIN	ANT CHLORITE AND	ACTINOLITE:					
=	3018	Splinter	Accessory plagioclase and omphacite; scarce jadeite	=	Х	=	=	=
ROCK W	ITH PREDOMIN	IANT GARNET AND P	LAGIOCLASE:					
=	5747	Axehead fragment	Accessory pyroxene and amphibole	3.25	Х	=	=	=

Table 1

Minerals Sample label Na-PYROX	axan axan axan axan axan axan axan axan	D jadeite	garnet	amphibole	hornbl./actinol.	clinochlore	plagioclase	ilmenite	rutile	antigorite	Lithotype	Notes
2700	v	xxx									indoitite	shoulders account for scarce
81	~	xxx					x				jadeitite	presence of ompnactie
4260	~~~						~				amphagitita	weak shoulders account for possible
4300	***										ompnacitite	weak shoulders account for
6602	XXX										omphacitite	possible presence of jadeite peak at $2\theta=32.53^{\circ}$ d _{bbl} = 2.751.
6830	ххх					х		x(?)			omphacitite	possible ilmenite
6636	xxx	хх									mixed Na-pyroxen.	omphacite
1548	xx	ххх									mixed Na-pyroxen	reflections not distinct but 'fringed'
7170		xx									· IN	reflections not distinct but 'fringed'
Na-PYROX	ENF	+ GA	RNFT	L BU	CKS						mixed Na-pyroxen.	(zoned pyroxenes)
							1					garnet is mainly almandine and
3088	XXX		XXX								eclogite	pyrope
4217	xxx	x(?)	xxx								eclogite	weak shoulders account for possible presence of jadeite
5653	xxx	x(?)	xxx			x					eclogite	weak shoulders account for possible presence of jadeite
7144		x(2)	vvv			~			v (2)			weak shoulders account for possible
/144	***	X(?)	***						X(?)		eclogite	garnet is mainly almandine
8936	XXX		XXX								eclogite	
3975	xxx		x(?)								garnet omphacitite	presence of aegirine
5319	xxx		x(?)								garnet omphacitite	splitting of omphacite peaks
7726	~~~		× ×			v					garnat amphasitita	splitting of omphacite peaks
OTHER LI	THOT	YPES	5			^					gamet ompnachtte	suggests pyroxelle zolling
			, 									antigorite is the only phase
5515										XXX	serpentinite	olinochlore is the only detectable
3256						xxx					chloritite	phase
1000						xxx					chloritite	clinochlore is the only detectable phase
7645	хх		vv		vv	vv	vv				meta-diabase	plagioclase is possibly albite
2010	xx	(0)	~~~			~~	~~					Unidentified reflection at d=2.675
3018		X(?)	X(?)		XXX	XXX	XX				chlorite/actin.rock	A; possible garnet Garnet spessartine: splitting of
5747	Х		xxx	xx		хх	xx				(omphacite-garnetite?)	omphacite peaks (zoning)

Table 2

Legend: %		0	<	5 %	1				5 %	6 - 2	0 %				•	20	0 % - 60 % ● > 60
Minerals Sample label	omphacite	jadeite	garnet	amphibole	zoisite	clinozoisite	white mica	biotite	clinochlore	plagioclase	rutile	ilmenite	titanite	zircon	apatite	sulfides	Notes
Na-PYR	OXE	NE .	ROC	CKS													
JADEITIT	ES																
3788								0					0	0	0		Presence of biotite is dubious
81	0				0	0											White mica is paragonite; coarse grained
OMPHAC	ITITE	ES															
4360														0			Fine-grained; mylonitic structure
MIXED N	a-PY	ROX	ENI	ГES													
6636														0	0		Foliation marked by abundant rutile
7179											0			0			= = =
Na-PYRC ECLOGIT	Na-PYROXENE + GARNET ROCKS ECLOGITES																
3088		0		0			0				0			0			Jadeite undetected at polarizing microscope
5653									0		0	0			0		Atoll-like garnets
7144											0			0			Jadeite shows small omphacitic exsolutions
8936												0			0		Atoll-like garnets in rounded aggregates
GARNET-	OMP	HAC	CITIT	TES													
3975			0								0	0				0	Clinopyroxene has intense green colour
5319			0										0		0		===
7736											0	0					Jadeite younger than omphacite

745 Table 3

- **Figure 1**, a) Map of NW Italy showing the position of the Chiomonte archaeological site (*star*) and of the other coeval archaeological sites cited in the text (1- Rocca di Cavour; 2- Alba; 3- Castello di Annone; 4- Villaromagnano; 5-Rivanazzano; 6- Momperone; 7- Brignano Frascata; 8- Gaione; 9- Ponte Ghiara). The position of the Monviso (Vi) and Voltri (Vo) 'massifs' is also shown. The blue rectangle indicates the area of the geological map in b). 765 The inset shows a simplified map of northern Italy, with indication of the sites of Chiomonte (star), San Lazzaro di Savena (10) and Sammardenchia (11). b) Simplified geological map of the Italian side of Cottian and southern Graian Alps (from Varaita Valley to Viù Valley), showing the position of the archaeological site of Chiomonte (star) and the distribution of the geological units, here considered as possible sources for the supply of raw materials (eclogite facies meta-ophiolites of the Liguria-Piemonte oceanic units, alluvial and glacial deposits). 770 Geological boundaries redrawn from Piana et al., 2017 (Italian part), Kerckhove et al., 1980 (French part, south of 45°N) and Debelmas, 1980 (French part, north of 45°N). Legend: Quaternary deposits: all- alluvial deposits (Holocene-Present); fl- terraced alluvial and fluvioglacial deposits (Pleistocene-Holocene); lr- landslide, block stream and rock glacier deposits; gla- glacial deposits. Tertiary Piemonte Basin and Pliocene succession: tpb. European palaeomargin units: mms- Mesozoic meta-sedimentary units; amb- Ambin 'massif'; dma- Dora-Maira 775 Unit, pre-Triassic basement rocks and associated meta-sedimentary cover. Liguria-Piemonte oceanic units: nonmetamorphic units (Chenaillet Unit; ch_b- basalt; ch_e- gabbro; ch_s- serpentinite and serpentinite breccia); blueschistfacies units (b_{s-} calc-schist, locally with gneiss intercalations; b_{s-} metabasite; b_{s-} serpentinite); eclogite-facies units (Monviso, Rocciavré, lower Susa Valley-Lanzo valleys-Orsiera Unit, SLO; ec_e- calc-schist; ec_b- metabasite; ec_{o} - metagabbro; ec_{s} - serpentinite; ec_{n} - peridotite of the Lanzo ultramafic 'massif'). Cargneules and 780 metasedimentary rocks: bcc- main bodies of cargneules, evaporites and metasedimentary rocks preserved along tectonic contacts.
- Figure 2. a) Examples of Neolithic tools from Chiomonte: i) 67140/3600 (axehead, serpentinite); ii) 3772 (axehead, eclogite); iii) 67138/4148 (axehead; jadeitite with albite?); iv) 4229 (axehead, mixed Na-pyroxenite; v) 86453/1000 (pendant, chloritite; studied with XRPD); vi) 67143/3208 (small axehead, mixed Na-pyroxenite); vii) 67141/5018 (small axehead, mixed Na-pyroxenite/eclogite) ; viii) 67144/8771 (axe fragment, mixed Na-pyroxenite); ix) 67161/5117 (taw, serpentinite); x) 86451/3256 (pendant, chloritite; studied with XRPD) (other details reported in the Supplementary Material, Table S1); b) diagram reporting the functional distribution of the polished stone tools from the archaeological site of Chiomonte, as resulting from morpho-typological studies;
- 790
- Figure 3. a) Histogram of density measurements, performed on 119 (out of 132) lithic implements from Chiomonte; b) preliminary lithotype distribution of the 132 tools from Chiomonte, obtained by combining stereo-microscopic observations and density measurements.
- Figure 4. X-ray powder diffraction patterns of selected tools from Chiomonte. In jadeitite (a: 3788) and omphacitite (b: 6602), the characteristic reflections of clinopyroxenes (-221, 310 and 002): see magnifications in the upper right corners] are sharp and mostly single. In mixed Na-pyroxenite (c: 7179), the coexistence of both jadeite and omphacite in almost equal amounts tend splits them in two, partially superposed, peaks. In eclogite (d: 67142/8936), reflections of garnets (i.e., almandine) also appear. (Jd, jadeite; Omph, omphacite; Alm, almandine; Cu-Kα radiation).
- 800
- Figure 5. a) Pyroxene classification diagram proposed by Morimoto *et al.* (1988) (a) reporting the compositional variation of clinopyroxenes in the Chiomonte tools; b) 'Na-pyroxene rocks' (5 specimens); c) 'Na-pyroxene + garnet rocks' (7 specimens). The bigger dots indicate the average composition of jadeite (light green) and omphacite (dark green) solid solutions, estimated by plotting the *d_{hkl}* values of the three characteristic clinopyroxenes reflections [-221, 310 and 002] on the compositional grid of Giustetto *et al.* (2008).

- **Figure 6**. Compositional variation of garnet, plotteod in the diagram almandine (Alm) + spessartine (Sps) grossular (Grs) pyrope (Prp), in 'Na-pyroxene + garnet rocks' (7 specimens).
- 810 Figure 7. Photomicrographs of jadeitite: a) jadeite granoblast (Jd) includes in the core tiny oriented linear exsolutions of omphacite (Omp) (3788, plane-polarized light, PPL); b) partly retrogressed jadeite (Jd) matrix, including crumbled crystals (hundreds of µm across) intertwined with 'dusky' portions (CMIX/81, PPL).
- Figure 8. Photomicrographs of omphacitite: a) pyroxene matrix, in which small omphacite crystals (Omp), green in colour and typically zoned, show tiny, darker and oriented inclusions in the core (4360, PPL); b) complex zoning of pyroxenes: a heterogeneous, darker matrix (richer in Na and Al) includes small lighter domains, richer in Ca and Mg (4360, SEM image, BSE; the numbered stars indicate the spots in which EDS analyses were collected see Table S4).
- 820 Figure 9. Photomicrographs of mixed Na-pyroxenite: a) small zircon (Zrn) and rutile (Rt) in a matrix of pyroxenes (Jd; Omp) whose zoning is appreciated only at high magnification (6636, PPL); b) the complex zoning of pyroxenes is evident: small and 'relict' jadeite crystals (Jd) are surrounded by a younger omphacite matrix (Omp), commonly slipping inside and partly corroding them (6636, SEM image, BSE; the numbered stars indicate the spots in which EDS analyses were collected see Table S5).
- 825
- Figure 10. Photomicrographs of eclogite: a) and b) fractured garnet (Grt), with an atoll-like habit, forms aggregates included in a matrix consisting of mylonitic omphacite (Omp) and occasionally contoured by (brown) rutile (Rt) [67142/8936, PPL; 3088, SEM image, BSE; the numbered stars indicate the spots in which EDS analyses were collected see Table S13 for pyroxenes (1, 4) and S14 for garnet (2)]; c) admixture of sub-millimetric, idioblastic crystals of jadeitic (light green; Jd) and omphacitic (dark green; Omp) pyroxenes, with scarce garnet; in the middle, a large rutile aggregate (Rt) (7144, PPL); d) restricted jadeite domains (darker), with a 'relict' appearance and including small 'blebs' of exsolved omphacite, are surrounded and crossed by an omphacitic matrix, showing a complex zoning (enhanced by the various shades of grey) (7144, SEM image, BSE).
- 835 Figure 11. Photomicrographs of garnet-omphacitite: a) porphyroclast of an omphacitic pyroxene (Omp), which shows a 'dusky' core with tiny inclusions of ilmenite (Ilm) (3975, PPL); b) an unusual zoning for pyroxenes, in which an older omphacitic core (light grey; Omp) is surrounded by a darker rim, richer in Na and Al (7736, SEM image, BSE; the numbered stars indicate the spots in which EDS analyses were collected – see Table S19).

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Figure 1: The logo of Copernicus Publications.