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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

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ABSTRACT

Rare H*P* meta-ophiolites of archeologic interest occur in the western Alps, both as small primary outcrops at high altitude located in the Monviso or Voltri massifs and as boulders/pebbles in the derived secondary conglomeratic deposits and/or alluvial beds downhill/downstream, originated after erosion of the former ones. Despite their scarceness, these rocks – in the archaeologic literature still grouped under the term "*greenstones*" – are of paramount importance for archaeologists, since they were used to produce polished stone tools rediscovered in prehistoric sites spread all over Europe. Tracing the sources of these raw materials is an important issue for reconstructing the migratory fluxes and trade routes of our ancestors. A certain number of "*greenstone*" geologic samples were retrieved from the alluvial beds of the Lemme valley streams (southeastern Piemonte, Italy) and in the Oligocene conglomerate units of the Tertiary Piemonte Basin, presently exposed in the same valley. Representative samples were analyzed with a classic mineralogical and petrographic approach, which includes XRPD, polarizing microscope and SEM-EDS. These rocks compositions and microstructures were then compared with those of analogous implements found in archaeological sites located nearby and already described in the literature, searching for analogous traits suggesting a common origin. The obtained outcomes show that these secondary deposits of the Lemme valley – originated from the dismantlement of upstream primary outcrops in the Voltri massif (or from a close, analogous palaeo-unit, nowadays completely eroded) – might have represented, during the early-to-middle Neolithic, one of the preferential supply sources of raw "*greenstones*" for the archaeologic sites of Brignano Frascata, Momperone, Villaromagnano and Rivanazzano.

1. Introduction

The most important primary sources of H*P*-meta-ophiolites in Europe are represented by very small outcrops (less than a few m^3) at high altitude in the Western Alps – Piemonte Zone (D'Amico, 2005, 2012; Pétrequin P. et al., 2005a, 2005b, 2006b; Compagnoni et al., 2012), characterized by alpine metamorphism at eclogite facies – namely in the Monviso and Voltri massifs (Compagnoni, 2003; D'Amico and Starnini, 2012; Pétrequin P. et al., 2012a). Secondary deposits, originated from the dismantling of these primary outcrops, occur both in the Oligocene conglomerate units of the Tertiary Piemonte Basin (Northwestern Italy) and in the Quaternary alluvial deposits exposed in vast areas of the Upper Po Valley, comprised among southern Piemonte, northern Liguria and western Lombardy (Compagnoni et al., 2006; D'Amico and Starnini, 2006). These H*P*-meta-ophiolites are extremely important for archaeologists, as their toughness rendered them excellent candidates for the production of stone tools during Neolithic. The main mineralogy of these scarce eclogite-facies rocks, also referred to as "*alpine greenstones*", includes complex Na-clinopyroxene solid solutions plotting in the diagram jadeite (Jd) – aegirine (Ae) – wollastonite + enstatite + ferrosilite (WEF or Q) (Morimoto et al., 1988). According to a recent petrographic classification (Giustetto and Compagnoni, 2014), mainly goaled at supplementing the official geologic rock nomenclature (Fettes and Desmons, 2007), these rare rock types of archaeologic interest mainly belong to two groups:

i) '*Na-pyroxene rocks*' (the true '*Jades*'), including:
   a. *jadeitite* (consisting of jadeite from 95 to 100 vol%);

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b. *omphacitite* (consisting of omphacite from 95 to 100 vol%);
c. *mixed Na-pyroxenite* (consisting of jadeite and omphacite, with intermediate modal compositions between jadeitite and omphacitite).

ii) '*Na-pyroxene + garnet rocks*', including:
a. *eclogite* (consisting of omphacite and garnet in substantial modal amounts, in the range 25–75 vol%);
b. *garnet-omphacitite* (consisting of omphacite prevailing over garnet, in the range 95–75 vol%);
c. *omphacite-garnetite* (consisting of garnet prevailing over omphacite, in the range 95–75 vol%).

All the lithologies of the first group ('*Na-pyroxene rocks*') may be found in Neolithic tools, while as far as '*Na-pyroxene + garnet rocks*' are concerned, only '*eclogite*' and (seldom) '*garnet-omphacitite*' were used. No implement in '*omphacite-garnetite*' was ever recovered. Besides, other lithologies, characterized by the same hue (e.g., serpentinite, amphibolite and prasinite), may also be comprised under the term "*greenstone*" – and occasionally employed in the production of prehistoric tools.

Many of these "*greenstone*" implements (axes, chisels, hatchets and ornamental tools, such as disc-rings) were found in archaeological sites spread all over the Western Europe – i.e., in Southern France and along a corridor running from Southern Italy to Great Britain (Pétrequin P. et al., 2002), but especially in the Po plain (Ricq de Bouard, 1993; Giustetto et al., 2008; D'Amico and Starnini, 2011). Implements of alpine origin were also reported from Slovakia, Czech Republic (Spišiak and Hovorka, 2005; Pétrequin P. et al., 2011), Bulgaria (Pétrequin P. et al., 2012c) and Hungary (Bendő et al., 2014). To this end, a sharp knowledge about the origin of the raw material sources – either from the Monviso or from the Voltri massif, and related downstream secondary deposits – is of paramount importance for reconstructing the possible migratory routes and/or trade channels – feasible purposes that might justify the occasionally long distances (hundreds to thousands of miles, as the crow flies) covered by these rocks, while 'travelling' from their provenance outcrops (in the form of raw materials) to the sites of their recovery (as finished tools and/or roughouts). Moreover, a debate exists about the nature of these sources – whether primary outcrops located at high altitude in the chain, or else secondary deposits in the low lands closer to the settlements. The former option would need sizable blocks to be detached directly from the primary chunk, using flame-cut techniques apparently hinted by parallel palaeoethnographic studies (Pétrequin P. and Pétrequin A.M., 1993; Pétrequin P. et al., 2006a; Pétrequin P., 2012; Pétrequin A.M. and Pétrequin P., 2012) as well as by the occasional discovery of mining-manufacturing traces, located close to some primary boulders in the Monviso massif (Pétrequin P. et al., 2005b, 2006b, 2008). Alternatively, the raw materials could have been retrieved in the form of cobbles from the Oligocene conglomeratic deposits, presently exposed at the outlet of Alpine valleys and/or from the alluvial beds of rivers flowing into the Po plain (Ricq-de-Bouard and Fedele, 1993; Ricq de Bouard, 1996; D'Amico et al., 2003; Giustetto et al., 2016). In these secondary settings, a greater resistance to both weathering and mechanical disruption causes the tougher lithologies (such as eclogite, jadeitite and omphacitite) to be enriched with respect to other, softer ones (D'Amico and Starnini, 2012; Giustetto et al., 2017; Vaczy et al., in prep.). This debate about the origin and nature of these *HP*-meta-ophiolites supply sources could possibly be solved only by comparing the distinctive mineral-petrographic features of the rocks used to manufacture the archaeological tools with those of analogous field samples of known provenance. Unfortunately, such a goal is not trivial due to the marked heterogeneity of these lithologies. Besides, the great mass of collected archaeometric data was seldom used for such a purpose, due to the scarceness of specific mineral-petrographic studies on geological specimens. A possible reference collection was recently set up by analyzing, with various techniques, hundreds of presumed alpine

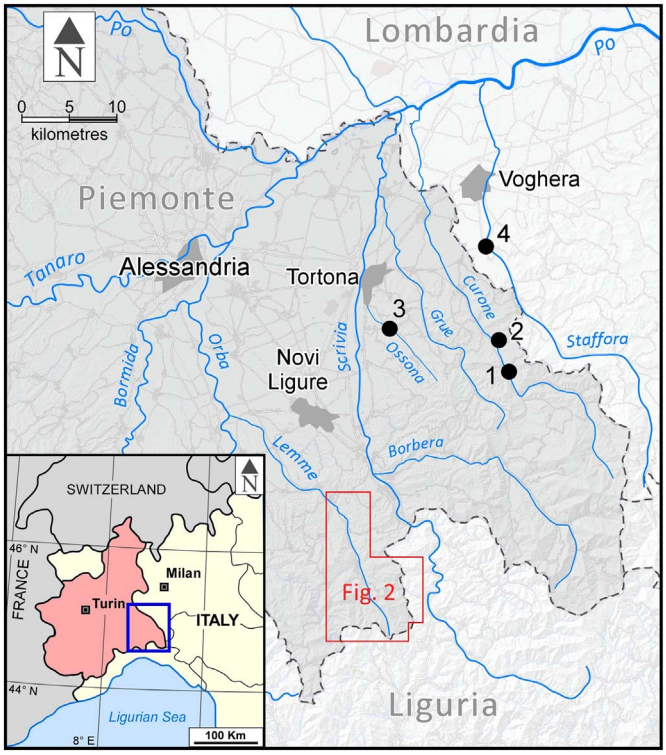

Fig. 1. Map of the southeastern part of Piemonte region showing the location of the Lemme valley as well as of Neolithic archaeological sites in the nearby Ossona, Curone and Staffora valleys (1, Brignano Frascata; 2, Momperone; 3, Villaromagnano; 4, Rivanazzano). The red polygon corresponds to the area magnified in Fig. 2. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

"*greenstones*" specimens (mainly '*Jades*') collected as raw materials or working debris during prospections in the Monviso and Voltri areas ('JADE' project; Pétrequin P. et al., 2012b, 2012c). In the current study, "*greenstone*" cobbles were collected from the alluvial deposits of the Lemme river (eastbound of the Voltri massif; Figs. 1 and 2) as well as from the Oligocene conglomerates cropping out in the same valley, and analyzed with a rigorous mineral-petrographic protocol. By keeping into account all literature data, the obtained outcomes are compared with those of Neolithic tools found in nearby archaeological sites.

2. Materials and methods

2.1. Geological setting and materials

Despite their scarcity, "*greenstone*" *HP*-meta-ophiolites can still be found nowadays. In the Voltri massif, primary outcrops are scarce but alluvial deposits have been identified to the west in the upper Erro valley, to the centre in the upper Orba valley, and also to the east in the Lemme, Ardana, Curone and Staffora valleys (D'Amico and Starnini, 2012; Pétrequin P. et al., 2012a; Vaczy et al., in prep.). These secondary *HP*-meta-ophiolite blocks are dispersed among other lithotypes, in Oligocene conglomerates and/or in Quaternary alluvial beds (Pétrequin P. et al., 2012b). The Lemme valley, located to the southeast of the Piemonte region, province of Alessandria, belongs to the Beigua East group according to Pétrequin P. et al. (2012a). The upper course of the Lemme valley (north of Voltaggio) is incised in the Sestri-Voltaggio Zone (Fig. 2), a tectonic slice zone about 25 km long and a few km large, stretching approximately N-S from Sestri Ponente, on the Ligurian coast, to the village of Voltaggio, in the Lemme valley (Cortesogno and Haccard, 1985; Capponi and Crispini, 2008; Piana et al., 2017). The Sestri-Voltaggio Zone separates the Voltri ophiolitic massif, to the west, from the non-metamorphic Ligurian units