WHETSTONES FROM BRONZE AGE HILL FORTS OF NORTH-EASTERN ITALY*

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A group of Bronze Age whetstones from protohistoric hill forts, locally called castellieri, *of eastern Friuli Venezia Giulia (north-eastern Italy) has been studied using different techniques, including non-destructive methods such as X-ray computed microtomography and portable X-ray fluorescence, in order to characterize the raw material and define its origin. The obtained results suggest that small pebbles of reddish subarkose and quartz arenites collected from the gravel deposits of the Isonzo River, perhaps deriving from Val Gardena Formation outcrops, were exploited for the production of the studied artefacts during the Bronze Age. These data complement our knowledge about the lithic raw materials exploitation strategies during the ancient phase of the* castellieri *culture, almost exclusively based on local rock types.*

KEYWORDS: NORTH-EASTERN ITALY, BRONZE AGE, WHETSTONES, SANDSTONE, microCT, PETROGRAPHIC AND GEOCHEMICAL ANALYSIS, PROVENANCE

INTRODUCTION

The archaeological landscape of the karstic region of eastern Friuli Venezia Giulia (north-eastern Italy) is characterized by numerous protohistoric hill forts protected by dry-stone walls, locally called *castellieri*, built from the Early Bronze Age to the Late Iron Age (Marchesetti 1903; Bandelli and Montagnari Kokelj 2005).

Among the studies on lithic tools from these sites, special attention has been given to the archaeometric analysis of grinding stones (Bernardini 2002, 2005a,b; Antonelli *et al*. 2004). In the Bronze Age sites, saddle querns made of local sandstone from flyschoid deposits are common (Bernardini 2002), while Iron Age volcanic imported rock types, trachytic volcanites and rare mugearites and hawaiites, testify to long-distance connections with the Euganean Hills, near Padua (Veneto), and with Mount Etna (Sicily), respectively (Bernardini 2002, 2005a,b; Antonelli *et al*. 2004). Other classes of lithic tools have never been studied in detail. Among them there are tools that could give indirect evidence of bronze metallurgy. Since the metal findings from settlements are almost completely unknown, with a few exceptions (Stacul 1972; Maselli Scotti 1997), the study of whetstones from Karst Bronze Age hill forts, not reported from coeval fortified settlements of western Slovenia, the Friuli plain and the Istria peninsula, has been carried out not only to improve our knowledge about raw material procurement strategies during the

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second millennium BC but also to collect possible indirect evidence connected to bronze metallurgy (Figs 1 and 2). They are made from reddish sandstone pebbles, apparently different from the carbonatic and flyschoid rock types outcropping in the south-eastern part of Friuli Venezia Giulia (Fig. 1; Lenaz 2000), suggesting a raw material procurement strategy based on the exploitation of secondary deposits.

MATERIALS AND METHODS

All the studied artefacts, stored in the Trieste Natural History Museum, are surface findings from protohistoric hill forts of the karstic area between Monfalcone and Trieste in north-eastern Italy (Fig. 1). Four of them are from the Bronze Age San Primo site (Cardarelli 1983), one from the contemporary Nivize hill fort (Moretti 1978) and three from the *castelliere* of Gradiscata, dated from the Bronze Age to the Iron Age (Marchesetti 1903; Montagnari Kokelj 1989). They are made from a fine-grained reddish rock and generally show at least one rounded face with polishing and/or very fine hammering traces (Fig. 2). The rounded morphology of most of them, produced by fluvial or marine abrasion, clearly suggests an origin from secondary deposits. Pebbles with a similar colour and macroscopic texture have only been identified in the gravel deposits of the Isonzo River, flowing close to the western margin of the karstic plateau (Fig. 1). The artefacts and a few fine-grained pebbles (Iso1–3), selected from amongst numerous samples

Figure 1 *A geological sketch map of eastern Friuli Venezia Giulia, showing the protohistoric hill forts where the studied artefacts have been found and the area where secondary fluvial deposits of the Isonzo River have been sampled (black asterisk): scale bar 10 km.*

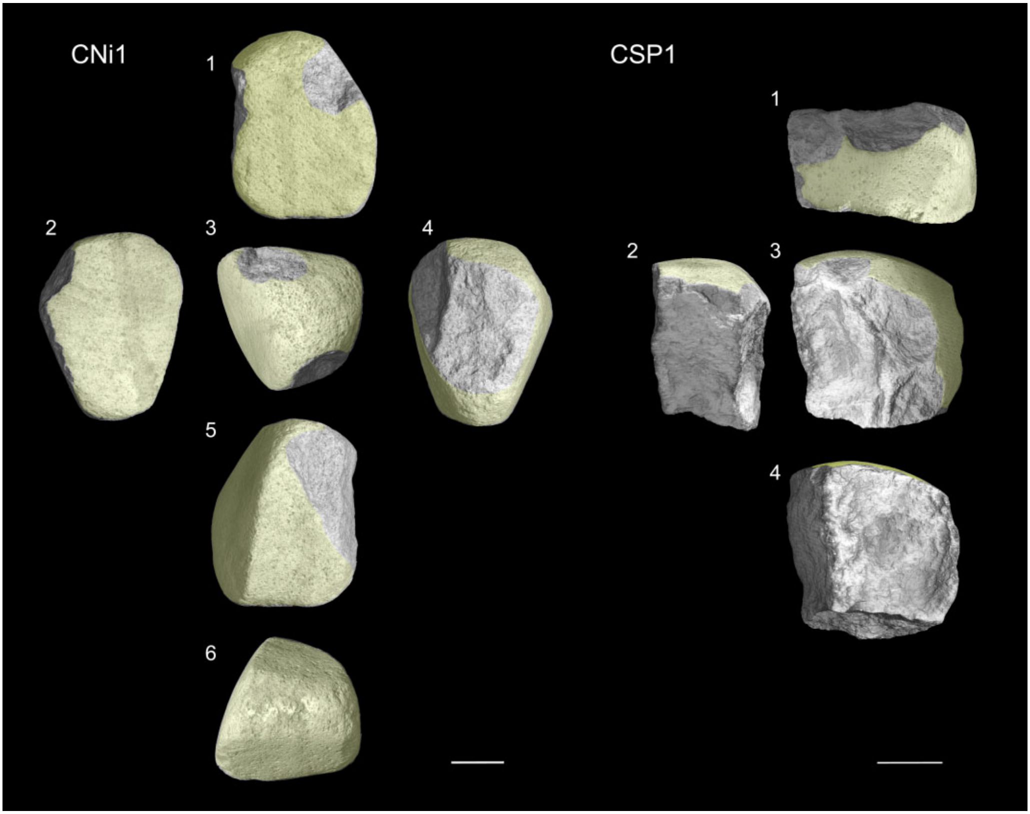

Figure 2 *Virtual renderings of the artefacts CSP1 and CNi1, showing the areas with use traces: isotropic voxel sizes 29 μm for CSP1 and 37 μm for CNi1; scale bars 2 cm.*

from the Isonzo River, have been analysed using various techniques, which are described in the following subsections (Table 1).

Stereomicroscopy

The surfaces of the artefacts have been observed by means of a stereomicroscope, in order to provide evidence of use wear traces. Scanning electron microscopy (SEM) has also been tested by means of a Quanta250 SEM (FEI, Oregon, USA), operating in secondary electron detection mode, at the Department of Medical Sciences of the University of Trieste, but the results have been unsatisfactory due to the large sample size and bad electron transmission.

X-ray computed microtomography

Computed microtomography (microCT) has been used to collect textural information on sample CNi1—which has not been analysed by optical microscopy due to conservation reasons—and on another artefact (CSP1) used as a comparison sample. Moreover, the microCT virtual renderings have been used to visualize the manufacturing and use traces, which are particularly well visible in samples CSP1 and CNi1.

Table 1 *A list of the studied whetstones and pebbles from the Isonzo River: microCT, X-ray computed microtomography; SM, stereomicroscopy; XRD, X-ray diffraction; OM, optical microscopy; ICP, inductively coupled plasma emission and mass spectrometry; PXRF, portable X-ray fluorescence*

	Number	Analytical methods
Archaeological site		
Castelliere San Primo	CSP1	MicroCT, SM, XRD, PXRF
Castelliere San Primo	CSP2	XRD, OM, PXRF
Castelliere San Primo	CSP3	XRD, OM, PXRF
Castelliere San Primo	CSP4	XRD, PXRF
Castelliere Gradiscata	CGr1	XRD, PXRF
Castelliere Gradiscata	CGr2	XRD, OM, PXRF
Castelliere Gradiscata	CGr3	XRD, PXRF
Castelliere Nivize	CNi1	MicroCT, SM, XRD, PXRF
Sampling locality		
Isonzo River	Iso1	XRD, OM, ICP, PXRF
Isonzo River	Iso2	XRD, OM, ICP, PXRF
Isonzo River	Iso3	XRD, OM, ICP, PXRF

The analyses have been carried out at the Multidisciplinary Laboratory (MLAB) of the 'Abdus Salam' International Centre of Theoretical Physics (ICTP), where a cone beam microCT system has recently been built in collaboration with Sincrotrone Trieste S.C.p.A. (Trieste, Italy) (Bernardini *et al*. 2012; Tuniz *et al*. 2012, 2013).

The ICTP system is based on a microfocus X-ray source (minimum focal spot size 5 mm, voltage up to 150 kV) and a large-area flat-panel sensor. The microCT scans were carried out with a source voltage of 140 kV, a current of 200 µA and the recording of 2400 projections of the sample over 360°. The final volume renderings were reconstructed using DigiXCT in 16-bit format, at isotropic voxel sizes of 29 and 37 µm. Ring artefacts correction has been applied in order to improve the image quality (Figs 2 and 3).

X-ray diffraction

X-ray diffraction (XRD) patterns were obtained on powdered samples spread out on aluminium plates, using a STOE D 500 X-ray diffractometer at room temperature at the Department of Mathematics and Geosciences of the University of Trieste. Cu–K_α radiation was used through a flat graphite crystal monochromator. The current used was 20 mA and the voltage was set at 40 kV. The scanning angle ranged from 2 to 40° 2θ, the steps were of 0.01° 2θ and the counting time was 2 s per step.

Optical microscopy

Thin sections of seven artefacts and three fluvial pebbles from the Isonzo River have been produced and observed using a polarizing microscope at the Department of Mathematics and Geosciences of the University of Trieste in order to define the mineralogical and petrographic features of the investigated samples (Table 1).

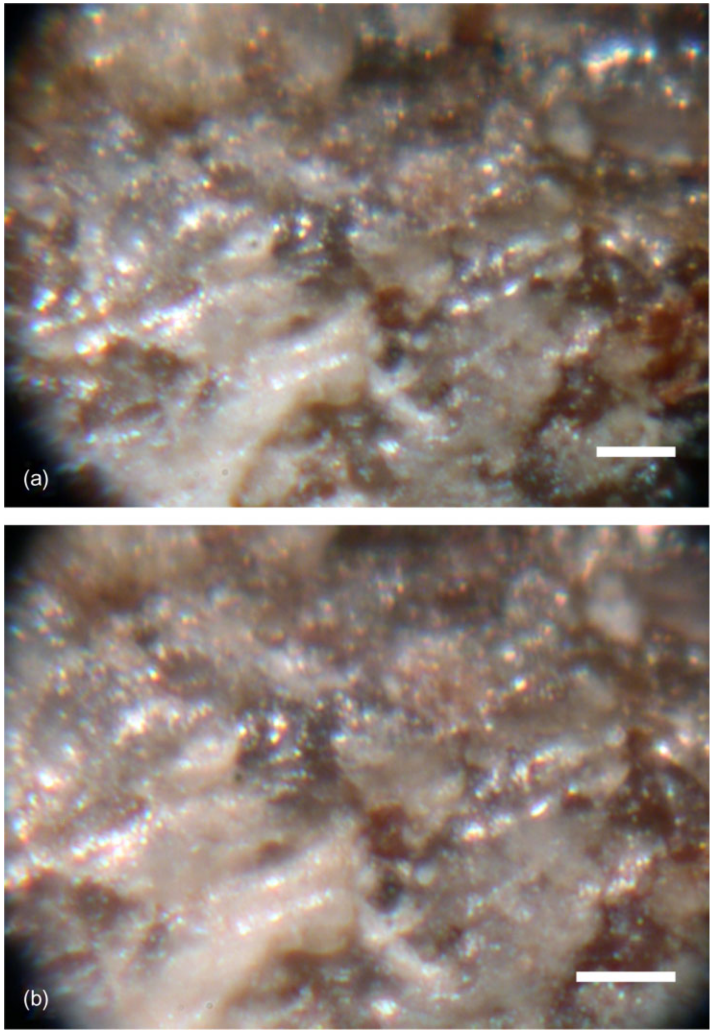

Figure 3 *Microphotographs showing oblique use stripes on the polished surface of sample CSP1: scale bars 200 μm.*

Geochemistry

ICP–ES and ICP–MS Major and trace element determinations of two samples from the Isonzo River (Iso1 and Iso2; Table 1) have been carried out by inductively coupled plasma emission and mass spectrometry (ICP–ES and ICP–MS) at Acme Analytical Laboratories Limited, Vancouver, Canada. The analytical uncertainties are estimated to be between 5 and 10% (Govindaraju and Mevelle 1987; Table 2). The samples have been previously powdered using a mill at a 150-mesh fraction in the laboratory of the Department of Mathematics and Geosciences of the University of Trieste. Major elements and some minor ones have been analysed by inductively coupled plasma emission spectrometry (ICP–ES) following a lithium borate fusion and a dilute acid digestion of 0.2 g of samples' pulp. The loss on ignition (LOI) was determined by measuring the weight lost during heating at 1000°C for a 3-h period. Trace elements were determined by

Table 2 *The major (wt%) and trace (ppm) elements of rock samples Iso1 and Iso2 analysed by ICPS (ICP–ES and ICP–MS) and PXRF: LOI, loss on ignition; dl, detection limit*

		ICP		*PXRF*	
		Iso1	*Iso2*	*Iso1*	*Iso2*
SiO_2	(wt%)	85.77	80.74		
TiO_2		0.47	0.75	0.29	0.43
Al_2O_3		6.74	8.75		
Fe_2O_3		1.61	2.39	1.42	2.25
MnO		<0.01	0.02	0.02	0.03
MgO		0.53	0.92		
CaO		0.10	0.65	0.17	0.45
Na_2O		1.33	1.83		
K_2O		1.18	1.48	1.04	1.52
P_2O_5		0.06	0.09		
Cr_2O_3		0.00	0.01	<dl	<dl
LOI		1.90	2.10		
Sum		99.69	99.73		
Ni	(ppm)	<20	<20		
V		32.00	44.00		
Rb		42.10	48.50	31.972	45.154
Ba		106.00	145.00		
Th		6.10	12.20		
U		2.10	3.70		
Pb		4.30	7.70		
Sr		36.30	58.90	17.387	49.427
Nb		8.20	11.70	18.45	19.77
Ta		0.80	0.90		
Zr		251.80	567.80	322.06	335.47
Hf		7.00	15.70		
Y		15.50	33.50	22.04	25.84
La		15.60	28.20		
Ce		31.50	54.90		
Pr		3.33	6.25		
Nd		12.40	23.80		
Sm		2.38	4.53		
Eu		0.37	0.84		
Gd		2.17	4.93		
Tb		0.36	0.88		
Dy		2.40	5.68		
Ho		0.52	1.24		
Er		1.65	3.58		
Tm		0.26	0.56		
Yb		1.62	3.40		
Lu		0.26	0.52		

inductively coupled plasma mass spectrometry (ICP–MS). Rare earth and refractory elements have been analysed following a lithium borate fusion. Additionally, a fraction of 0.5 g was removed for digestion in aqua regia (heated to 95°C) and analysed for base metals and precious metals.

PXRF All the artefacts and the three pebbles from the Isonzo River (Table 1), including those studied by ICP–ES and ICP–MS, have been analysed by means of a portable X-ray fluorescence spectrometer (PXRF), recently built at the Multidisciplinary Laboratory (MLAB) of the 'Abdus Salam' International Centre of Theoretical Physics (ICTP) (Tuniz *et al*. 2013). The system is based on light, compact and relatively low-cost components, including a set of low-power X-ray tubes, energy-dispersive detectors and a high-contrast hybrid detector (working in the single-photon counting mode).

Both the whetstones and the fluvial pebbles show at least one very flat surface, which has been carefully selected to perform the analysis in order to avoid surface irregularity effects (Potts *et al*. 1997). The samples have been irradiated with a collimated X-ray beam (30 kV and 0.010 mA) produced by an Amptek Mini X-ray tube (target material Ag, voltage 10–40 kV, maximum current 200 µA, focal spot size 2 mm, analysed spot size diameter about 10 mm, cone angle 120°). The resulting scattered beam has been measured using an Amptek Super X-123SDD silicon drift detector (SDD) and the corresponding spectra have been acquired by means of a multichannel analyser (MCA). The concentrations of some major and trace elements have been obtained using the 'Simple Quantitative Analysis—Elemental Sensitivity' approach in the QXAS-AXIL quantitative X-ray analysis package (software developed by the IAEA). The system has been calibrated using several geological standards certified by the US Geological Survey (W-2a, BCR-2, AGV-2, SCo-1, GSP-2, DNC-1a and BHVO-2; Tables 2 and 3). The accuracy of the results is generally between 5 and 10% for major elements and between 10 and 20% for trace elements. Among the major elements, the most accurate results have been obtained for Ca (<5%) and Ti (~5%).

RESULTS AND DISCUSSION

Macroscopic observation of the samples

All the samples show a reddish colour and a homogeneous fine to medium-grained texture, rarely crossed by thin quartz veins. Lamination and probable cross-bedding could be related to aeolian sedimentary conditions or to a turbidite sequence (Bouma *C* horizon).

Samples CSP1 and CNi1 preserve particularly evident use traces (Figs 2–4). The last one is characterized by an artificial prismatic shape with four vertical faces. Three of them, flat and polished, display some transversal stripes and are connected through sharp angles. In addition to polishing traces, fine hammering can be detected in correspondence with the two opposite bases. In sample CSP1, only two faces are very polished and are connected through a very sharp angle.

Stereomicroscopy

Samples CSP1, CSP3 and CNi1 provide evidence of use traces in the form of polished areas and parallel stripes. In addition to this, fine hammering marks are detectable in correspondence with the two opposite ends along the longitudinal axes of sample CNi1. Notably, the stripes, when visible, show directions inconsistent with the natural lamination and sometimes cut single granules (Fig. 3).

Rare minerals with a metallic lustre, perhaps sulphides or oxides, have been observed in sample CNi1.

Table 3 *The major (wt%) and trace (ppm) elements of the archaeological artefacts and rock samples from the Isonzo River analysed by PXRF: dl, detection limit*

		Iso1A	*Iso1B*	*Average*	*Iso2A*	*Iso2B*	*Average*	*Iso3A*	*Iso3B*	*Average*	*CGr1-1*
TiO_2	(wt%)	0.28	0.30	0.29	0.33	0.52	0.43	0.23	0.29	0.26	0.26
Fe_2O_3		1.53	1.31	1.42	2.06	2.44	2.25	1.41	1.24	1.32	1.26
MnO		0.02	0.02	0.02	0.03	0.03	0.03	0.05	0.02	0.04	0.02
CaO		0.08	0.26	0.17	0.36	0.54	0.45	0.11	0.11	0.11	0.32
K_2O		1.16	0.92	1.04	1.34	1.70	1.52	0.80	0.73	0.77	0.42
Cr_2O_3		<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl
Rb	(ppm)	37.96	25.98	31.97	40.85	49.46	45.15	18.99	15.94	17.47	20.91
Sr		18.85	15.92	17.39	45.51	53.34	49.43	33.15	28.35	30.75	17.27
Nb		19.33	17.57	18.45	19.27	20.27	19.77	14.37	15.22	14.80	13.27
Zr		323.14	320.98	322.06	295.71	375.22	335.47	153.55	190.82	172.19	269.65
Y		23.25	20.84	22.04	18.27	33.40	25.84	19.94	20.17	20.05	25.97

		CGr1-2	*Average*	*CGr2-1*	*CGr2-2*	*Average*	*CGr3-1*	*CGr3-2*	*Average*	*CSP1-1*	*CSP1-2*
TiO_2	(wt%)	0.24	0.25	0.24	0.18	0.21	0.08	0.12	0.10	0.26	0.33
Fe_2O_3		0.96	1.11	0.69	0.82	0.76	0.52	0.44	0.48	0.90	1.14
MnO		0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.17	0.02
CaO		0.34	0.33	0.28	0.32	0.30	0.19	0.21	0.20	0.20	0.23
K_2O		0.29	0.35	0.29	0.33	0.31	0.23	0.24	0.23	0.87	1.07
Cr_2O_3		<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl
Rb	(ppm)	18.14	19.52	14.77	12.65	13.71	14.85	16.03	15.44	12.73	18.19
Sr		16.87	17.07	19.55	17.75	18.65	14.75	13.97	14.36	22.32	16.07
Nb		13.89	13.58	15.03	15.83	15.43	16.17	15.48	15.82	11.88	13.38
Zr		260.15	264.90	97.66	97.58	97.62	91.16	113.69	102.43	388.85	294.80
Y		16.93	21.45	14.69	16.91	15.80	19.09	16.61	17.85	17.85	26.04

		CSP1-4	*CSP1-5*	*CSP1-6*	*Average*	*CSP2-1*	*CSP2-2*	*Average*	*CSP3-2*	*CSP3-3*	*Average*
TiO_2	(wt%)	0.21	0.20	0.11	0.22	0.33	0.37	0.35	0.48	0.27	0.37
Fe_2O_3		1.03	0.91	0.99	0.99	0.88	1.42	1.15	1.98	1.74	1.86
MnO		0.02	0.02	0.02	0.05	0.02	0.02	0.02	0.03	0.02	0.03
CaO		0.25	0.31	0.42	0.28	0.27	0.20	0.23	0.33	0.24	0.29
K_2O		0.88	0.74	0.83	0.88	0.57	0.73	0.65	1.06	0.93	1.00
Cr_2O_3		<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl
Rb	(ppm)	19.72	17.76	19.44	17.57	17.66	33.49	25.58	41.76	45.23	43.49
Sr		20.93	22.58	18.43	20.07	17.34	30.71	24.03	36.42	28.97	32.70
Nb		10.32	12.32	30.37	15.65	14.98	19.41	17.19	14.87	17.19	16.03
Zr		218.95	142.20	148.83	238.73	433.04	393.10	413.07	368.15	214.63	291.39
Y		25.70	23.50	29.74	24.57	37.18	18.36	27.77	20.37	18.67	19.52

		CSP4-1	*CSP4-2*	*Average*	*CNi1-1*	*CNi1-2*	*CNi1-3*	*CNi1-4*	*CNi1-5*	*CNi1-6*	*Average*
TiO_2	(wt%)	0.23	0.16	0.19	0.43	0.21	0.32	0.23	0.21	0.32	0.29
Fe_2O_3		0.64	0.64	0.64	1.13	1.28	0.80	1.07	1.55	1.28	1.18
MnO		0.02	0.02	0.02	0.04	0.04	0.02	0.05	0.06	0.04	0.04
CaO		0.19	0.11	0.15	0.63	0.67	0.41	0.63	0.95	0.62	0.65
K_2O		0.28	0.19	0.23	0.98	1.03	0.60	0.91	1.05	0.74	0.88
Cr_2O_3		<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl	<dl
Rb	(ppm)	15.93	13.46	14.69	31.88	35.59	23.26	21.69	23.00	37.82	28.87
Sr		12.66	11.21	11.94	21.87	17.27	14.34	16.80	13.26	15.88	16.57
Nb		14.47	17.89	16.18	16.79	16.86	14.93	12.93	13.96	13.47	14.82
Zr		209.07	241.15	225.11	150.15	161.08	151.99	127.55	104.18	149.28	140.70
Y		16.01	17.12	16.56	16.60	20.12	23.53	15.61	15.46	16.81	18.02

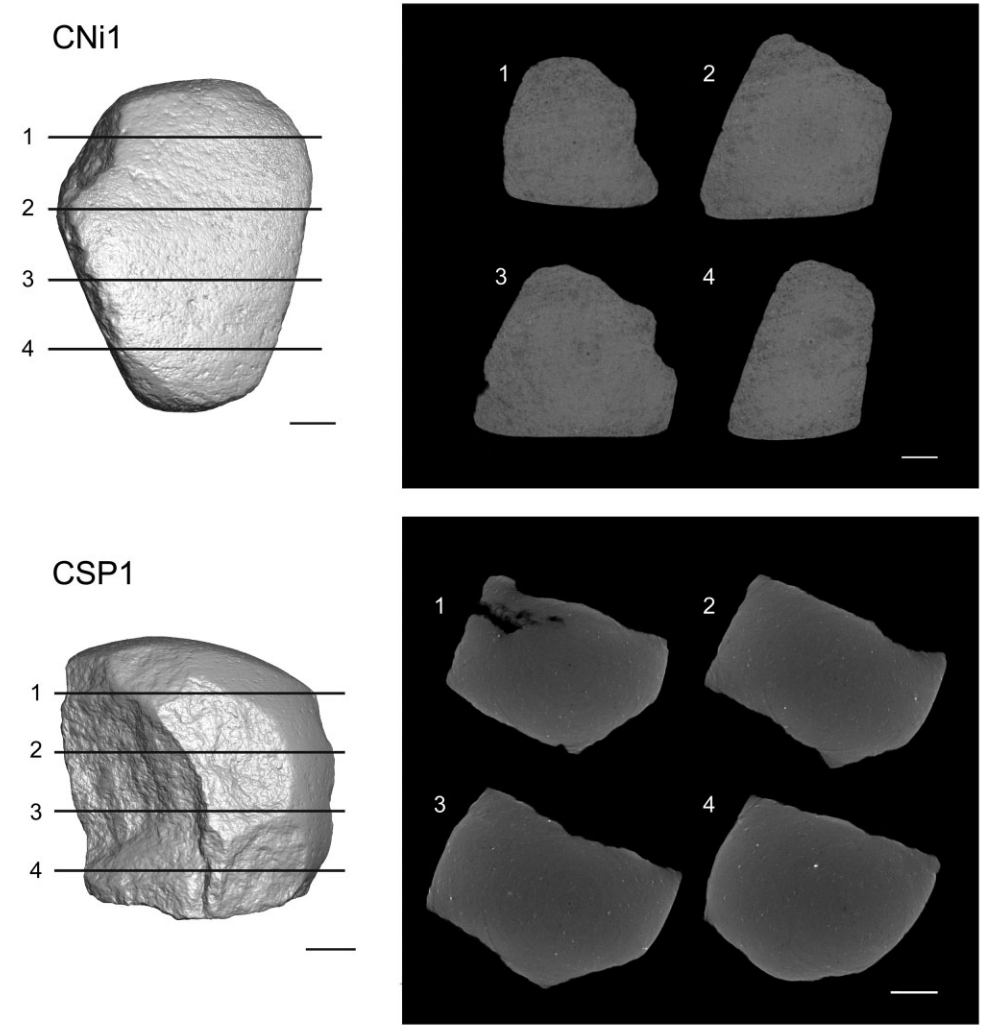

Figure 4 *Virtual renderings and transversal sections of artefacts CNi1 and CSP1: isotropic voxel sizes 29 μm for CSP1 and 37 μm for CNi1; scale bars 1 cm.*

Computed microtomography

Both the analysed artefacts are characterized by a very fine texture and, although the isotropic voxel size is relatively small (CNi1, 37 μm; CSP1, 29 μm), the grains forming the rocks cannot be identified, with the exception of the most dense ones, which can be easily recognized in the virtual sections (Fig. 4) as small white spots. These minerals probably correspond to Ti–Fe oxides or sulphides visible in thin sections. Moreover, sample CNi1 shows an evident lamination that is more easily detectable in the external parts, probably due to weathering processes that occurred after its burial. In general, the very homogeneous grey levels suggest that both samples are composed of a main mineral component. Although a ring artefacts correction has been applied, they have not been completely eliminated, mainly in the transversal sections of sample CSP1 (Fig. 4), reducing the image quality.

X-ray diffraction

The X-ray diffraction (XRD) patterns of the artefacts indicate that the main mineral phases present in the samples are prevalent quartz (94–99%) and very little feldspar (1–6%; Fig. 5). The

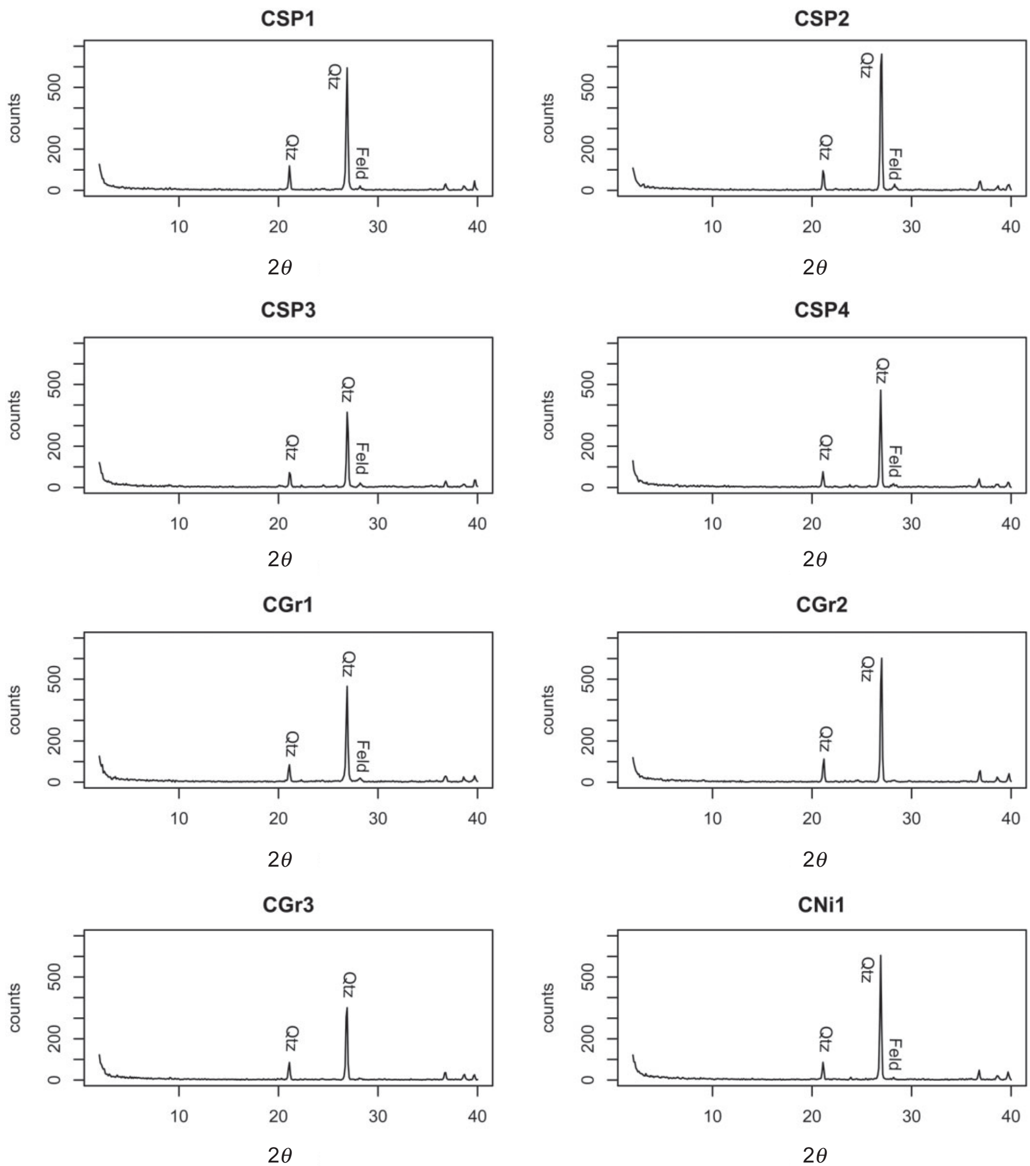

Figure 5 *X-ray diffractograms of studied artefacts: Feld, feldspar; Qtz, quartz.*

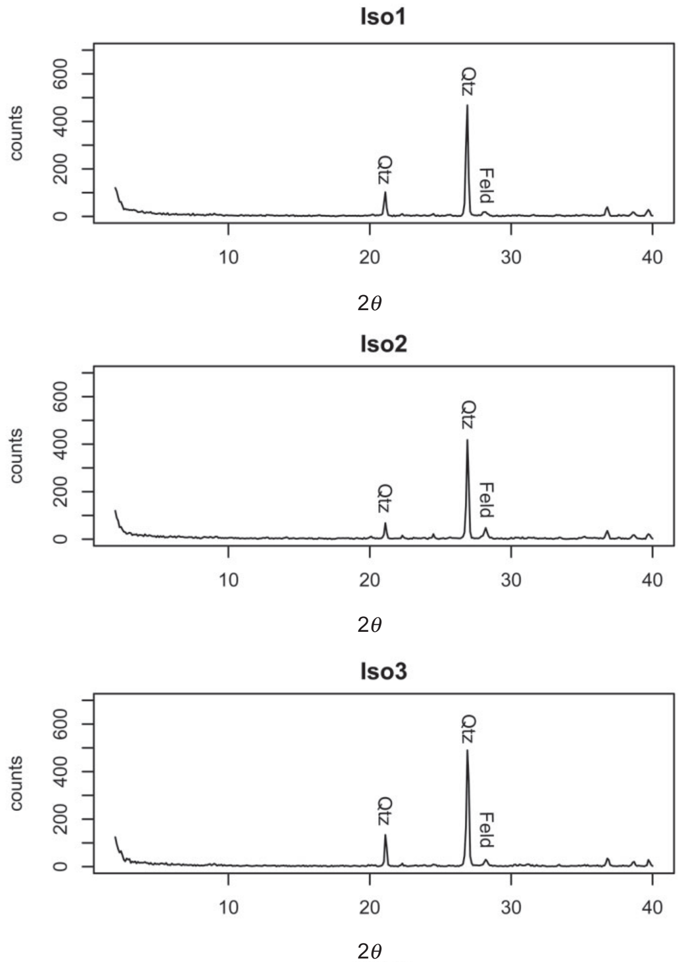

Figure 6 *X-ray diffractograms of sandstone pebbles from the Isonzo River: Feld, feldspar, Qtz, quartz.*

analysis of the fluvial pebbles from the Isonzo River has yielded comparable results (quartz higher than 90% and feldspar lower than 10%; Fig. 6).

Optical microscopy and classification

All the analysed artefacts are sandstones, constituted by angular or slightly rounded quartz clasts and rare feldspar (in most cases less than 5 modal%; Fig. 7). Extremely fine-grained authigenic oxides are present as stains covering the grains, giving a characteristic pink-reddish colouration to the rock. According to Pettijohn's classification (1975) and both the optical and X-ray investigations, the archaeological samples are quartz arenites, with the exception of two artefacts that fall in the subarkose field (CSP2-3). Although all of them are well sorted, two different grain sizes have been identified: fine-grained samples (Fig. 7, CSP3 and Iso1; particle size < 0.3 mm) and coarser samples (Fig. 7, CGr2; particle size 0.5–1.0 mm). The only exception is artefact

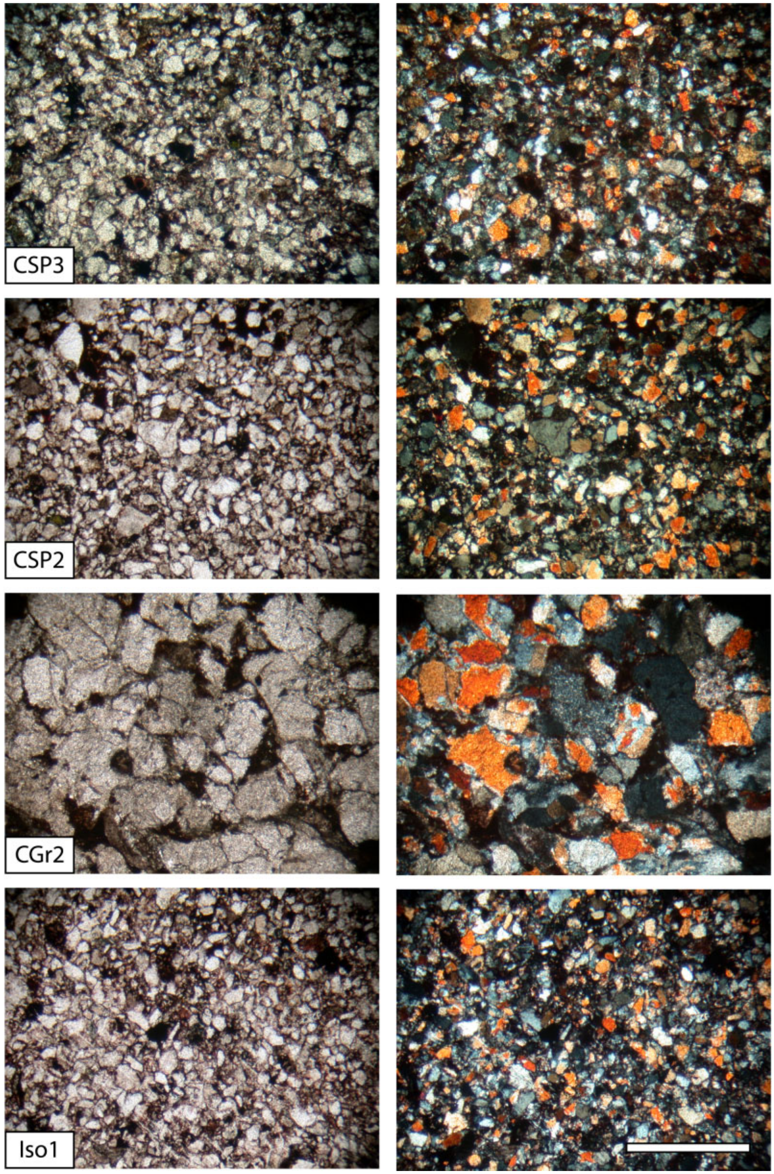

Figure 7 *Thin-section photomicrographs of artefacts CSP3, CSP2 and CGr2 and pebble Iso1 from the Isonzo River. The left-hand images were taken using plane-polarized light, while the right-hand ones were obtained via crossed polars. All the identifiable granules are quartz fragments. Scale bar 1 mm.*

CSP2, characterized by a bimodal texture, which, according to Folk (1968) and Pettijohn (1975), could be related to a deflationary aeolian environment.

We note that sandstones from the local Trieste flysch show differing chromatic characteristics, having a grey to brownish colour. To our knowledge, no published classification exists for these

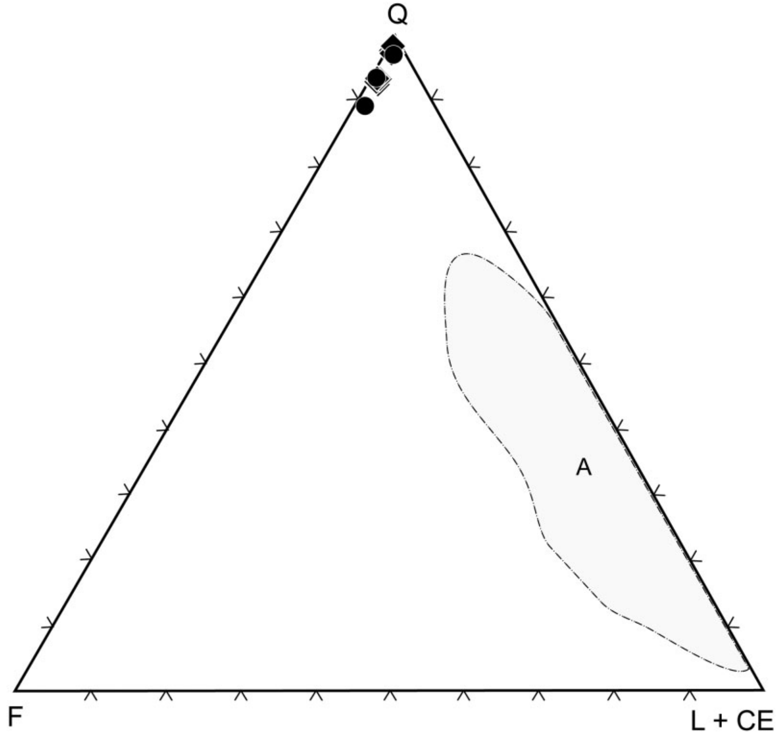

Figure 8 *The petrographic classification diagram (according to Zuffa 1980) of the investigated whetstones (black diamonds) in comparison to Isonzo River pebbles (black circles) and Claut, Belluno and Clauzetto flysch formations (field A; data from Stefani* et al. *2007): Q, quartz; F, feldspar; L + CE, fine-grained lithic fragments plus carbonate extrabasinal grains.*

rocks (quartz – feldspar – lithic fragments diagram), but they are usually to be considered as greywackes or lithic sandstones (± carbonate). Stefani *et al*. (2007), considering the petrography of the nearby Claut, Clauzetto and Belluno basins, showed that all the investigated samples can be classified as litharenites according to Zuffa (1980), with sometimes more than 50% of extrabasinal carbonate material (Fig. 8). The sandstones of the Brkini and Julian basins share the same petrographic features (Bertolla 1997; Cigno 1997).

In the classification diagram proposed by Zuffa (1980), the whetstones plot far from the mentioned flyschoid rocks, while the mineralogical and petrographic features of the pebbles from the Isonzo River make them indistinguishable from the archaeological artefacts (Figs 7 and 8).

Geochemistry

The major and trace element contents measured by PXRF show reasonable analytical accuracy and precision (Table 2). In spite of the fine-grained texture and relatively homogeneous mineralogy of the samples, several analyses have been carried out in order to obtain representative results. The few major and trace elements measured by non-destructive PXRF (Table 3) have

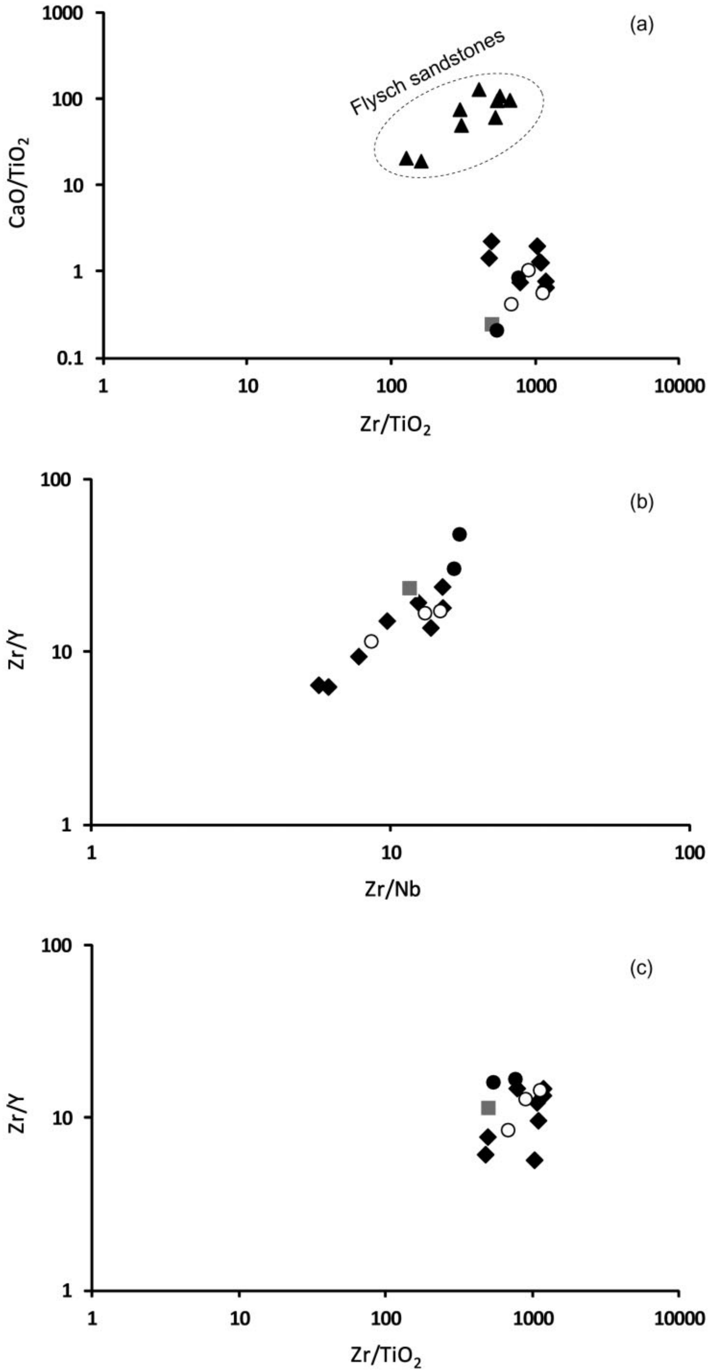

Figure 9 *Bivariate bilogarithmic diagrams comparing the whetstones (black diamonds, analysed by PXRF) to the pebbles from the Isonzo River (white circles, samples Iso1–3 analysed by PXRF; black circles, samples Iso1 and Iso2 analysed by ICP–ES and ICP–MS). The grey square is a Gröden/Val Gardena Formation sample (from Mader and Neubauer 2004) and the black triangles are local flysch sandstones (from Lenaz 2000).*

been used to compare, via bivariate diagrams, the whetstones to the fluvial pebbles from the Isonzo River (Fig. 9).

The elemental ratios considered take into account elements particularly related to heavy minerals such as Ti–Fe oxides (Ti, Nb), zircon (Zr) or garnet (Y) (whose concentrations can be related to changes in transport energy) and carbonates, which are abundant in the flysch sandstones that outcrop close to the *castellieri*. In all of the plots (Fig. 9), and considering the PXRF results, samples from the Isonzo River fall in correspondence with the archaeological specimens, indicating a very similar chemical composition. In the same diagrams, samples Iso1 and Iso2, analysed by ICP–ES and ICP–MS, and a Gröden/Val Gardena Formation sample (data from Mader and Neubauer 2004) are shown for comparison. Moreover, the CaO/TiO_2 ratio (Fig. 8 (a)) clearly discriminates the investigated whetstones from the local flysch sandstones (data from Lenaz 2000).

CONCLUSIONS

The optical and geochemical characterization of the studied artefacts indicates that the materials used for manufacturing the whetstones consist of reddish subarkose and quartz arenites that are indistinguishable from those found as pebbles in the gravel deposits of the lower course of the Isonzo River, 10–35 km from the archaeological sites. These pebbles probably derive from the Permian Val Gardena Formation, a continental red-bed unit that is exposed

Figure 10 *A schematic map of eastern Friuli Venezia Giulia, showing the provenance of the whetstones raw material, corresponding to the Isonzo River fluvial deposits, in relation to the protohistoric hill forts where the artefacts have been discovered); scale bar 10 km.*

across a very wide area, from Lombardy in north-western Italy to the Karawanke mountains in Slovenia (Neri 2006), and is crossed by the eastern tributaries of the upper course of the Isonzo River in western Slovenia (Mlakar 2002; Skaberne 2002). Other types of sandstones available in the area show clearly different mineralogical, petrographic and geochemical features. Accordingly, it is suggested that during the Bronze Age small pebbles of reddish arenites from the nearby Isonzo River were exploited for the production of whetstones by the inhabitants of the Karst hill forts (Fig. 10).

These data complement our knowledge about the lithic raw materials used during this ancient phase of the *castellieri* culture, largely represented by local rock types. Grinding stones, commonly found in most of the hill forts (Marchesetti 1903; Bernardini 2002), were, in fact, produced from sandstone derived from flysch successions outcropping both north and south of the karst anticline (Fig. 1). In the same period, local calcareous flint, outcropping in the Komen territory and in a small karstic depression (the Dolina Velike Nive) close to the village of Aurisina, were used for the production of rough flaked tools found in several hill forts (Marchesetti 1903). It is only during the Iron Age that the lithic raw materials of the grinding stones clearly indicate the development of long-distance connections with northern and southern Italy (Bernardini 2002, 2005a,b; Antonelli *et al*. 2004).

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