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The Urgonian chert from Provence (France): the intra-formation variability and its exploitation in petro-archeological investigations

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Abstract

Understanding details of stone tool procurement and transfers is for a major research avenue in improving our knowledge about prehistoric societies. The accuracy of the provisioning sources identifications is based on the establishment of large regional repositories. Recent studies show that specific investigations on the evolution of cherts were effective in distinguishing primary sources from the various secondary sources of a raw material. In this paper, we focus on another difficulty that is the distinction between different primary sources of the same geological layers.

We consider the specific case of the Bedoulian cherts from southeastern France. This chert was exploited and circulated over large distances during the whole prehistoric record. It is particularly known to have been heat-treated during Late Chassey culture (Neolithic). We show in this paper that paleogeographical variability exists due to variations in the bioclastic and detrital components. With the support of foraminifera data, the granulometry of detrital quartz grain provides the possibility to distinguish between different primary sources. A first test in archeological contexts illustrates the efficiency of the method as well as indicates major changes in provisioning practices between upper Paleolithic and Neolithic groups.

Keywords

Chert

Petroarcheology

Southern France

Paleolithic

Neolithic

Provenance studies

Introduction

Stone tool procurement and transfer modalities are of interest for specifying the economic patterns as well as inter-cultural relationship of prehistoric societies (Phillips 1980; Renfrew 1984). Moreover, the use of concepts and methods of cultural anthropology and prehistoric technology provides a framework to construct these relationships (Lemonnier 2010; Tixier 2012; Perlès 2016). Indeed, the latter allows adding qualitative data to a description of quantitative transfers and then highlights social aspects considering both temporal and spatial segmentation of goods trading (Binder and Perlès 1990; Geneste 2010).

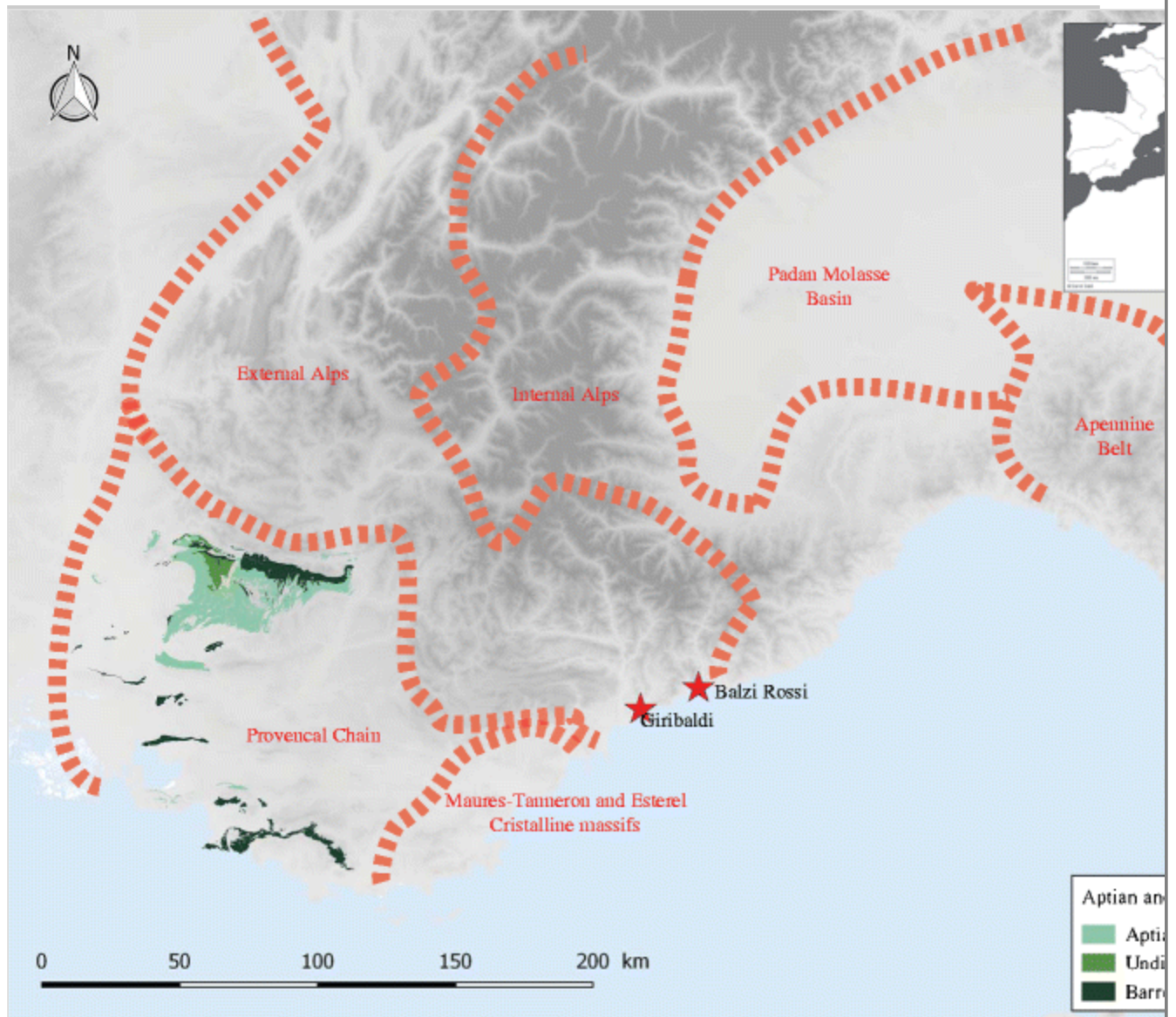
In the western Mediterranean area, Provence and Liguria are regions where these issues can be studied with thanks to a large set of archeological data and the specific setting of lithic resources. Indeed, the latter has a discrete distribution according to a mosaic of geological formations whose localization depends on successive and complex events and processes (Lemoine et al. 2008). Thus, chert suitable for knapping activities is available in a primary position within several structural units (Fig. 1). The structural, tectonic, and sedimentary processes that occurred during the Neogene are at the origin of the current distribution of siliceous formations and lithic resources. According to the ancient paleogeography and relief partitioning, successive dismantling of primary

deposits did not dramatically alter this macro-structuration of chert resource, which is of a great help for prehistoric sourcing.

Fig. 1

Simplified structural elements of the Liguro-Provençal arc and localization of Barremian and Aptian outcrops

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In such a context, Cretaceous limestones from the Provençal chains provide the most important chert resources of the region, as regard to their abundance as well as to their high quality for knapping, particularly blades. In this paper, we focus our attention on the so-called honey flints (Phillips 1980), the Barremo-Bedoulian cherts from the Urganian platform which formed during the Early Cretaceous and which are considered the most desirable, in a technical perspective, among the Barremo-Bedoulian resources (Binder 1998).

Several recent archeological studies revealed the significant role of these sources for long-distance transfers (by this term, we identify the different circulations modalities, e.g., trade or individual transport) that crossed the whole Provence region and reached Liguria as soon as the Proto-Aurignacian, c 40kY BCE (Before Common Era) (Porraz et al. 2010; Grimaldi et al. 2014). Current studies applied to the Late Upper Paleolithic highlight the continuation of such long-distance transfers for the Middle Gravettian c 25kY BCE (Santaniello 2016) and the Epigravettian sequence up to 9.5kY BCE (Tomasso 2014a, 2014b). On the contrary, the diffusion of these cherts to the North and the West is not documented so far, although there are rare mentions (Mével et al. 2014). Even if based on different socio-economic background, and even if the roots and evidences of networking highly differed from Neolithic ones (Binder and Perlès 1990), Upper Paleolithic chert sourcing has a key role for catching parts of the mobility systems at different scales in connection to environmental and cultural variations.

The question of “honey flint” diffusion is recurrent as far as Neolithic raw material procurement strategies, workshops, and networks are concerned in the northwestern Mediterranean. Indeed, the Barremo-Bedoulian cherts from Provence were intensively exploited and traded across Southern France and neighboring areas during the 6th and 5th millennium BCE (Binder 1998; Léa 2004). During the 4th millennium BCE in the context of Late Chassey culture, such cherts have been the object of a systematic heat treatment (Binder 1984; Léa 2005; Roqué-Rosell et al. 2011). At that time, this craft activity was at the origin of an extended network that reached Spain to the West and Central Italy to the East (Léa 2004). Archeological studies have recently improved the understanding of heat treatment processes (Roqué-Rosell et al. 2011; Schmidt et al. 2012, 2013; Delagnes et al. 2016; Milot et al. 2016). It is commonly assumed that these treatments aim to facilitate knapping and specifically pressure knapping. While empirical, this statement is shared by all researchers. It has also been demonstrated for other raw materials (i.e., silcrets; Mourre et al. 2010). On the other hand, heating treatment also improves the cutting edges efficiency of Barremo-Bedoulian knapped flints (Torchy 2013). Even though less than obsidian, the use of the Provence Barremo-Bedoulian cherts was intense during the Neolithic, at least of a similar range than cherts from the Italian Pre-Alps (Barfield 1990), the Gargano Promontory (Tarantini and Galiberti 2011), and the Pre-Balkan platform (Biagi and Starnini 2013).

More recently, Barremo-Bedoulian cherts from Provence have been intensively used for gunflint production and most of the Neolithic wastes were obviously exploited from modern times until the early twentieth century.

In the 1990s, thematic geological surveys have been organized by D. Binder to draw a general picture of chert resource in the southeastern France. Since 2008, this program has been reinforced for extending sampling and databases towards Liguria and Tosco-Emilian Apennine and second, for improving sourcing accuracy and reliability. In parallel, another collective project conducted by V. Léa is aimed to run high-resolution analysis of thermic behavior.

The current study synthesizes the available data and new methodological advances concerning the sourcing of Barremo-Bedoulian cherts. The latter are detailed, thanks to the two case studies dedicated to Upper Paleolithic and Neolithic contexts, namely the Fanciulli's cave at Balzi Rossi (Ventimiglia, Italy) (Tomasso 2014b) and the Giribaldi settlement (Nice, France) (Binder 2016) both in the Liguro-Provencal corridor (Fig. 1). The following descriptions focus on the characterization of primary sources, which is a critical step in sourcing methodology.

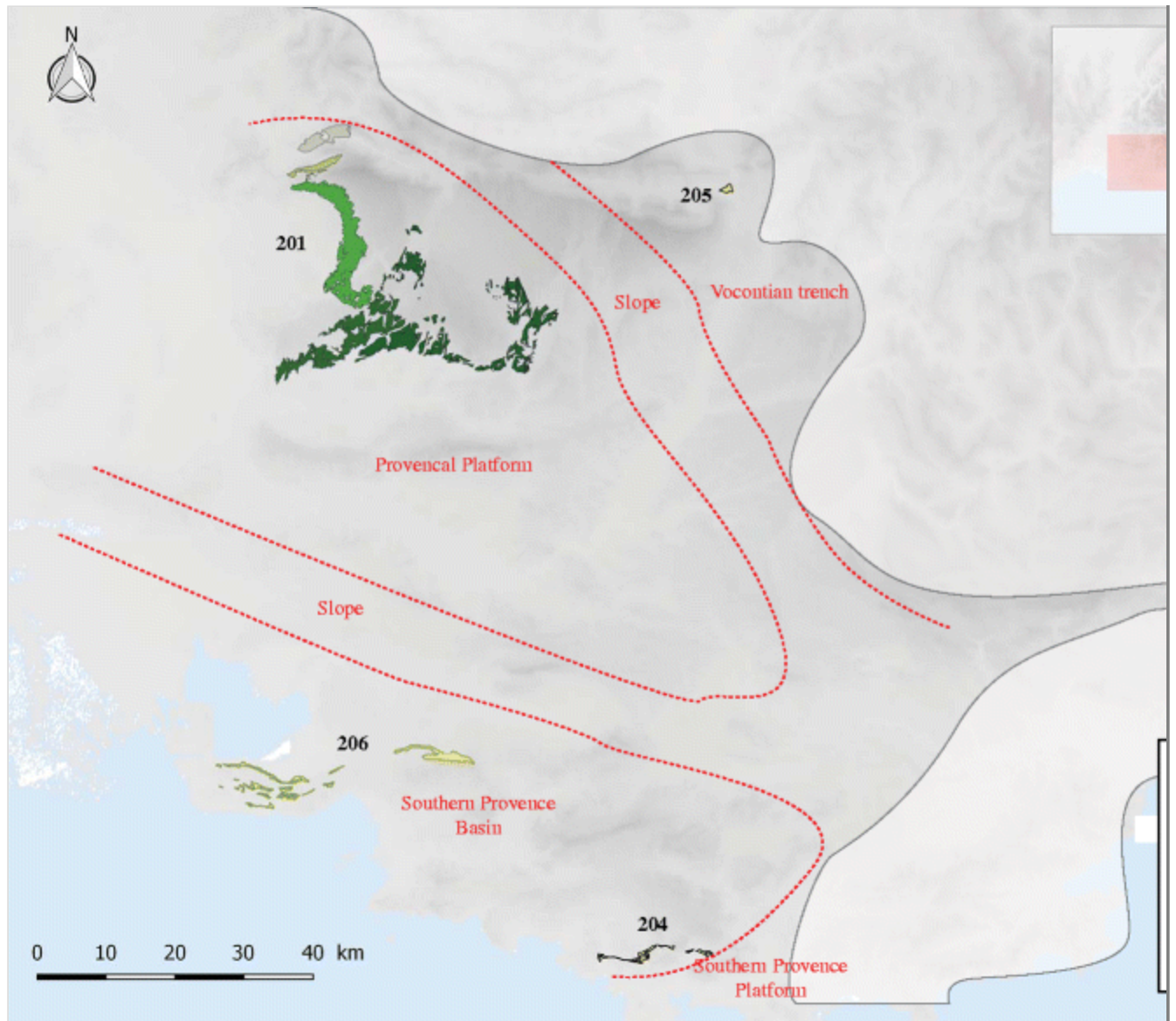
Material and methods

Geological context and previous characterizations

During the Early Cretaceous, the region of Provence was an open oceanic area whose depth increased towards the North where pelagic formations of the Vocontian basin spread (Fig. 2). The extension of the different environmental domains varied during the Berriasian and Barremian periods and the limestone deposits reveal clear paleogeographical differentiations (Rat and Pascal 1982; Cotillon et al. 1984; Moullade and Tronchetti 2004). Thus, four main domains are identified from the South to the North: the southern Provence platform, the southern Provence basin, the Provencal platform, and the Vocontian trench. The entire area displays significant lateral and vertical variations highlighted, thanks to the analysis of the micro-paleontological assemblages. For instance, the dominant foraminifera, namely *Orbitolinidae*, are progressively dominated by conic shapes at the end of the period (Cotillon et al. 1984).

Fig. 2

Paleogeographic structure of the Provencal chains area during the Bedoulian (from Moullade and Tronchetti 2004) and localization of the different families of cherts

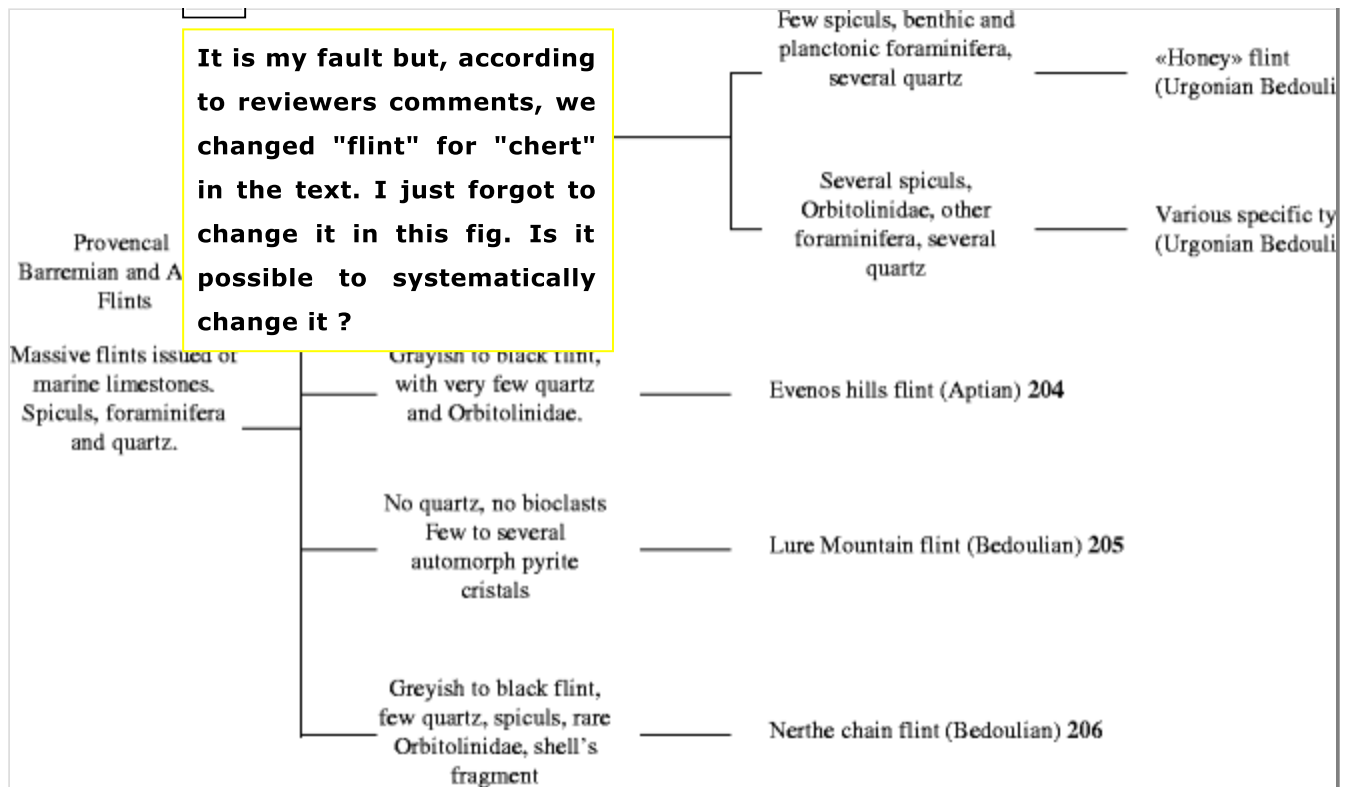


This paleogeographic frame is necessary for understanding most of the chert diversity and distribution among the Early Cretaceous layers (Tomasso 2014a; Tomasso et al. 2016). These cherts are associated with specific paleogeographic context. Consequently, they are easy to discriminate using classical petrographic proxies as texture, structure, and clasts (Tomasso 2014a; Tomasso et al. 2016). On this basis, we defined several families associated with the major outcrops domains (Fig. 3). In the South, the platform deposits provide cherts in the Nerthe chain (family 206) and in the Evenos hills (family 204). In the North, the Vocontian trench provides cherts in the Lure mountain (family 205).

Fig. 3

Schema of the main criteria to distinguish the principal types of Bedoulian cherts. See Tomasso 2014a for details





The Urgonian cherts (family 201) are located within the Provençal platform where they are specifically associated with the third term of the Urgonian facies (n5U3, Leenhardt 1883). Within this family, we distinguish several types according to the bioclasts (nature, proportion). This study is focusing on the type 201A, defined by the low preservation of bioclasts (less than 10%). They can be either yellows (those frequently called honey flint), grays, or even blacks. Unlike the other families of Bedoulian cherts, they are displayed in a wide zone including several massifs from the South to the North: the Vaucluse Mounts, the Ventoux, the Ventouret, and the Rissas (Blanc et al. 1975; Monier and Cavelier 1991). In the South, a first set is associated with the brachy-anticlinal of the Vaucluse Mounts, which has a NE-SW direction; its northern limit corresponds with a beam of faults (the Monieux fault) following the Nesque's Gorge. Here, chert is embedded in a thin-grained calcarenite, which constitutes the basal part of the n5U3 subset. In the North, the Ventoux' anticlinal shows some difference in terms of lithology and the U3 subset shows a stratigraphic evolution from biocalcarenes to calcilutites. There, chert is only present in the second petrofacies of this series, which is upside-down from the North to the South. Further to the North, the Urgonian deposits are lesser developed in Ventouret and the n5U3 subset is made of calcarenite. Finally, in the Rissas, chert is associated with calcilutites.

The accuracy of the Urgonian chert sourcing is a critical point for designing prehistoric procurement patterns in this broad region. First, the environmental and surrounding rock conditions determine their lithology, and further, their accessibility, the method of extraction, and the related human behavior.

Moreover, the selection of a specific outcrop unlike the gathering of cherts coming from several distinct points over the territory result from contrasted provisioning strategies we aim to distinguish.

For this purpose, several studies have been previously carried out to attempt the characterization of these cherts.

M. Barbier (Barbier 1996) tried to classify these materials according to micro-paleontological and mineralogical criteria such as the dominant form of silica, the accessory minerals, and the presence of carbonates. Thanks to her observation of chert's host rock samples and associated thin sections, she was able to identify their typical environments of formation. Nevertheless, she was unable to distinguish these samples because of the differences in the relative abundance of fossil species observed between the chert and its corresponding host rock.

AQ3

Pioneer elemental analyses have been performed on a large set of geological chert samples from the Provence region by M. Lemarquand-Blet (Blet 1999; Blet et al. 2000) using destructive (liquid ICP-MS, ARNC) and minimally destructive techniques (LA-ICP-MS). Her study has shown that the analysis of minor elements was unable to characterize the Bedoulian chert meaningfully, according to previous work demonstrating that the variability was very high (i) at the geological stage scale for minor elements (Rio 1982) and (ii) at the nodule scale for trace elements (~~Aspinall et al. 1981, 1976~~, [Aspinall et al. 1981, 1976](#)). However, some chemical signatures have been obtained for a few types of Bedoulian cherts, depending on elemental enrichments occurring through post-depositional processes.

According to these studies, Barremo-Bedoulian Urgonian cherts can be defined as massive cherts with a mixed siliceous matrix of chalcedony and crypto- to microcrystallin quartz and chalcedony. Their color is essentially due to iron oxydes. Bioclasts, initially dominant in the calcareous rock, are intensively altered and are rare in the cherts. They consist of spicules, echynoderms, foraminifera (*Orbitolina*, *Miliolida*, *Textularida*, *Glomospira*), lamellibranch, bryozoans, and ostracodes. Several detrital quartz can be observed associated with rare pyrite and zircon. Some minor elements are present in very low concentration, frequently close to the limit of detection of the used methods.

In this frame, highlighting an intra-formation variability remained the most challenging because of an apparent homogeneity which contrasts the diversity of its paleoenvironments and the correlated outcrop areas they came from. Recent

studies carried out in other regions (Fernandes 2012; Delvigne 2016) suggest that the apparent uniformity is artificial and the consequence of post-genetic evolutions is inducing geochemical processes at the origin of transformations of the mineral structure and alterations of the bioclastic component (Fernandes et al. 2016).

AQ4

Outcrop sampling

Our study focuses on the third term of the Urgonian set (n5U3). Samples were collected in different sites. Sampling has been organized in different sites, following the mapping realized by the French Bureau de Recherches Géologiques et Minières (Blanc et al. 1975; Monier and Cavelier 1991). The samples have been encoded according to (i) the geological map number, (ii) the collection point number, and (iii) the sample number. All chert nodules thus received individual identifiers.

We prospected a total of 92 different Barremo-Bedoulian outcrops among which 53 belong to the n5U3 subset. Not all of them provide suitable cherts and not all of them provide the type 201A; 52 samples of chert of the type 201A coming from 21 distinct outcrops were identified. Among them, 32 thin sections were cut and observed while detrital quartz grain analysis was performed on 33 samples. In addition, the whole 256 samples from Barremo-Bedoulian outcrops were described at the mesoscopic scale and 34 thin sections were cut and observed among the other types of Barremo-Bedoulian cherts.

Characterization method

Our characterization method takes into account the *chaîne évolutive* (Fernandes 2012) of the cherts, from its genesis to its discovery within archeological deposits, i.e., the successive events that occurred in the raw material formation and transformation processes. The related qualitative and quantitative analyses are multi-scalar: (i) macroscopic; (ii) mesoscopic, i.e., observations of dry and wet samples with a stereomicroscope (magnifications $\times 40$ to $\times 200$); and (iii) microscopic, i.e., observation of thin sections with a petrographic microscope at magnifications $\times 50$ to $\times 100$ LED-polarized light. These observations focused on the identification of the most discriminant proxies which enable to distinguish the transmitted characteristics from the host rock and those that developed along times. They are based on the analysis of (i) mineral phases, (ii) newly formed elements, and (iii) surface conditions. Then, the consideration of diagenetic, epigenetic and post-deposition mechanisms, and features enables an accurate determination of exploited geomaterials.

Running this general protocol shows that most of the exploited chert did acquire an evolved appearance. Post-genetic transformations induced a homogenization of the matrix, which masks the original petro-fabric.

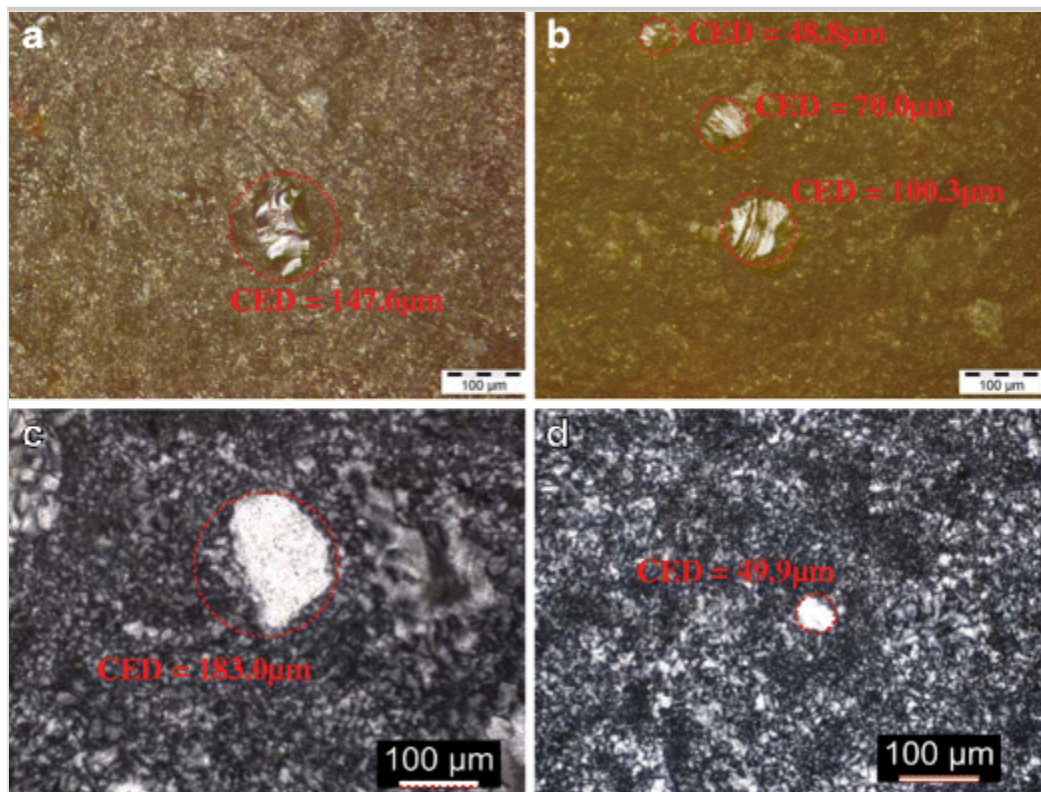
Then, for this study, we add a new semi-quantitative and non-invasive method of characterization based on the analysis of detrital quartz, which constitutes the more stable chert component.

The detrital quartz analysis

While detrital quartz grains are visible macroscopically, their identification is only accurately possible with a metallographic microscope, by direct observation on flake's surface with reflected light. At this scale, the quartz grains are perfectly identifiable and measurable (Fig. 4a, b). Thin sections were used to confirm their identification (Fig. 4c, d).

Fig. 4

Quartz in Urgonian cherts. **a, b** Direct observation with reflected light on flakes surfaces. **c, d** Thin section observation, polarized light microscopy (Samples: **a** 941.19.P15; **b** 915.93.03; **c** 916.01.03; **d** 915.63.P36)



The observation of the quartz grains has been performed on the flake's surfaces with a reflection microscope (Olympus) at a magnification of $\times 200$. For each sample, we have considered a surface of 1 cm^2 where each quartz grain has been systematically identified. Each quartz grain was drawn using Olympus Image

Analysis Software. Their circular equivalent diameter (CED; i.e., the diameter of a circle that could exactly contain the grain), their factor of form, their convexity, the surface of each grains, and the number of grain identified were considered.

The equivalent diameter is classically used as a reference for granulometric studies. In our case, we have considered two categories of grain, respectively, under and over 1/16 mm (62.5 μm). This limit has been chosen per the classical distinction between lutites and arenites, regarding the grain size distribution of sedimentary deposits, and because of being significant, regarding the granulometry of quartz in the Urganian cherts. The grain size distribution index (I_g) is defined as the proportion of grains inferior to 1/16 mm ($d_{<1/16}$) respect to grains superior to 1/16 mm ($d_{>1/16}$): $I_g = \frac{d_{<1/16}}{d_{>1/16}}$.

AQ5

Results and discussion

Description of geological samples

The macroscopic aspects of Urganian chert result are very homogeneous. Most of the samples are deep yellow to strong yellow, sometimes grayish. Some have orange shades. They are semi-translucent and bright.

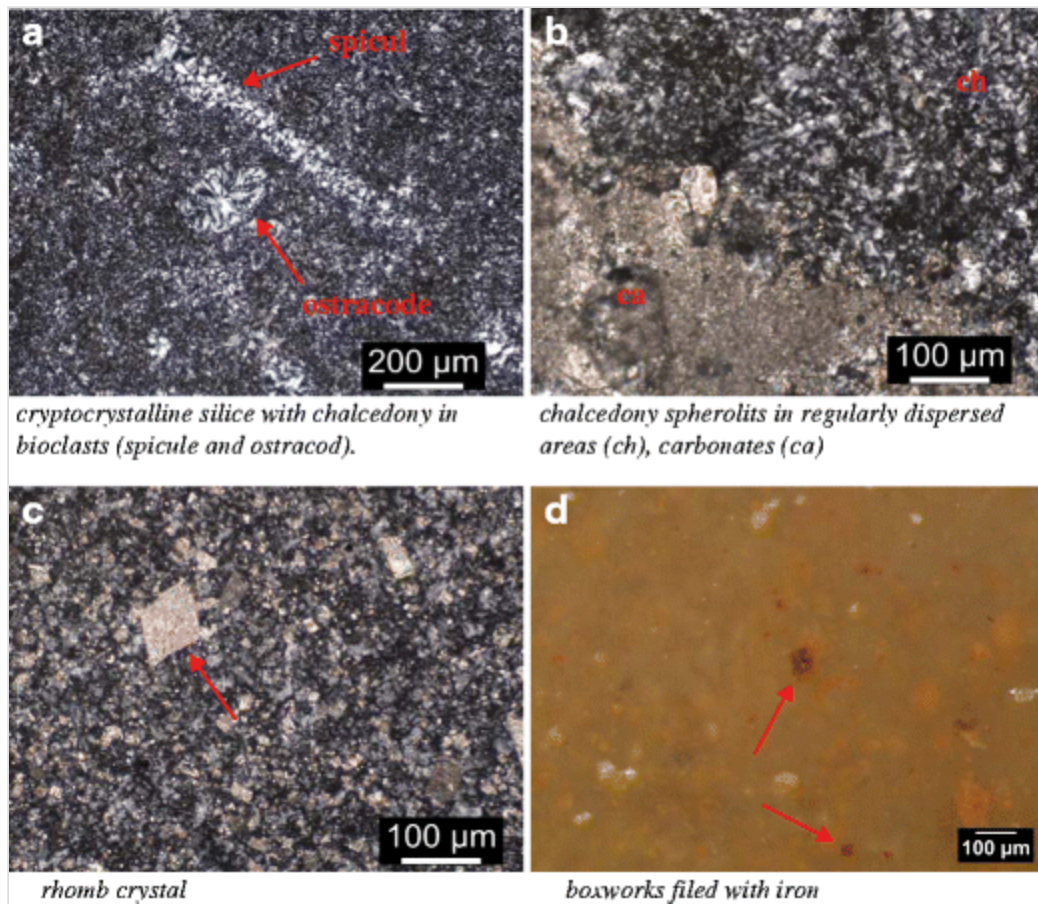
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Matrix and detrital component

In thin sections, the siliceous matrix appears predominantly composed by a cryptocrystalline silica with chalcedony in bioclasts (Fig. 5a), chalcedony spherules in regularly dispersed areas, carbonates (Fig. 5b) and rhombs crystals (Fig. 5c), or boxworks filled with iron (Fig. 5d). Detrital component is low, from 1 to 5 to 10%. Some samples ($n = 9$) with higher proportion of detrital elements (from 20 to 30%) are close to the 201B1 type. Their sorting varies from very good to moderate.

Fig. 5

Matrix (Samples: **a** 941.01.P22; **b** 915.65.P30; **c** 917.02.#; **d** A3-941-22-P5)



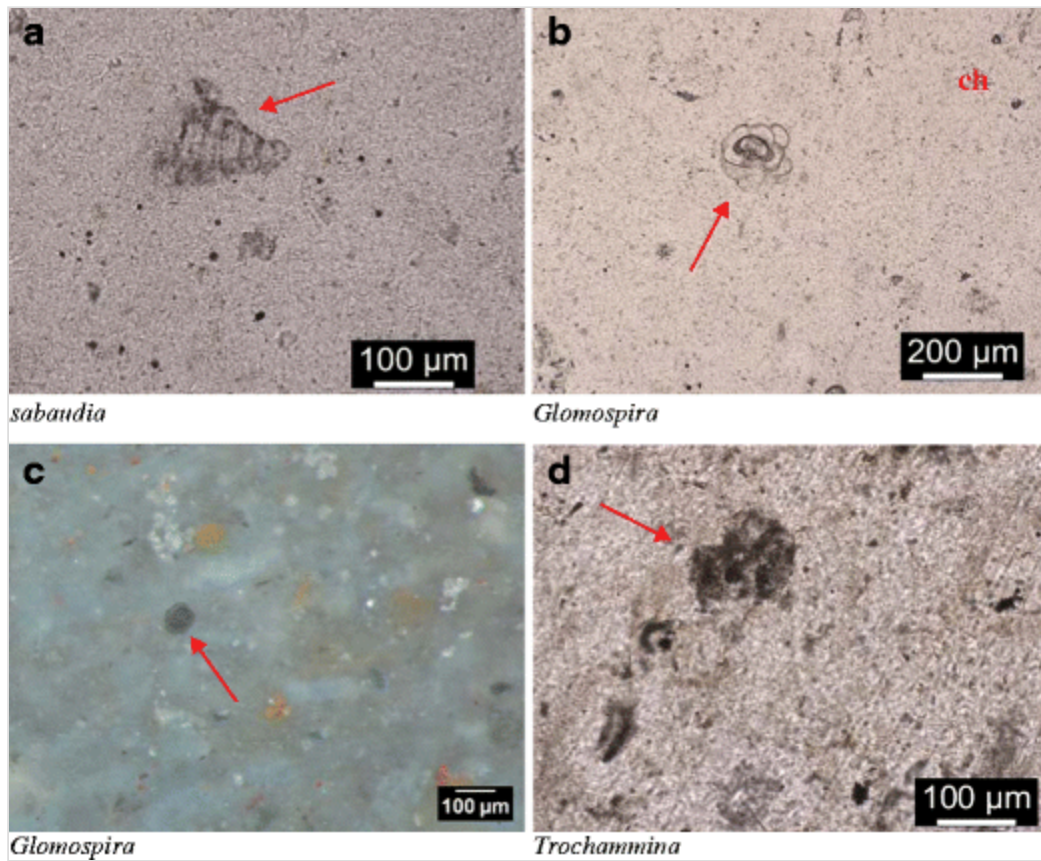
Bioclasts

All samples are characterized by the presence of thin and elongated monoaxones spicules (Fig. 5a) whose preservation varies from one sample to another. The range of their dimensions is wide, from 200 µm to 1 mm, more rarely up to 5 mm. Fragments of bryozoans, crinoids, and echinoids are also present in some samples with a dimension from some micrometers up to 5 mm.

The other bioclasts, especially Foraminifera, are geographically limited. Their repartition seems to support a contrast between the north and the south of the outcropping area. *Sabaudia* (Fig. 6a), *Nezzazata*, and *Globigerinelloididae* are more frequent in the south. *Glomospira* (Fig. 6b, c), *Trochammina* (Fig. 6d), *Tritaxia*, *incertae sedis*, and undetermined algae are frequent in the north. Biserial foraminifera are present in both southern and northern outcrops.

Fig. 6

Foraminifera (Samples: **a** 941.01.P22; **b** 915.66.P29; **c** A3-941-22-P5; **d** 941.18.P13B)



AQ7

Detrital quartz component

We tested several characters for the grains such as factor of form and convexity. Both reveal a global homogeneity, contrary to the CED. As shown in Table 1, the convexity and the factor of form ~~result~~ are very homogeneous between the Rissas and the Vacluse Mounts (respectively, the northern and southern extremities of outcrops area) with respectively 0.2 and 2.3% of variation from one domain to the other on the medians. By contrast, the CED shows a variation of 11.2% on the medians between the two areas.

Table 1

Differential of values for CED, factor of form, and convexity between the two oppos considered areas (Rissas and Vacluse Mounts)

	Rissas AQ10			Vacluse Mounts			Dif	
	Factor of form	Convexity	CED	Factor of form	Convexity	CED	Factor of form (%)	C
Minimum	0.20	0.75	11.69	0.28	0.69	9.32	36.4	–
Q1	0.66	0.95	33.46	0.63	0.95	32.03	– 3.8	–

	Rissas AQ10			Vaucluse Mounts			Dit	
	Factor of form	Convexity	CED	Factor of form	Convexity	CED	Factor of form (%)	C
Median	0.72	0.98	51.95	0.70	0.98	46.15	- 2.3	-
Q3	0.77	0.99	70.45	0.76	0.99	60.76	- 1.3	-
Maximum	1.74	1.98	169.90	0.91	1.00	136.95	- 47.6	-
Average	0.74	1.05	53.69	0.69	0.96	48.47	- 6.2	-
Standard deviation	0.19	0.28	23.84	0.10	0.04	21.39	- 48.4	-



AQ8

AQ9

In order to identify a relevant surface of observation, we tested the variation of values in a sample for different measured areas. Our results show that no major variation can be recorded beyond a surface of 0.5 cm² (Table 2). Indeed, up to this area, variations can exceed 35% for critical values (I_g , average and median). For areas exceeding 0.5cm², only a minor variation could be noticed with a maximum value around 10% for the I_g and 5% for average and median.

Table 2

Variation of values in relation with the analyzed areas

Analyzed area	Number of quartz				Grain size			
	Total	< 1/16 mm	> 1/16 mm	I_g	Average	Standard deviation	Min	Q1
0.07	70	42	28	1.5	61.2	31.0	35.3	43.0
0.14	77	42	35	1.2	66.0	29.1	35.3	42.7
0.21	94	47	47	1.0	72.9	28.4	37.6	44.4
0.28	81	42	39	1.1	69.3	27.3	37.6	43.4
0.36	85	45	39	1.1	68.3	25.9	37.6	45.9
0.43	96	59	38	1.6	61.1	26.8	23.3	41.9
0.50	93	56	36	1.6	62.8	27.5	23.3	42.9
0.57	97	53	44	1.2	62.8	27.1	22.4	42.9

Analyzed area	Number of quartz				Grain size			
	Total	< 1/16 mm	> 1/16 mm	<i>I</i>	Average	Standard deviation	Min	Q1
0.64	111	61	50	1.2	62.0	26.6	12.8	42.9
0.71	120	68	52	1.3	59.4	25.6	12.8	41.2
0.78	117	67	50	1.3	58.4	25.0	12.8	41.5
0.85	128	70	58	1.2	60.4	24.9	12.8	40.5
0.92	134	72	63	1.1	63.1	26.2	12.8	39.5
0.99	134	70	63	1.1	61.4	27.1	8.0	39.0
1.07	141	73	68	1.1	59.9	26.8	8.0	37.9
1.14	165	90	76	1.2	56.2	28.6	8.0	32.8
1.21	172	97	75	1.3	54.9	28.1	8.0	32.6
1.28	171	97	74	1.3	54.7	28.3	8.0	32.6

A critical matter was to test the variability of grain size inside a single nodule to define its homogeneity. We then aimed to test two samples coming respectively from the Rissas at the extreme north of the outcrop area (915-61-P40) and the Vaucluse Mounts at the south (941.21.P9). For each of them, we conducted three independent analyses in different parts of the nodules from the subcortical zone towards the block core. Results (Table 3) show a relative variability in measured values especially for limits (maximum and minimum sizes) and counts. The median shows the best homogeneity (respectively, 19 and 5% of variability) and the average remains globally homogeneous, too (respectively, 21 and 13% of variability). Whenever the I_g shows comparable variations (around 30% of variability, from 2.1 to 2.6 and from 0.7 to 0.9), it remains very different from one sample to the other.

Table 3

Intra-nodular variability regarding quartz grains

Sample	Density (cm ⁻²)				Grain size			
	Total	< 1/16 mm	> 1/16 mm	I_g	Average	Standard deviation	Min	Q1
915.61-P40	90	38	52	0.7	69.0	22.2	16.5	54.
	119	53	66	0.8	65.4	23.1	20.3	49.

Sample	Density (cm ⁻³)				Grain size			
	Total	< 1/16 mm	> 1/16 mm	<i>I</i>	Average	Standard deviation	Min	Q1
	137	66	71	0.9	65.8	23.8	17.1	50.
941.21.P09	73	49	24	2.1	54.2	19.6	15.8	38.
	90	61	29	2.1	54.3	16.6	21.6	43.
	116	84	32	2.6	54.7	17.3	24.4	42.

The microscopic semi-quantitative analysis of quartz grains offers more accurate data and reveals three groups of samples (Table 4). Their characteristics are summarized in Table 5.

Table 4

Quartz analysis of Bedoulian cherts (*Murs/**201B1)

Sample	Density (cm ⁻²)				Grain size			
	Total	< 1/16 mm	> 1/16 mm	<i>I_g</i>	Average	St. dev.	Min	Q1
915.65-P31	3	3	0	–	55.9	4.8	50.4	54.4
941.02-P19	4	4	0	–	32.4	12.6	20.7	22.7
915.65-P32	5	5	0	–	42.4	11.7	27.4	33.9
915.63-P37	5	4	1	4.0	35.7	16.2	23.9	29.0
915.65-P30	7	7	0	–	32.5	9.4	23.3	25.9
915.64-P35	8	5	3	1.7	49.2	18.4	22.8	33.0
915.63-P36	8	8	0	–	35.0	8.6	20.7	30.1
915.83-P50	13	7	6	1.2	51.3	24.0	22.5	31.0
915.61-P58	14	11	3	3.7	45.5	23.8	18.8	29.7
915.61-P41	15	5	10	0.5	65.3	21.5	26.4	50.5

Sample	Density (cm ³)				Grain size			
	Total	< 1/16 mm	> 1/16 mm	<i>I</i>	Average	St. dev.	Min	Q1
915.83-P46	17	8	9	0.9	63.95	22.81	24.58	49.96
915.61-P59	21	17	4	4.3	49.5	13.1	31.5	38.8
915.76-P53	38	10	28	0.4	68.1	19.1	31.2	59.6
915.61-P40	90	38	52	0.7	69.0	22.2	16.5	54.4
915.61-P40	119	53	66	0.8	65.4	23.1	20.3	49.7
915.62-P39	89	42	47	0.9	61.5	21.7	17.6	43.5
915.61-P40	137	66	71	0.9	65.8	23.8	17.1	50.0
915.61-P40	73	37	36	1.0	60.3	18.9	13.8	47.7
915.62-P38	125	66	59	1.1	58.9	18.3	21.6	47.7
941.01-P20	162	94	68	1.4	56.1	28.5	8.0	32.5
941.22-P05	72	42	30	1.4	53.2	22.5	14.2	35.0
941.01-P22	53	33	20	1.7	57.1	27.6	13.1	36.5
941.22-P06	47	31	16	2.0	56.9	18.7	24.7	45.2
941.21.P09	73	49	24	2.1	54.2	19.6	15.8	38.9
941.21.P09	90	61	29	2.1	54.3	16.6	21.6	43.3
941.19-P14	143	98	45	2.2	51.1	20.8	17.7	34.4
941.10-P23**	98	70	28	2.5	49.8	19.0	20.2	34.6
941.21.P09	116	84	32	2.6	54.7	17.3	24.4	42.7
941.19-P15	101	73	28	2.6	46.0	21.9	13.8	26.4
941.18-P16*	56	44	12	3.7	45.33	22.80	14.10	25.11

Sample	Density (cm ⁻²)				Grain si			
	Total	< 1/16 mm	> 1/16 mm	<i>I</i>	Average	St. dev.	Min	Q1
941.21-P09	126	102	24	4.3	44.0	18.9	10.7	27.8
941.27-P26	122	101	21	4.8	45.1	17.2	17.0	31.8
941.22-P04	195	164	31	5.2	45.8	19.4	16.0	29.9
941.18-P17*	100	84	16	5.3	47.2	21.4	12.3	32.2
941.01-P21	60	52	8	6.5	44.5	16.2	17.3	32.1
941.19-P13	101	89	12	7.3	43.3	15.5	17.5	31.1
941.20-P12	90	80	10	7.7	41.3	17.0	15.8	28.2
941.18-P18*	147	131	16	8.3	38.2	17.3	9.3	24.5
941.22-P07	143	129	14	9.3	42.8	15.1	15.7	30.9

Table 5

Synthesis of the granulometric classification of the Bedoulian cherts

Type		201A1	201A2	201A3
Density of quartz (cm ⁻²)	Minimum	3.0	38.0	47.0
	Maximum	21.0	137.0	195.0
	Average	10.0	95.9	104.8
<i>I_g</i>	Minimum	0.5	0.4	1.4
	Q1	1	0.8	2.1
	Median	2	0.9	3.2
	Q3	4.2	1.0	5.6
	Maximum	10	1.1	9.3
	Average	3.0	0.8	4.1
	Standard deviation	3.6	0.2	2.5

Type		201A1	201A2	201A3
Median size	Minimum	30.1	59.6	34.9
	Maximum	72.4	66.6	56.7
	Average	54.7	63.7	47.7
Average size	Minimum	32.5	53.2	38.2
	Maximum	69.0	65.8	56.9
	Average	58.9	59.0	47.3
Sample number		12	7	20

To test the consistency of these groups, we have compared the CED of the population of individual quartz per groups (Table 6). We considered three criteria: (a) density; (b) I_g ; and (c) individual quartz grains CED (Fig. 7).

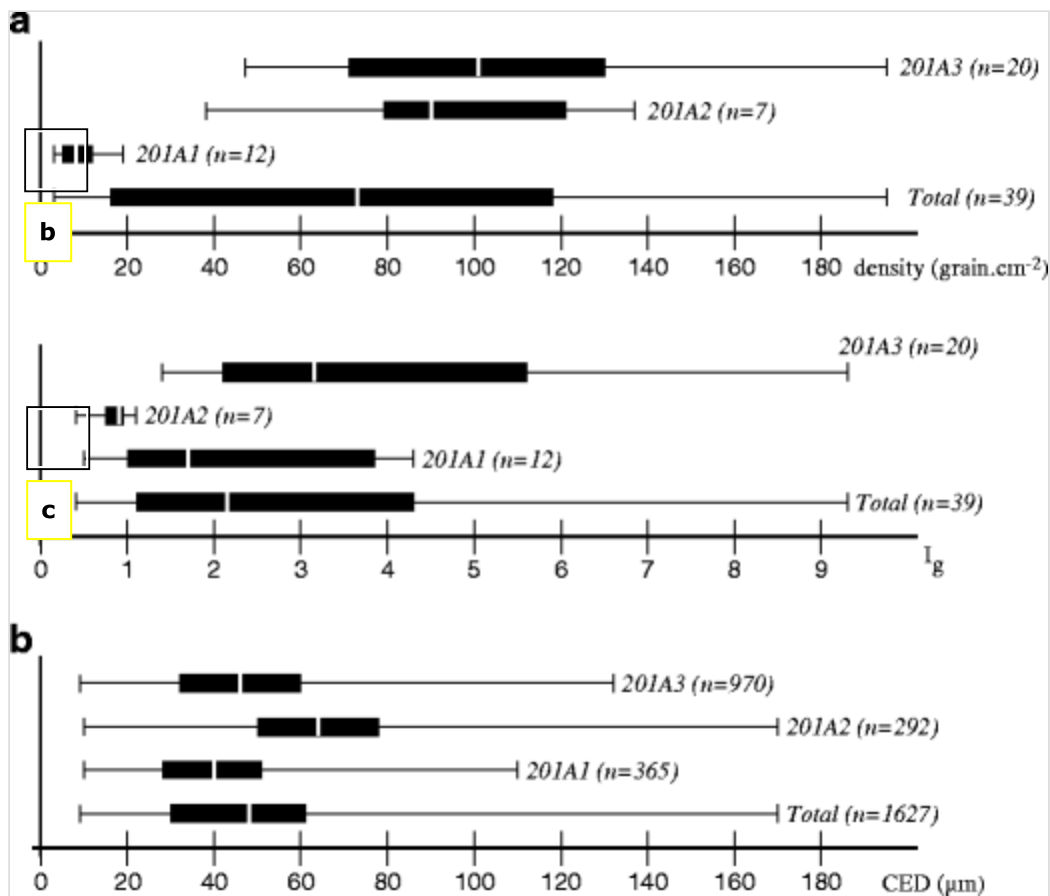
Table 6

CED values (μm) of the individual quartz grains by groups

Group	Total	201A1	201A2	201A3
<i>n</i>	1627	365	292	970
Average	50.11	42.90	63.26	48.86
Standard deviation	22.24	18.83	22.47	21.73
Minimum	9.3	11.69	13.75	9.32
Q1	32.6	27.72	47.91	32.12
Median	47.6	40.41	63.90	46.52
Q3	64.1	54.61	77.79	61.55
Maximum	169.9	111.65	169.90	136.95

Fig. 7

~~Boxplot. a I_g per samples analyzed and b CED of individual quartz grouped by types~~ Boxplot. (a) density of detrital quartz grains per semplaes (b) I_g per samples analyzed and (c) CED of individual quartz grouped by types



Group 1 is composed of 12 samples exhibiting few detrital quartz (less than 21 grains cm^{-2}). Because of the low quantity of grain, the I_g value is of low relevance. The quartz grains CED are relatively low and the interquartile range (from 27.7 to 54.6 μm) is the lowest of the three groups.

Group 2 is composed of 7 samples. I_g is very homogeneous (0.4 to 1.1). Densities are variable, with an interquartile range from 81 to 102 grains cm^{-2} . The quartz grains CED vary in a wide range with an interquartile range (47.9 to 77.8 μm) higher than the two other groups.

Group 3 consists in 20 samples. Their I_g values (1.4 to 9.3) are the highest of the three groups and the interquartile range (2.1 to 5.6) shows a relative heterogeneity. The densities are comparable to those of the group 2 whenever the interquartile range (47 to 101 grains cm^{-2}) is slightly higher. The quartz grains CED appear clearly lower than the group 2 but are comparable with the group 1.

Classification

The semi-quantitative analysis of detrital quartz shows the existence of three groups of cherts (Table 7). Globally, these groups show a north-south repartition (Fig. 8). The Ventoux that forms an intermediary domain introduces some uncertainties. The type 201A2 is exclusively associated with the Rissas while the two others are respectively associated with the northern (201A1:

Rissas and Ventoux) and the southern (201A3: Vaucluse and Ventoux) parts of the outcropping area. This north-south repartition is supported by the bioclastic component. *Incertae sedis*, *Glomospira*, and *Trochamina* are associated with northern outcrops and types 201A1 and 201A2. *Sabaudia*, *Nezzazata*, and *Globigerinelloididae* are associated with the southern outcrop and with the type 201A3 (Fig. 8).

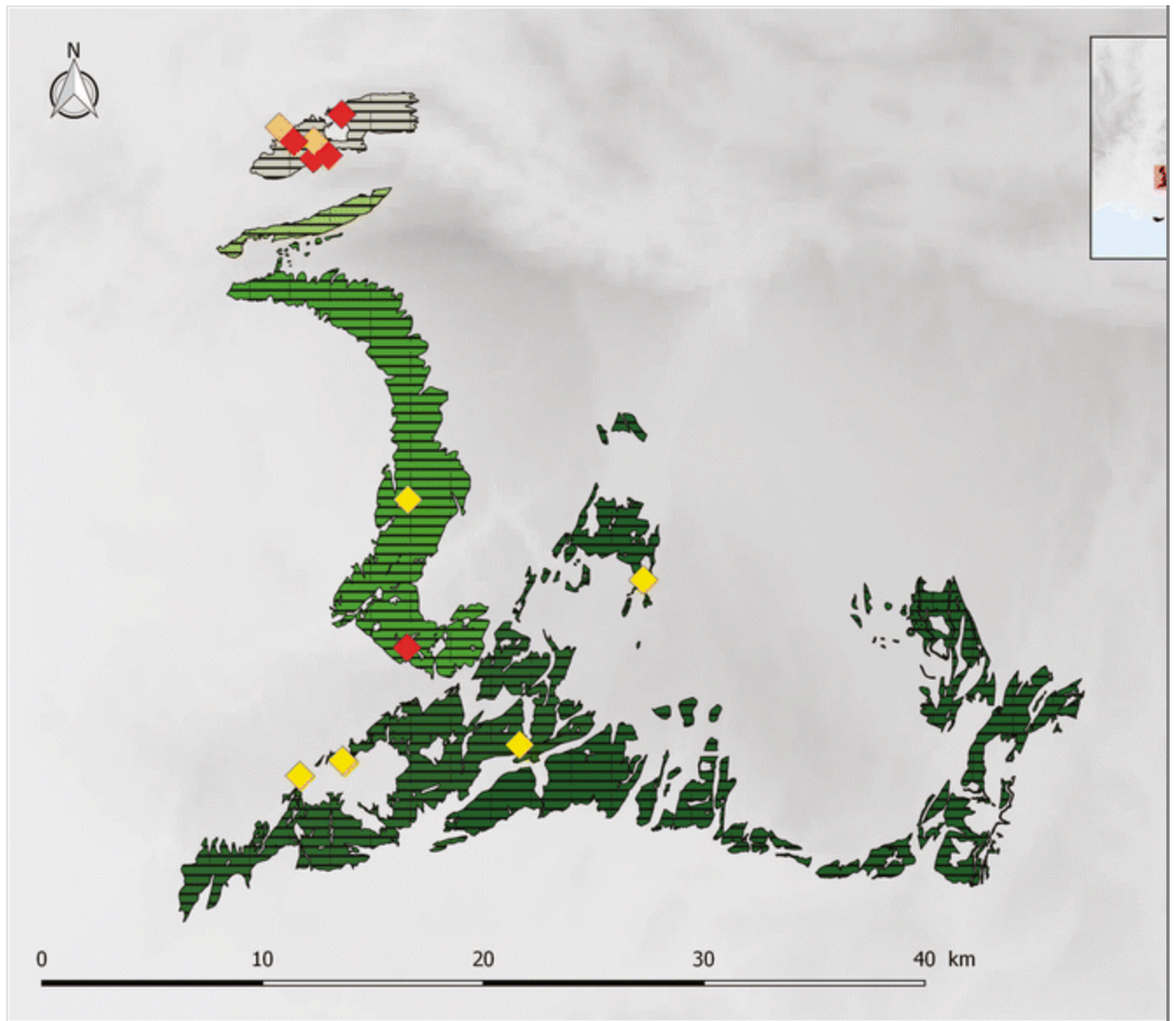
Table 7

Definition of the three types of Urgonian cherts and location of the outcrops

Type AQ12	201A1	201A2	201A3
Detrital quartz component	< 21 quartz cm ⁻²	> 38 grains cm ⁻²	
		$I_g < 1.1$	$I_g > 1.4$
Most characteristic bioclast	Incertae sedis, <i>Glomospira</i> , and <i>Trochamina</i>		<i>Sabaudia</i> , <i>Nezzazata</i> , and <i>Globigerinelloididae</i>
Outcrop's area	Rissas and Ventoux	Rissas	Vaucluse Mounts and Ventoux

Fig. 8

Repartition of each group among the Bedoulian outcrops



AQ11

Archeological application

The Urgonian chert in the Epigravettian layers of the Grotta dei Fanciulli (Ventimiglia, Italy)

The Fanciulli's cave belongs to the well-known Balzi Rossi complex close to the French border at c. 170 km southeast to the closest in situ Urgonian chert sources. Albeit the main excavations were performed in the early twentieth century, the site is still to be considered as one of the major prehistoric sites of northwestern Italy due to its successive Upper Paleolithic occupations from the Aurignacian up to the Late Epigravettian. Indeed, recent studies provided new results concerning technical systems, territories, and resource management (Tomasso 2014b; Santaniello 2016; Tomasso and Porraz 2016).

A set of 33 artifact samples (Table 8) has been selected from the Epigravettian layers (layers 1 to 5) which are the best known at this time. This sampling reflects the entire variability estimated at the mesoscopic scale. Non-altered as

well as altered pieces (with patina, desilicification) have been selected to appreciate the effects of alteration on our observations. Largest flat flakes have been favored to facilitate the observations.

Table 8

Sample selection from Ventimiglia-Fanciulli cave (Tomasso 2014a, Tomasso 2016)

Layer	Attribution	Total Nb. Bedoulian cherts	Selected samples
1	Late Epigravettian (ER3a)	20	6
2	Early or Late Epigravettian	5	2
4	Early Epigravettian (EA3)	54	18
5	Gravettian/Early Epigravettian (EA1)	88	6
Total		167	33

Among the selected samples, patina induces major variations regarding the macroscopic aspect; in global view when developed, patina tends to make bioclasts more visible. We also notice differences in relation with the raw material itself. A subset of the sample yielding many rhombohedral boxworks and orange color is characterized by the richness in bioclasts. Another subset, with pale yellow color, rarely provides identifiable bioclasts. It is not yet possible to define precise groups within this diversity.

AQ13

The semi-quantitative quartz grain analysis (Table 9 and Fig.9) has been crossed with other observations. A first set of 22 pieces belongs to the type 201A1 with less than 21 quartz cm^{-2} . While of low consistency, the I_g value of these pieces could support this attribution. However, the quartz grains CED are clearly too high and are comparable to those of the type 201A2 among the geological samples. In addition, the identification of *Incertae Sedis* (EnfD-905), *Glomospira*, and *Trochamina* (EnfE-236) supports the northern origin of these cherts.

Table 9

Quartz analysis of Fanciulli's cave samples

Sample	Density (cm^{-2})				Grain size				
	Total	< 62.5 μm	> 62.5 μm	I_g	Average	St. dev.	Min	Q1	Media

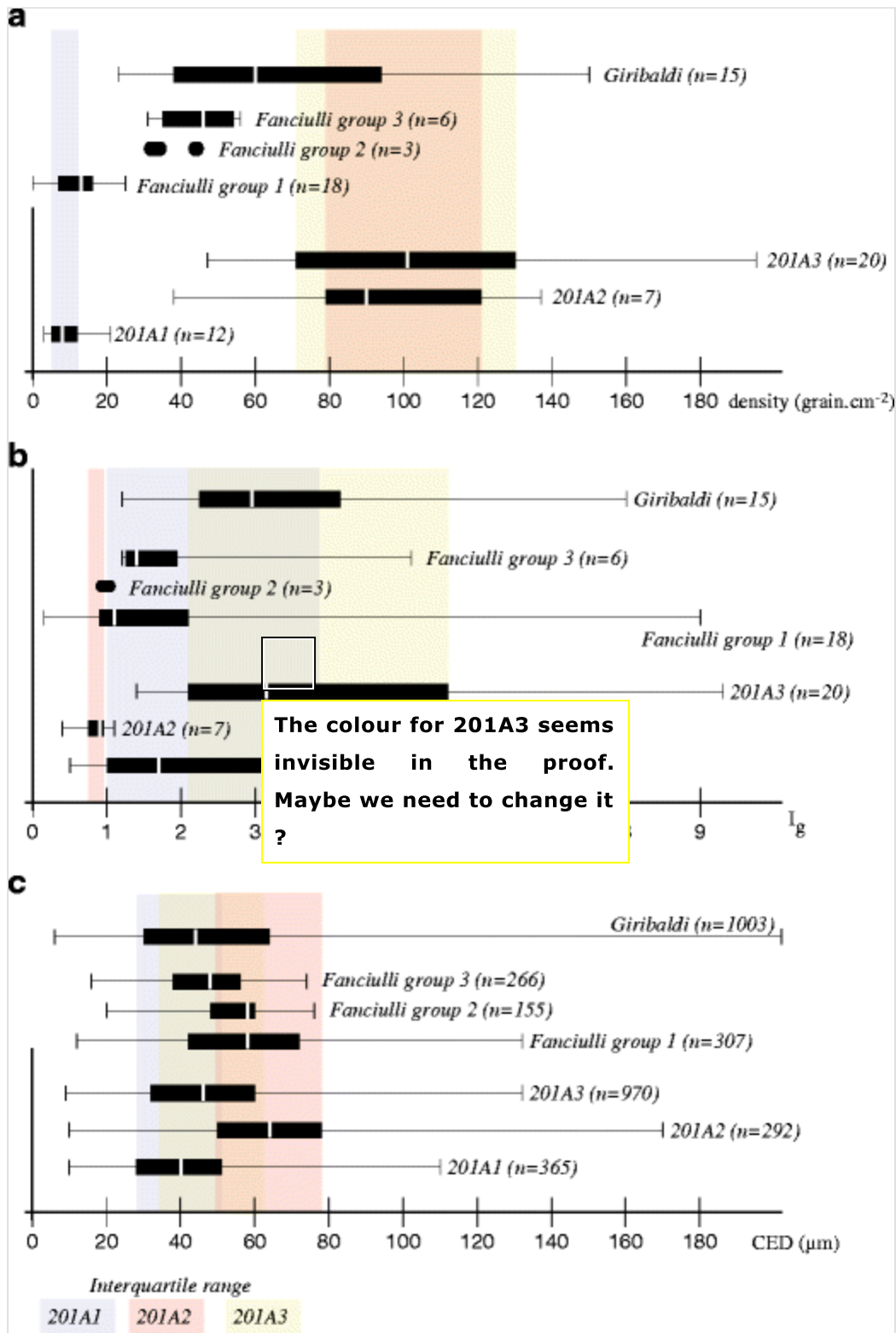
EnfD-095	0	0	0	–	–	–	–	–	–
EnfF-303	1	1	0	–	28.2	–	–	–	–
Enf1-475	4	4	0	–	38.9	16.1	15.5	34.9	44.8
EnfE-038	5	5	0	–	31.5	13.2	15.7	24.1	29.4
EnfE-113	5	2	3	0.7	70.4	10.2	57.8	61.4	74.4
EnfE-003	6	3	3	1.0	51.1	21.0	30.0	33.4	49.6
EnfC-012	10	9	1	9.0	44.2	11.7	23.2	38.2	41.5
Enf1-481	10	5	5	1.0	61.0	16.2	30.4	50.2	62.2
Enf1-476	13	7	6	1.2	65.7	17.5	41.5	50.5	59.4
EnfE-166	13	3	10	0.3	70.9	10.4	52.4	63.4	70.7
Enf1-490	15	9	6	1.5	62.2	24.6	32.4	44.0	53.1
EnfE-141	15	7	8	0.9	63.0	15.8	22.8	47.0	55.8
EnfF-302	15	8	7	1.1	61.8	23.4	18.7	50.5	62.2
EnfE-369	16	11	5	2.2	51.2	37.6	15.5	27.8	39.5
EnfF-303	16	12	4	3.0	52.7	23.5	13.6	36.9	47.2
EnfE-006	18	12	6	2.0	52.8	15.5	26.9	43.1	52.6
EnfE-120	18	4	14	0.3	70.5	17.6	27.9	64.3	73.6
EnfE-236	18	8	10	0.8	60.7	16.6	30.3	50.7	63.6
EnfF-174	18	13	5	2.6	55.5	17.4	26.6	42.9	56.1
EnfE-173	21	16	5	3.2	53.7	15.8	22.8	47.0	55.8
Enf4-003	25	10	15	0.7	67.4	21.5	31.2	48.9	69.3

EnfE-005	25	14	11	1.3	57.4	16.2	30.2	47.6	59.4
Enf4-002	34	16	18	0.9	63.4	15.1	33.9	54.7	63.4
EnfC-110	45	22	23	1.0	62.4	19.9	25.2	45.3	66.0
EnfE-386	36	19	17	1.1	61.4	20.7	21.6	47.9	60.7
Enf4-022	31	18	13	1.4	58.1	17.6	28.7	45.7	59.7
Enf4-004	40	24	16	1.5	57.3	18.3	27.3	43.3	53.6
EnfF-310	54	33	21	1.6	54.8	22.8	17.9	35.0	52.4
EnfD-001	52	32	20	1.6	60.6	16.7	35.0	48.4	59.0
Enf4-001	33	21	12	1.8	58.4	16.2	24.2	50.3	56.7
EnfE-247	56	47	9	5.2	45.0	19.2	17.3	29.4	40.6



Fig. 9

Boxplot of archeological and geological samples. **a** Densities. **b** I_g . **c** Individual quartz grains CED



A piece (EnfE-247) has a high I_g (5.2) and high density (56 grains.cm⁻²) and reveals to contain Textularidae. All these indications are convergent to indicate a southern origin. The individual quartz grain CED of this piece with an interquartile range from 29.4 to 55.9, while very similar to those of the type 201A1, is also compatible with the type 201A3.

AQ14

A third group (Enf4-022, Enf4-004, EnfF-310, EnfD-001, Enf4-001) reveals densities higher than 31 grains cm⁻². The I_g of these samples should indicate the

type 201A3 but remains inferior to the first quartile of our geological sample (from 1.4 to 1.8). In addition, the individual quartz grains CED show a clear similarity with those of the type 201A2. No specific foraminifera were determined for most of these pieces but the presence of *Glomospira* in EnfF-310 is another element supporting a northern origin for these cherts. This group remains matter of uncertainty. A fourth group (Enf4-002, EnfC-110, and EnfE-386) can be more accurately attributed to the type 201A2. The presence of *incertae sedis* in one sample (EnfE-386) is coherent with this diagnostic.

This first test of the granulometric analysis of quartz grain in an archeological context gave positive results. Despite a group of pieces remains matter of uncertainty, several other ones can be attributed to one of the three types we defined. Foraminifera, when identifiable, always comfort the diagnostic. While preliminary, these results could suggest stimulating remarks. Bedoulian's cherts used in the Epigravettian layers of the Fanciulli's cave appear to come from various sources, both in northern and southern outcropping areas identified in the Provence shelf. An exploitation of the southern outcrops was already expected regarding the exploitation of neighboring formations in the same archeological phase (Oligocene cherts, Evenos' Southern Bedoulian chert). The acquisition of chert from the northern ones is even more so surprising, considering its dominant frequency. These results clearly illustrate that provisioning strategies are oriented towards a large panel of outcrops, which support previous assessment in this chronological context (Tomasso 2015). This first step encourages us to engage a systematic analysis to verify this unexpected importance of northern sources in Epigravettian provisioning strategies and extend investigations on other Upper Paleolithic contexts.

AQ15

The Urgonian honey chert from the Neolithic site of Giribaldi (Nice, France)

The open-air settlement of Nice-Giribaldi is c. 150 km southeast to the closest in situ Urgonian chert sources. The occupation, principally concentrated during the second half of the 5th millennium BCE, displays three main phases (B1, C1, and C2) that helped to define the formative period of the Chassey culture. Among the abundant related industries, Barremo-Bedoulian chert from the Provence shelf plays a major role among identified siliceous resources ($n = 1392$), i.e, 65.1% within phase B1, 58.4% within C1, and 47.7% within C2. Urgonian honey chert is clearly dominating, as rare pieces from other Barremo-Bedoulian types are displayed in phases B1 up to C2 as gray-black chert from Murs type 201A4 ($n = 144$) and light gray from Banon/Sault type 201B3 ($n = 8$). None of these artifacts received heat treatment. The knapped production is clearly focused on flakes during phase B1, while few blades appear during phase C1 (Binder 2016).

A set of 11 flakes and 4 blades has been selected among honey chert from C1 ($n = 6$) and B1 ($n = 9$) (Table 10).

Table 10

Sample selection from Nice-Giribaldi

Layer	Attribution	Total Nb. Bedoulian cherts	Selected samples
C1	Early Chassey culture	436	6
B1	Proto-Chassey culture	625	9
Total		1061	15

The semi-quantitative quartz analysis (Table 11) provides obvious results: 13 of the 15 pieces fall into the type 201A3. Only two remain dubious with I_g densities of quartz of 23 and 28 cm^{-2} which are comprised between the higher values of 201A1 and the lowest values of the two other types. However, the I_g is consistent with an attribution to 201A3. For the 15 pieces, the quartz grains CED are totally consistent with the type 201A3. The densities are lower than those of the geological sample (Fig.9). These relatively low densities were already noticed for the pieces of Fanciulli's cave. Further studies are needed to explain this observation.

Table 11

Detrital quartz analysis in the samples of Giribaldi

Sample	Density (cm^{-2})				Grain size (μm)				
	Total	< 62.5 μm	> 62.5 μm	I_g	Average	St. dev.	Min	Q1	Media
VG-4404	23	19	4	4.8	51.2	16.9	25.3	39.8	50.1
VG-4654	28	23	5	4.6	47.1	17.4	25.0	34.6	41.0
VG-774	30	24	6	4.0	50.1	22.0	13.6	33.3	47.7
VG-293	54	48	6	8.0	40.3	18.7	10.4	25.0	38.4
VG-686	41	24	17	1.4	58.4	19.0	28.1	41.8	57.6
VG-4492	60	42	18	2.3	54.4	20.8	19.8	39.3	49.6

Sample	Density (cm ³)				Grain size (µm)				
	Total	< 62.5 µm	> 62.5 µm	<i>I</i>	Average	St. dev.	Min	Q1	Media
VG-4402	71	50	21	2.4	51.5	19.9	17.7	36.4	47.6
VG-209	35	25	10	2.5	52.2	15.6	17.9	39.8	50.1
VG-317	150	112	38	2.9	47.9	22.2	7.0	30.6	44.6
VG-682	90	69	21	3.3	48.6	23.9	10.9	30.4	44.9
VG-4658	98	84	14	6.0	42.5	19.1	10.4	28.6	42.6
VG-1049	97	69	28	2.5	55.9	23.7	14.7	45.0	55.0
VG-411	67	50	17	2.9	50.1	20.9	19.1	34.0	44.4
VG-684	59	34	25	1.4	57.0	16.4	25.3	44.8	55.8
VG-685	100	72	28	2.6	54.4	20.3	12.2	40.9	50.7

All the selected pieces from the phase B1 have the same aspect with white-colored subcortical zonation. Intra-clastic porosity is important and oxidized rhombohedra are numerous. Spicules are present as well as rare Foraminifera (*Textularidae*). The pieces coming from C1 are deep yellow and very homogeneous with many boxworks. The clasts are well sorted with low density (less than 10%). Identified bioclasts (spicules, ostracods) are rare, i.e, only one occurrence of each one.

There is no correlation between the quartz count and the two groups recognized at the mesoscopic scale. The difference seems to be in relation with the evolution of cherts in secondary position rather than to different subtypes.

The application of the granulometric analysis of quartz grains on this first set of Neolithic pieces shows a great homogeneity for all analyzed pieces. All measured values are consistent with an attribution to the type 201A3 and could indicate a southern origin. This observation is consistent with the presence in the industry of few other characteristic types of southern Barremo-Bedoulian

outcrops (201A4, 201B3) as well as Oligocene chert whose sources are rather close in distance.

Conclusions and perspectives

Our study allowed to identify three different groups among the Barremo-Bedoulian cherts. The grain size classification of detrital quartz added to the mesoscopic description including the identification of some foraminifera provides stimulating results in the perspective of identifying with a great accuracy the provisioning modalities within an extended set of primary and secondary formations which is considered as one of the major chert reservoirs in the western Mediterranean. The next steps are (1) to strengthen geological sample in primary deposits and (2) to extend the study to the secondary deposits in order to define the dispersion of different types from their respective sources.

In addition, the application test we applied to some archeological samples confirms the applicability of the method in archeological context and illustrates the type of results we can expect from its systematic application. While preliminary, these tests seem to highlight contrasted patterns. Whenever these results cannot be generalized without a new large examination towards regional sites, it provides some stimulating perspectives.

In the Upper Paleolithic site of the Fanciulli's cave, the source data highlights the diversity of sources used. The finding is consistent with previous studies that have shown the diversity of sources exploited in the regional Late Upper Paleolithic layers (Tomasso 2015). It will be interesting to compare with other site and particularly with Early Upper Paleolithic sites with notable proportion of Bedoulian cherts, e.g., the Observatoire cave in Monaco (Porraz et al. 2010).

As a contrast, the results obtained for the Giribaldi's Neolithic series seem to indicate a more specialized exploitation over one group of the southern sources. In this very specific context of the increasing craft specialization during the Chassey culture (Léa et al. 2012), this result has a high significance. From the application of this analysis method at the scale of the Neolithic Barremo-Bedoulian cherts circulation network, we can expect major results. By relating receiver sites at the scale of the northwestern Mediterranean Basin producer workshop around outcrops and specific outcrops, we will assess the economic structuration of this network. One of the main issues is to test the hypothesis of the unicity or the multiplicity of producing centers eventually associated with different skills.

In addition, we believe that this method could be applied to other types of cherts with similar precision. Indeed, several cherts contain mineral fragments,

frequently quartz, or gravel, and the granulometric analysis seems to be effective for discriminating fine variations of paleogeographic conditions within a formation or between convergent types.

This perspective is critical for the development of techno-economic perspectives. Indeed, the geological availabilities in an area could imply convergences in the composition of assemblages. Because of these convergences, our capacity to interpret the provisioning practice could be limited. Our ability to distinguish with the best accuracy the different source areas is then crucial and it is necessary to go beyond the simple identification of the geological formation.

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AQ16

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