

Raw material procurement and land use in the northern Mediterranean Arc: insight from the first Proto-Aurignacian of Riparo Mochi (Balzi Rossi, Italy)

Beschaffung von Rohmaterialien und Landnutzung im nördlichen Mittelmeerraum: Erkenntnisse des anfänglichen Proto-Aurignacien aus dem Riparo Mochi (Balzi Rossi, Italien)

Stefano GRIMALDI^{1,2*}, Guillaume PORRAZ^{3,4} & Fabio SANTANIELLO¹

¹ Dipartimento di Lettere e Filosofia, Università degli studi di Trento, via Tommaso Gar 14, I-38122 Trento, Italia; e-mail: stefano.grimaldi@unitn.it

² Istituto Italiano di Paleontologia Umana, Anagni, Italia

³ USR 3336, UMIFRE 25, Institut Français d'Afrique du Sud, Braamfontein, Johannesburg, South Africa

⁴ Evolutionary Studies Institute (ESI), University of the Witwatersrand, Johannesburg, South Africa

ABSTRACT - This study aims to provide a general model of one of the settlement/mobility dynamics adopted by human groups during the very early Upper Palaeolithic in Western Europe. Two lithic assemblages - coming from the base of the Proto-Aurignacian layer (Unit G) and from the top of the semi sterile Unit H - located in the east sector (1959 excavation) of the well-known Italian prehistoric key-site, Riparo Mochi (Grimaldi caves, Balzi Rossi) have been dated to about 41 500 calBP. Both assemblages are analyzed from a petrographical, technological, and functional perspective. The data suggest the existence of a large territory from the Rhone valley to central Tyrrhenian Italy where the earliest Proto-Aurignacian human groups developed their adaptations, moving raw material inside a system of long-distance mobility. Moreover, the archaeological evidence provides different chronological frames of human behavior; accordingly, the first Proto-Aurignacian human groups, while crossing the Liguro-Provençal Arc, gathered and used available resources in a similar way, but with different intensity and effectiveness in time. Two interpretations are possible: either this change in the raw material spectrum reflects a difference in the role played by the Riparo Mochi site within the territory or it documents populations who were better organised to supply rocks of greater suitability.

ZUSAMMENFASSUNG - Diese Studie beabsichtigt ein allgemeines Modell einer der von Menschengruppen im westlichen Europa übernommenen Siedlungs- und Mobilitätsdynamiken während des anfänglichen Jungpaläolithikums zu erstellen. Zwei lithische Vergesellschaftungen, welche aus der Basis des Proto-Aurignacien (Einheit G) der bekannten prähistorischen Fundstelle Riparo Mochi (Grimaldi-Höhlen, Balzi Rossi) stammen, circa 41 500 calBP datiert, wurden unter petrographischen, technologischen und funktionellen Blickpunkten analysiert. Die Daten lassen auf das Bestehen eines umfangreichen Gebietes vom Rhone-Tal bis an die zentral-tyrrhenische Küste Italiens schliessen, in welchem die frühesten Menschengruppen des Proto-Aurignacien sich in ihrer Anpassung entwickelt und verändert haben, indem sie Rohmaterialien in einem weitreichenden Mobilitätssystem bewegten. Des Weiteren liefern die archäologischen Zeugnisse verschiedene chronologische Rahmen des menschlichen Verhaltens. Demzufolge sammelten und nutzten die ersten Gruppen des Proto-Aurignacien die vorhandenen Ressourcen, während sie den ligurisch-provenzalischen Bogen durchquerten in einer ähnlichen Weise, aber mit einer verschiedenen zeitlichen Intensität und Qualität. In Betracht kommen zwei Interpretationsmöglichkeiten: entweder spiegelt diese Veränderung des Spektrums der Rohmaterialien einen Unterschied in der Rolle des Fundortes Riparo Mochi im Territorium wider, oder sie belegt eine Population, die besser organisiert ist, sich mit geeigneten Steinen zu versorgen.

KEYWORDS - Middle-Upper Palaeolithic transition, Mobility, Raw material, Proto-Aurignacian, Riparo Mochi
Übergang Mittel-Jungpaläolithikum, Mobilität, Rohmaterialien, Proto-Aurignacien, Riparo Mochi

*corresponding author

Introduction

To understand the technological organization of a prehistoric assemblage, raw material availability, lithic technology, tool design, and reduction strategy are crucial aspects. In particular, the relation between abundance/quality of raw materials and mobility strategies has been ethnographically and archaeologically explored by many scholars (see, among many others, Bamforth 1986, 1990, 1991; Beck & Jones 1990; Bettinger 1987; Binford 1977, 1978; Boldarian 1991; Carr 1994; Jones et al. 2003; Kelly 1988; Kuhn 1991; MacDonald 1968; Morrow & Jefferies 1989; Nelson 1991; Odell 1996; Parry and Kelly 1987; Torrence 1983, 1989).

In the broadest sense, mobility refers to the manner in which humans move across the landscape in relation to the properties of the environment, particularly the distribution of subsistence resources (Binford 1980; Kelly 1983, 1992). As mobility involves several dimensions of group movement – such as the size of the territorial range, seasonal and/or logistical moves,

and who actually moves (individuals, task groups, or the entire group) – its precise definition is quite difficult. In fact, as archaeologists debate if rocks transported over a long distance can be interpreted as by-products of mobility (embedded procurement, according to Binford 1979) or as targeted resources (specific procurement, according to Bamforth 1991), the relation between the geologic provenance of stone tools and mobility, as Kelly (1992:55) notes, “provides a rough indication only of the range, rather than mobility, since the raw material could have been acquired through residential or logistical movement, or trade”.

In this paper, the earliest Proto-Aurignacian lithic assemblage found in the Italian prehistoric key site of Riparo Mochi (Grimaldi caves, Balzi Rossi) is investigated. The Riparo Mochi site is part of the Grimaldi sites, Balzi Rossi (43°47'3.66"N, 7°32'4.18"E) (Fig. 1: a & b). The site is located in the so-called Liguro-Provençal Arc, a narrow littoral corridor, 400 km long and a few km wide, delimited by the Apennines and the Western Alps to the North, and the Tyrrhenian Sea to the

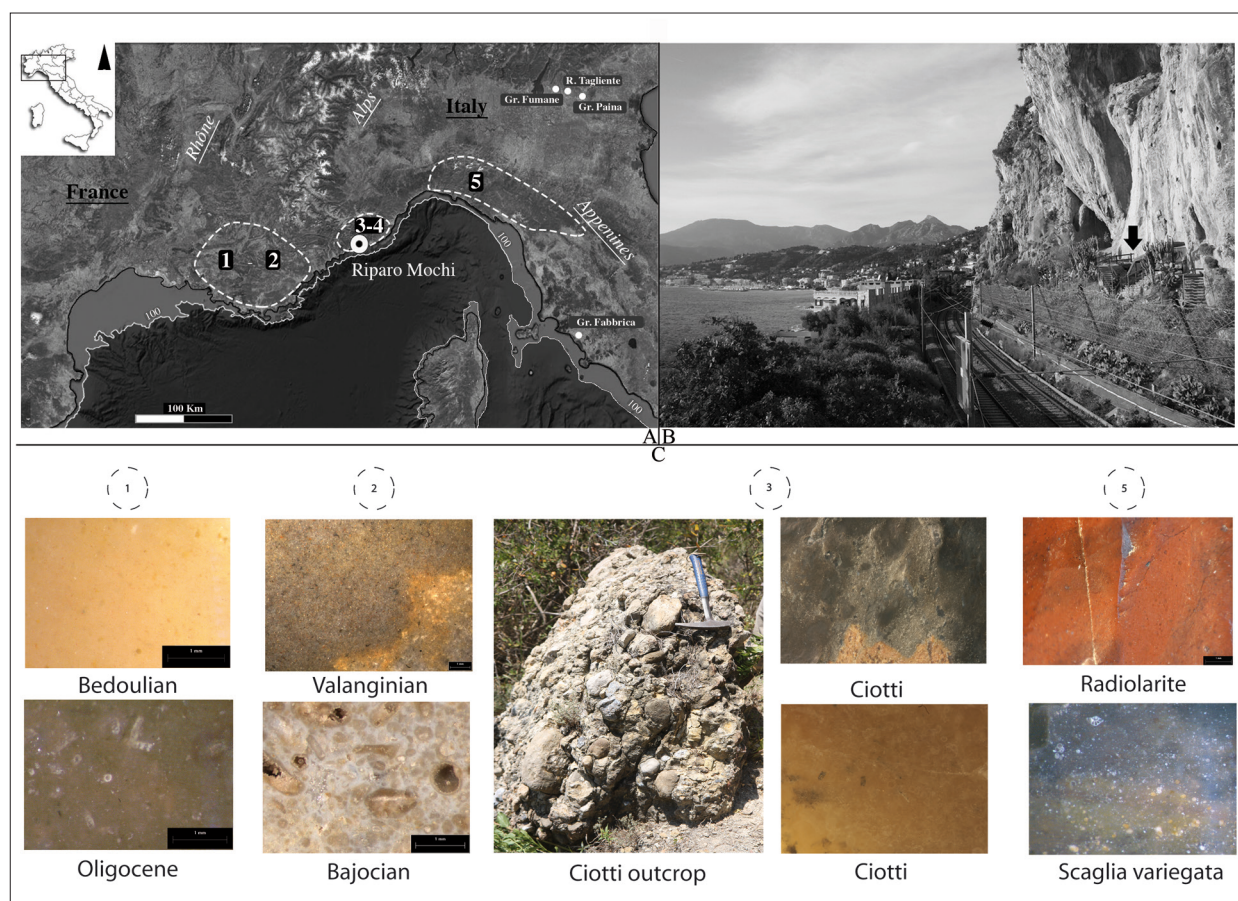


Fig. 1. A) The Liguro-provençal Arc and the LGM sea level at 100m. Location of sites cited in the text and the main areas of flint procurement (1-Western Provence, 2- Eastern Provence, 3- on site, 4- perilocal, 5- Eastern Liguria/Central Italy); B) the Riparo Mochi (Balzi Rossi); C) macro-photos of some of the lithofaciès that typified the region.

Abb. 1. A) Der Ligurisch-provenzalische Bogen und der Meeresspiegel während des LGM (-100 m). Lage der im Text genannten Fundstellen und das Hauptgebiet für Beschaffung von Flint (1- Westliche Provence 2- Östliche Provence 3- vor Ort 4- perilocal 5- Östliches Ligurien/ Zentral-Italien); B) Riparo Mochi (Balzi Rossi); C) Macroaufnahmen einiger der Region entsprechenden Lithofazies.

South, further linking Central Tyrrhenian Italy to the Rhône Valley (Fig. 1: a). During the OIS 3, the landscape of the Liguro-Provençal Arc was not very different from today's (Arobba & Caramiello 2009; Pons-Branchu et al. 2010; Watts et al. 2000). This region was a narrow corridor even during glacial time according to the bathymetry of the sea bottom (IBCM 2014). Consequently, from an archaeological perspective, the Liguro-Provençal Arc should have been a natural axis channelling the circulations of both humans and animals between central Italy and Southern France (Porraz et al. 2010).

The Riparo Mochi stratigraphic sequence, approximately 10 m deep, has been sub-divided into nine chronocultural macro-units, named A to I from top to bottom (Laplace 1977; Palma di Cesnola 1993). Following the 1941, 1949, and 1959 field documents (see a brief history of researches on the site in Douka et al. 2012), these macro-units are related to the Upper Palaeolithic deposit (Units A to G), a semi sterile deposit (Unit H), and the Mousterian deposit (Unit I). The Unit H was firstly defined by L. Cardini who excavated the central trench of the deposit in 1949 and the East part of the deposit in 1959 (Laplace 1977). Cardini considered this 60cm-thick, semi-sterile unit as a mixture of both Mousterian and Aurignacian implements. According to Cardini, a typical Mousterian assemblage was found below the base of H Unit representing the last Neanderthal occupation of the site. The Middle-to-Upper Palaeolithic succession at the Riparo Mochi was recently dated using radiocarbon dating (Douka et al. 2012). These ¹⁴C dates characterise Riparo Mochi as the oldest directly dated Aurignacian assemblage in Italy, and as one of the oldest in Southern Europe (see among others, Maroto et al. 1996; Normand & Turq 2005; Wood et al. 2012). As stated in Douka et al. (2012:295), "the Mousterian ends in unit I between 44 and 41.8 ka calBP (68.2% prob.). The earliest Aurignacian from unit G was dated at 37 ka BP or 42.7-41.6 ka calBP (68.2%)". Results suggest a very short time span between the last Middle Palaeolithic (top of Unit I) and the early Proto-Aurignacian occupations (Unit G-base) at the site. Nevertheless, the Unit G-base no longer represents the oldest Upper Palaeolithic record at the site, as earlier evidence has been found in a newly defined Unit G-H (see below).

Here, we provide new insights into the Proto-Aurignacian raw material economy in the Mediterranean area. This paper analyses if and how the technology of the first Proto-Aurignacian episode at the Riparo Mochi differs from the later and classic Proto-Aurignacian, typified by the Dufour bladelets. As described below, we interpret these changes as the expression of distinct steps within a process of large-scale "colonization", giving insight into the first settlement dynamics of the initial Upper Palaeolithic in Mediterranean Europe.

Materials and Methods

Lithic raw materials

In the Liguro-Provençal Arc, a project to create a regional flint database began in the 1980s at CNRS-CEPAM by Didier Binder, and at *Musée d'Anthropologie Préhistorique de Monaco* by Patrick Simon (Binder 1994, 1998; Simon 2007; Porraz 2005; Tomasso 2014a). Here, our purpose is not to relate each rock to its original source but, to indicate its general origin. This activity led us to identify four main subdivisions of material origin (Fig. 1: a & c):

1. Western Provence roughly spans from the Rhone Valley (about 200 km from the Riparo Mochi) to the western side of the Var and Alpes-de-Haute-Provence districts (about 80 to 100 km from the Riparo Mochi). Schematically, two main formations are worth individualising. The Bedoulian provides flint dominantly characterised by its honey colour, the abundant presence of small detrital quartz, the presence of iron oxides as well as spicules. The Oligocene provides a typical lacustrine flint with laminated structure, abundant charophytes, gastropods and ostracods. Both flint formations have been well studied because of their intensive exploitation and circulation during Neolithic times (e.g. Lea 2005).
2. Eastern Provence (less than 100 to 80 km from the Riparo Mochi) can be subdivided into two main areas: the Pre-Alps and the coast. The Pre-Alps provide abundant flints of good quality from various geological formations (Valanginian, Turonian and Lutetian among others), unlike the littoral where only a few occurrences exist, such as the Bajocian oolithic flint (Porraz 2005).
3. Western Liguria provides large Tertiary formations, known as the "Ciotti" conglomerate (Negrino 2002). This area is very close to the Balzi Rossi (less than 5 km) and contains abundant flint cobbles/pebbles of various origins; this explains their heterogeneity and the abundance of fissures. The Ciotti flint pebbles, occasionally found on the beach, represent the "on-site" source.
4. Eastward from Riparo Mochi, at about 20 to 30 km, one finds a few local occurrences such as the bluish flint from Perinaldo, characterised by an abundance of detrital quartz grains, and micro-quartzite cobbles/pebbles. These rocks are interpreted as the "local" raw materials.
5. Eastern Liguria/Central Italy roughly spans from the town of Genoa (about 150 km from the Riparo Mochi) to the Apennines in Tuscany (more than 200 km from the Riparo Mochi). This area provides formations of Jurassic radiolarite (also called Jasper), and other good quality flints ("Scaglia" and "Maiolica"), some of them being typified by their foraminifera, although a certain diversity occurs (Negrino & Starnini 2006).

In short, the rock distribution in the Liguro-Provençal Arc displays great variability in terms of availability (distribution, contexts and quality), and petrographic features, which are good methodological prerequisites for the study of raw material sourcing (Porraz & Negrino 2008; Porraz et al. 2010, Tomasso 2014b). Indeed, flints from France and Italy, by documenting different palaeo-contexts of formation, can hardly be confused with each other, or with the local and on-site raw materials.

The lithic sample

Since 2007, one of us (SG) has been working on a revision of the stratigraphy of Riparo Mochi and has been studying the old collections in collaboration with the *Soprintendenza per i Beni Archeologici della Liguria*. Today, new information on the stratigraphy (Boschian & Grimaldi, in preparation) and the cultural sequence of the site can be provided with regard to the Middle-Upper Palaeolithic boundary (Units I, H and G).

An important result concerns the semi-sterile Unit H, excavated by L. Cardini in 1949 and located in between the Middle and Upper Palaeolithic units. By

refreshing the old profiles of the site, it becomes clear now that Unit H is not a homogeneous lithological layer, rather it consists of about 40-50 cm of complexly interbedded lithological units that may be divided into three main layers (Fig. 2):

a) at the base, there is scant but clear presence of final Middle Palaeolithic evidence; today, this level should be referred to as being the top of the Mousterian Unit I.

b) in the middle, there is a sterile layer about 10 cm thick; the thickness of this layer rapidly decreases toward the rock wall. From now on, this sterile layer should be referred to as Unit H. Micromorphological analyses (Boschian & Grimaldi, in preparation) suggests that Unit H is a compacted/trampled surface that was stable - without sedimentation - for some time; it is also relevant that carnivore coprolites are particularly frequent in this unit, which is also completely sterile of cultural remains, indicating a phase of abandonment of the shelter by humans, that were substituted by carnivores, probably hyenas (Boschian, pers. comm.).

c) at the top, a 15- to 20 cm thick sediment provides the earliest evidence of Upper Palaeolithic

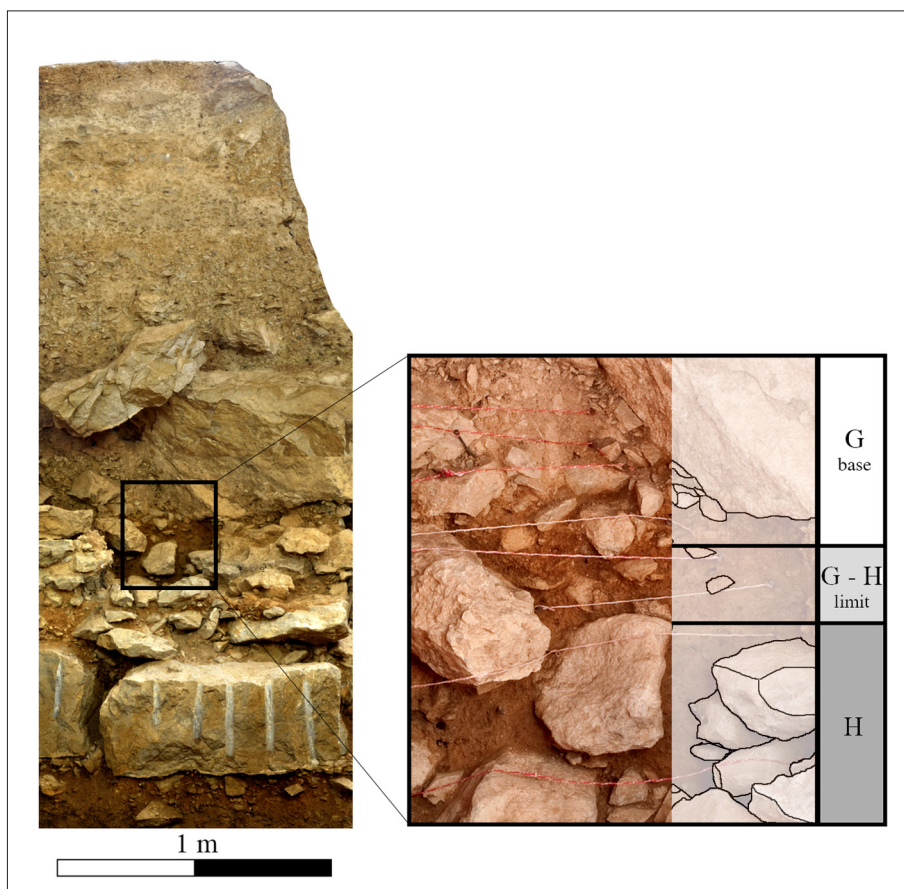


Fig. 2. Riparo Mochi (South section): stratigraphy and cultural phases (H- sterile layer, G-H limit- Proto-Aurignacian 1, G base- Proto-Aurignacian 2).

Abb. 2. Riparo Mochi (südliches Profil): Stratigraphie und Kulturphasen (H: sterile Schicht, G-H Limit: Proto-Aurignacien 1, G Basis: Proto-Aurignacien 2)

occupations at the site. This layer should be referred to as Unit G-H. This cultural change clearly divides the sequence into two main parts by a sharp and horizontal limit.

Following this new interpretation, the lithic assemblage coming from Cardini's 1959 excavation has been subdivided into three groups named: "Proto-Aurignacian Pulse 1" (PA1; Fig. 3) for the lithic sample coming from the newly characterised Unit G-H (i.e. the top of Cardini's Unit H), "Proto-Aurignacian Pulse 2"

(PA2; Fig. 4) for the lithic sample coming from the base of Cardini's Unit G, and "Proto-Aurignacian Pulse 3" (PA3) for the lithic sample coming from Cardini's Unit G. Here, we will deal with only PA1 and PA2 lithic assemblages, while PA3, already described by previous scholars (see Kuhn & Stiner 1998), is not included in this paper. It should be stressed that the Unit G-base is not a lithological ensemble distinct from Unit G; accordingly, little typological difference may be observed between their lithic assemblages. As

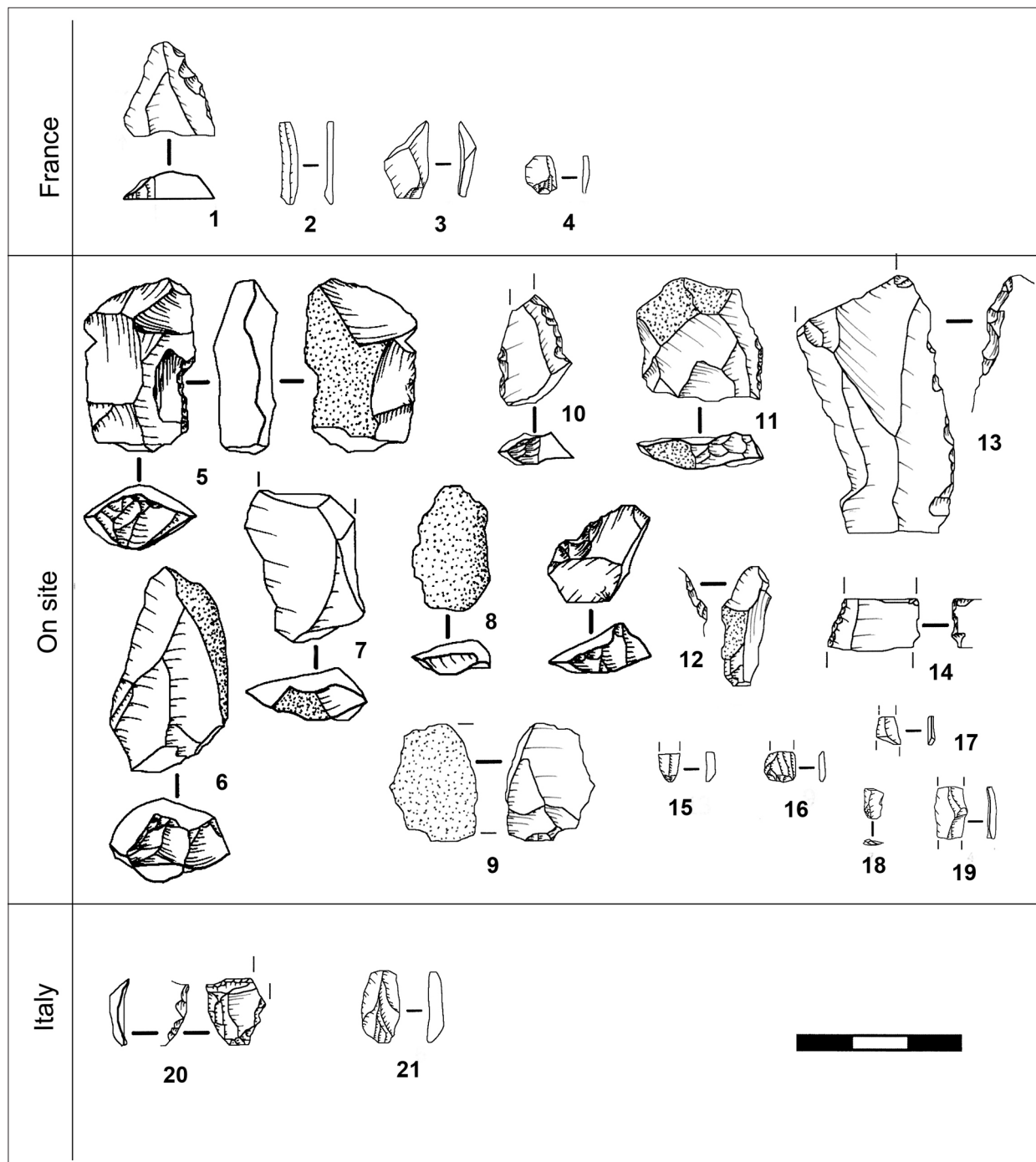


Fig. 3. Riparo Mochi: lithic assemblage vs. raw material provenience (Proto-Aurignacian 1) (Drawings: S.Grimaldi).

Abb. 3. Riparo Mochi: lithische Zusammensetzung im Vergleich zur Herkunft der Rohmaterialien (Proto-Aurignacien 1) (Zeichnungen: S. Grimaldi).

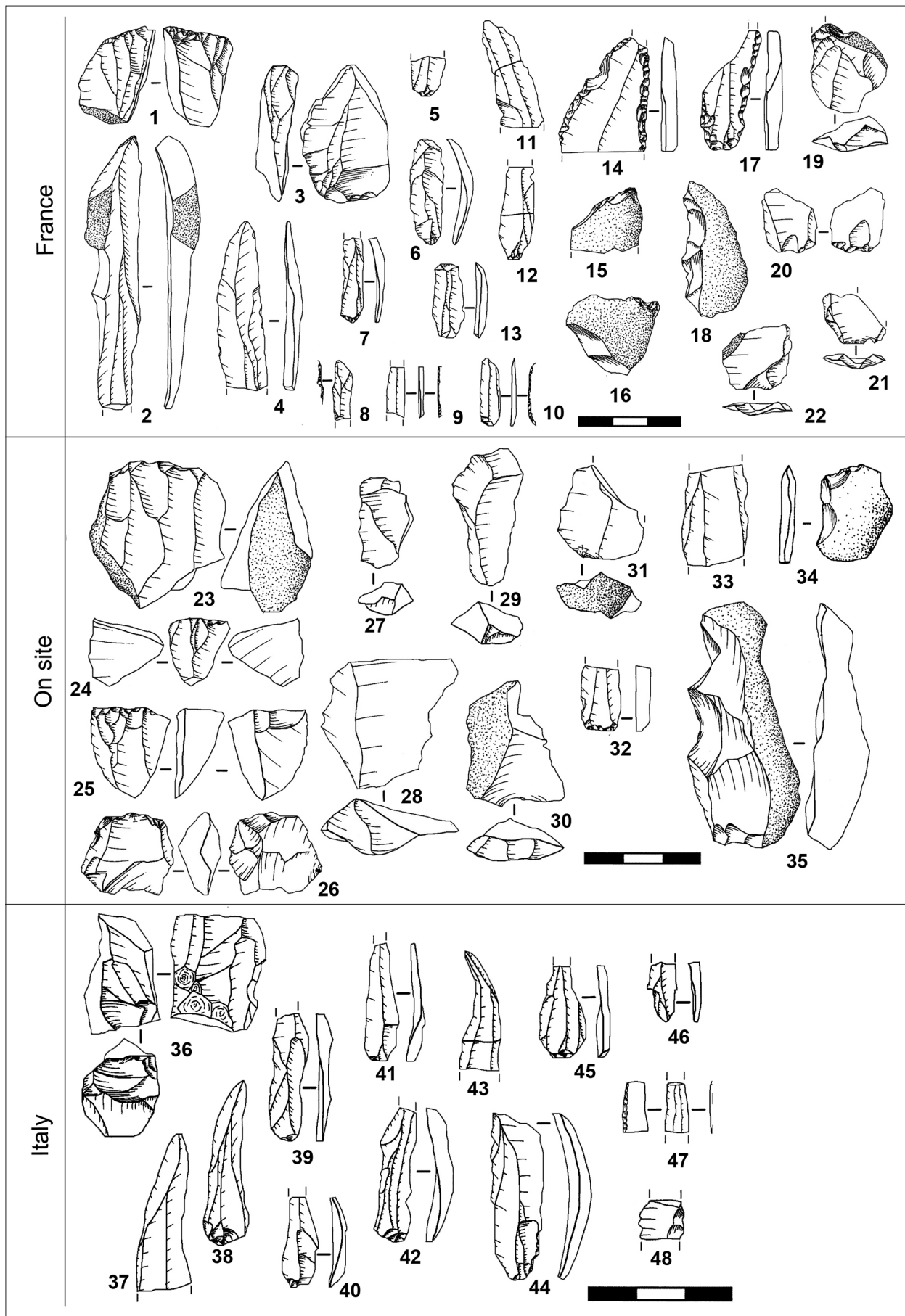


Fig. 4. Riparo Mochi: lithic assemblage vs. raw material provenience (Proto-Aurignacian 2) (Drawings: S.Grimaldi).

Abb. 4. Riparo Mochi: lithische Zusammensetzung im Vergleich zur Herkunft der Rohmaterialien (Proto-Aurignacien 2) (Zeichnungen: Grimaldi).

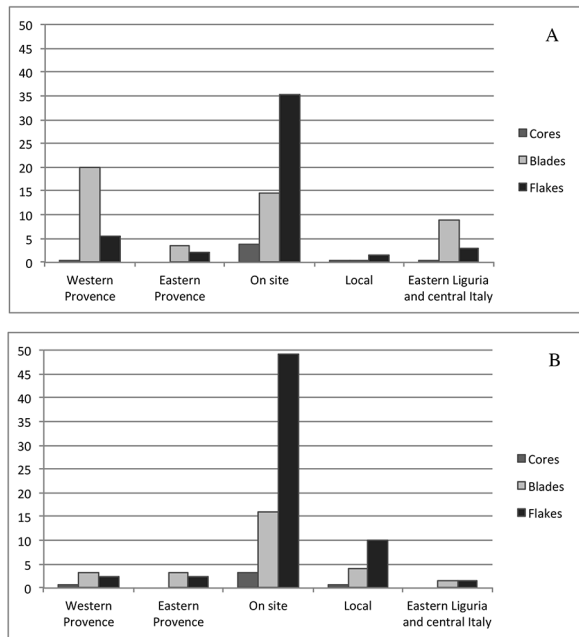


Fig. 5. Riparo Mochi: early Proto-Aurignacian lithic assemblage. Blanks vs. raw materials (A- Proto-Aurignacian 2, B- Proto-Aurignacian 1).

Abb. 5. Riparo Mochi: lithische Zusammensetzung des frühen Proto-Aurignacien. Vorform im Vergleich zu den Rohmaterialien (A- Proto-Aurignacien 2, B- Proto-Aurignacien 1).

both units provide palimpsests of several occupations, the lithic assemblage found in the Unit G-base should be considered as early evidence of the “typical” Proto-Aurignacian assemblage, which characterizes the whole Unit G.

Several data allow us to discard the hypothesis that PA1 and PA2 are not inter-mixed: no refits have been found between the two assemblages; the presence of several blanks showing the same petrographical features (i.e. blanks probably coming from the same core) is observed in each assemblage; several broken blanks (i.e. broken pieces with no evidence of fresh fracture) have been refitted in each assemblage; sediments from the two layers show macro- and micro-morphological differences (Boschian & Grimaldi, in prep.).

Results

During the most ancient phase (PA1, Fig. 5: b & Fig. 6), blades and bladelets represent the technical objective of the reduction sequence and, interestingly, micro-bladelets (less than 6-mm wide) are well represented. Flints from France (especially from Western Provenience) and from Eastern Liguria/Central Italy, have been introduced mostly in the form of blades/bladelets, and occasionally in the form of small bladelet cores

PA2	Cores	%	Blades	%	Flakes	%	Debris	%	Fragments	%	Total	%
Western Provenience	1	0.7	98	68.1	27	18.8	14	9.7	4	2.8	144	16.6
Eastern Provenience	0	0.0	17	48.6	10	28.6	8	22.9	0	0.0	35	4.0
On site	19	5.0	72	18.8	172	45.0	40	10.5	79	20.7	382	44.2
Local	1	7.7	2	15.4	8	61.5	0	0.0	2	15.4	13	1.5
Eastern Liguria and Central Italy	1	1.3	44	58.7	15	20.0	9	12.0	6	8.0	75	8.7
Not determined	2	0.9	66	30.6	31	14.4	86	39.8	31	14.4	216	25.0
Total	24	2.8	299	34.6	263	30.4	157	18.2	122	14.1	865	100
PA1	Cores	%	Blades	%	Flakes	%	Debris	%	Fragments	%	Total	%
Western Provenience	1	7.1	4	28.6	3	21.4	4	28.6	2	14.3	14	6.3
Eastern Provenience	0	0.0	4	28.6	3	21.4	1	7.1	6	42.9	14	6.3
On site	4	3.2	19	15.1	58	46.0	22	17.5	23	18.3	126	57.0
Local	1	3.7	5	18.5	12	44.4	1	3.7	8	29.6	27	12.2
Eastern Liguria and Central Italy	0	0.0	2	40.0	2	40.0	0	0.0	1	20.0	5	2.3
Not determined	0	0.0	3	8.6	5	14.3	19	54.3	8	22.9	35	15.8
Total	6	2.7	37	16.7	83	37.6	47	21.3	48	21.7	221	100

Fig. 6. Riparo Mochi: distribution of Early Proto-Aurignacian lithic assemblages. Relative percentages refer to the total frequency of each raw material.

Abb. 6. Riparo Mochi: Verteilung des lithischen Materials des frühen Proto-Aurignacien. Relative Prozentanteile beziehen sich auf die gesamte Häufigkeit jedes Rohmaterials.

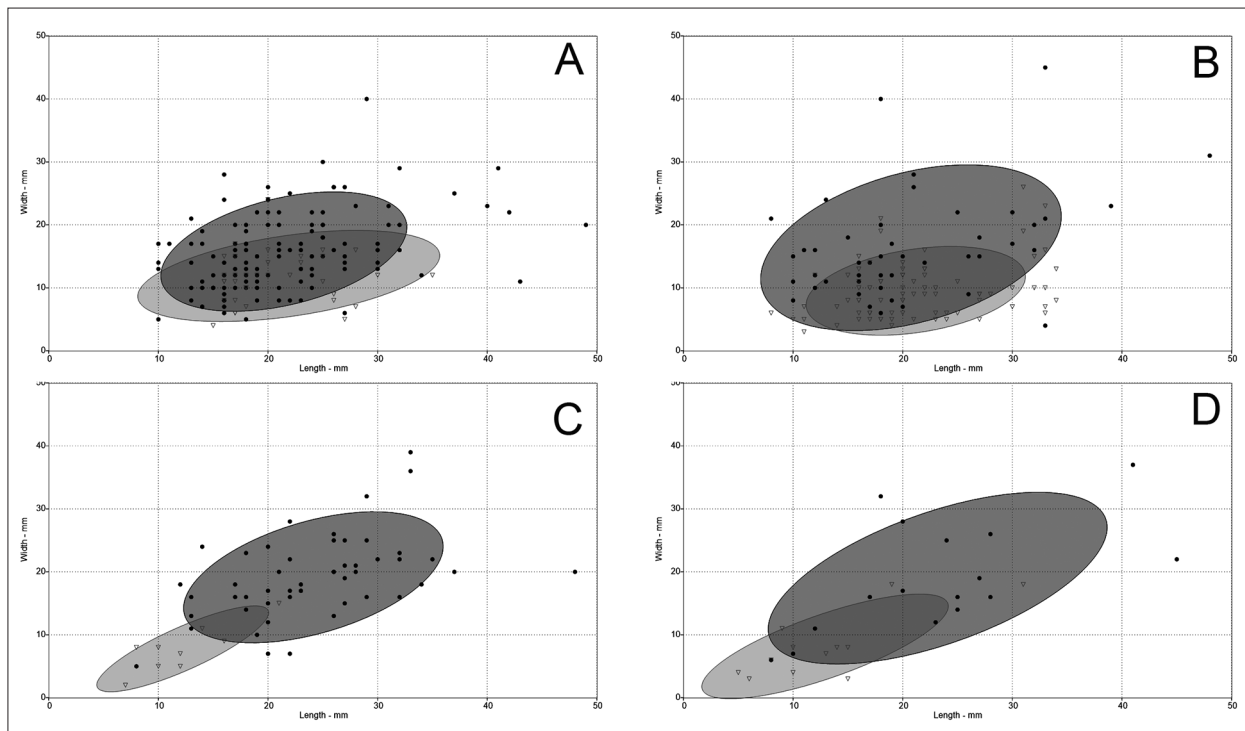


Fig. 7. Riparo Mochi: early Proto-Aurignacian lithic assemblage. Length/Width ratio of flakes (black circles-dark grey area) and blades (white triangles-light grey area). Proto-Aurignacian 2: A- on site blanks, B- imported blanks; Proto-Aurignacian 1: C- on site blanks, D- imported blanks.

Abb. 7. Riparo Mochi: lithische Zusammensetzung des frühen Proto-Aurignacien. Längen-/Breitenverhältnis der Flintabschläge (schwarze Kreise-dunkelgraue Fläche) und Klingen (weiße Dreiecke-hellgraue Fläche). Proto-Aurignacien 2: A- Abschläge vor Ort B- importierte Abschläge; Proto-Aurignacien 1: A- Abschläge vor Ort B- importierte Abschläge;

often made from large, thick flakes (Fig. 7: d). Local raw materials are rare, while, despite its varied quality, the on-site Ciotti flint is dominant. It was largely used to produce elongated flakes (as already pointed out by Kuhn & Stiner 1998 for PA3) and, when good quality pebbles were found, to produce blades and bladelets. An on-site reduction sequence may be associated with the Ciotti flint (Fig. 7: c). Typologically, PA1 is characterised by the predominance of notches, denticulates and artefacts with marginal retouches (Fig. 8: c & d). Most of them are made from Ciotti flint, either from blades or flakes, while very few pieces from Italian flint have been retouched. No Dufour bladelets have been found during this stage.

Several changes occurred during the later stage, PA2 (Fig. 5: a & Fig. 6). While Ciotti flint is still largely used, local stones are almost absent, and a remarkable increase in the number of blades made from Western Provence flint and, to a lesser extent, from Italian raw materials can be observed. A clear selection of the Ciotti raw material is visible (Fig. 7: a); blades/bladelets show a dimensional – as well as technological – pattern similar to that shown by blades made from French flints (Fig. 7: b). Cores made from good quality raw material lead to a reduction in waste products, to the more suitable maintenance of the cores, and to a more standardized production of elongated blanks. French

and Italian flints show technical features similar to those observed in PA1; here, the increased length of the blades may be tentatively attributed to a change in raw material provisioning strategies characterized by a selection and/or importation of larger nodules or pre-formed cores. Among the retouched items (Fig. 8: a & b), French flint is largely used to produce a high variability of typological types even if the notches, denticulates and artefacts with marginal retouches remain the most abundant types. Dufour bladelets are documented for the first time; none of them were made from Ciotti flint.

All implements (debris and fragments not included) have been functionally analysed (Grimaldi, in press). Macro- and micro-wear traces have been found on 177 lithic pieces. Action and movement are recognizable on about 70% of the blanks. Some of them were used for scraping (15%), engraving (2%) or perforating (3%) hard animal material (namely, bone). The most common tools include 98 (55%) items (hereafter “knives”) showing longitudinal action on soft animal material, such as fresh skin and/or meat (Figs. 9, 10 & 11). PA1/PA2 knives do not show morphological (i.e. made on both elongated flakes and blades), petrographic (i.e. made from any raw material) or typological (i.e. retouched or not) differences. Neither do metrical characters appear to have played a

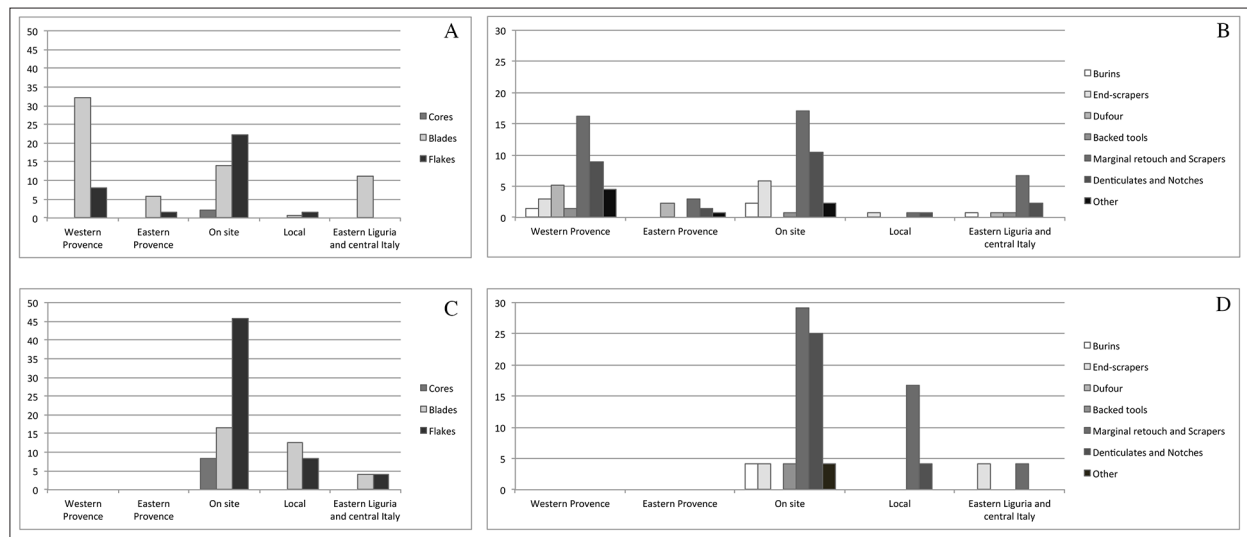


Fig. 8. Riparo Mochi: early Proto-Aurignacian lithic assemblage. Frequencies of retouched tools. Proto-Aurignacian 2: A- total frequencies; B- typological frequencies; Proto-Aurignacian 1: C- total frequencies; D- typological frequencies.

Abb. 8. Riparo Mochi: lithische Zusammensetzung des frühen Proto-Aurignacien. Häufigkeit der retuschierten Werkzeuge. Proto-Aurignacien 2: A- gesamte Häufigkeit; D- typologische Häufigkeit

relevant role in the selection of blanks. The few Dufour bladelets found in PA2 show little and uncertain evidence of use.

The presence of Dufour bladelets (sub-type Dufour) in PA2 typified the Proto-Aurignacian, as described by previous scholars (Bon 2002; Laplace 1977; Teyssandier 2007, among others). But their absence in our PA1 lithic sample challenges its

techno-cultural attribution. Regardless of this typological feature, PA1 and PA2 share some similarities, depicted by the range of rock selection, the geometry of the blade/bladelet core (unidirectional, plain/abraded platform), the exploitation of flakes as bladelet cores (in the narrow trench of the flake, often with a preparation of a single crest), and by the use-wear analysis that shows similarities in blank

		Blanks				Action		Material	
		Blades	Flakes	Fragments	Total	Longitudinal	Indet.	Animal	Indet.
PA2	Western Provence	27	0	0	27	24	3	20	7
	Eastern Provence	5	1	0	6	5	1	3	3
	On site	15	16	6	37	24	13	20	17
	Local	1	1	0	2	1	1	0	2
	Eastern Liguria and Central Italy	12	2	1	15	15	0	11	4
	Not determined	0	1	0	2	2	0	2	0
	Total	61	21	7	89	71	18	56	33
PA1	Western Provence	0	0	0	0	0	0	0	0
	Eastern Provence	0	0	0	0	0	0	0	0
	On site	0	5	1	6	5	1	3	3
	Local	3	0	0	3	3	0	3	0
	Eastern Liguria and Central Italy	0	0	0	0	0	0	0	0
	Not determined	0	0	0	0	0	0	0	0
	Total	3	5	1	9	8	1	6	3
	Total PA2 + PA1	64	26	8	98				

Fig. 9. Riparo Mochi: Early Proto-Aurignacian "Knives"

Abb. 9. Riparo Mochi: "Messer" des frühen Proto-Aurignacien.

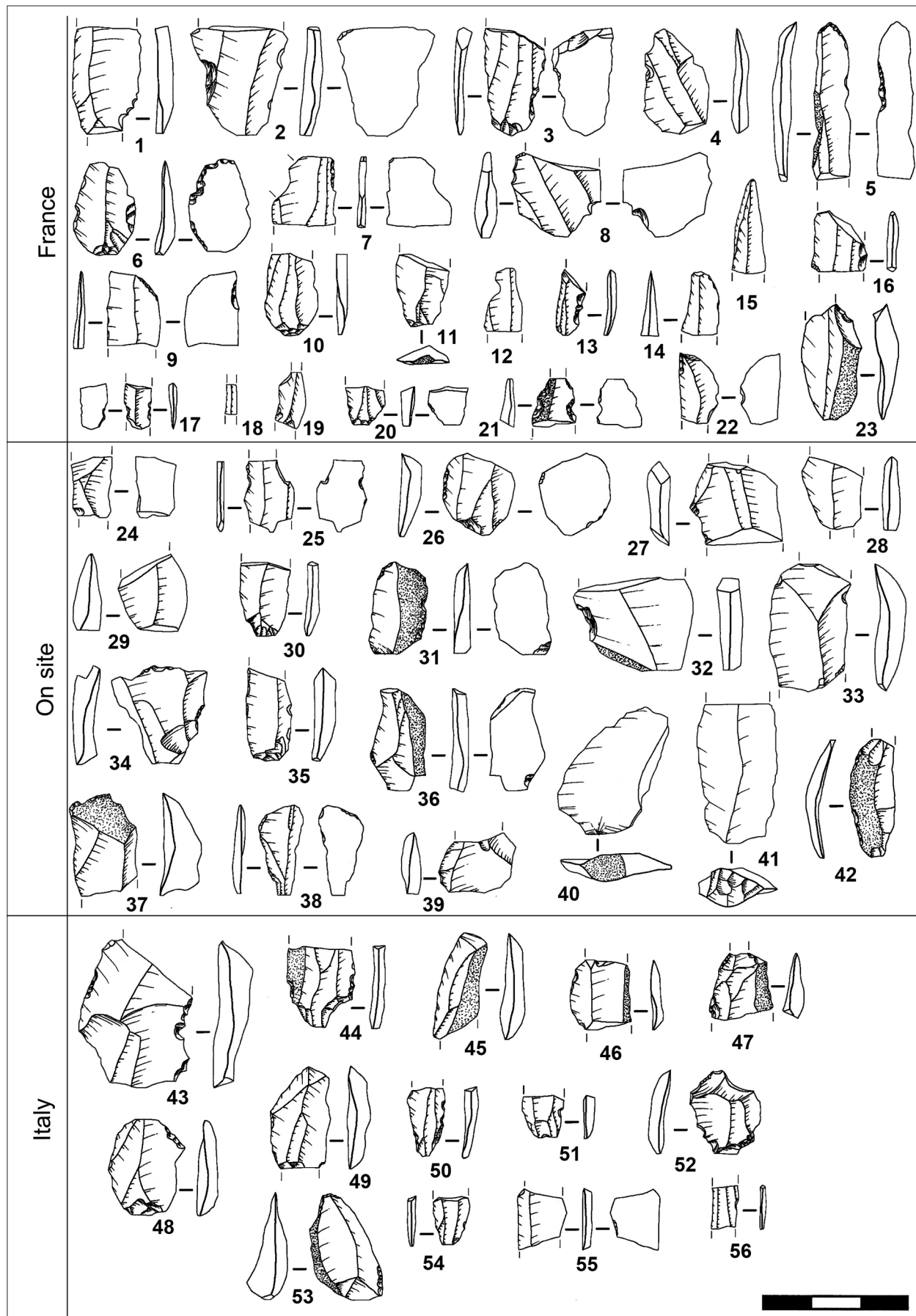


Fig. 10. Riparo Mochi: early Proto-Aurignacian "Knives" (Drawings: S.Grimaldi).

Abb. 10. Riparo Mochi: "Messer" des frühen Proto-Aurignacien (Zeichnungen: S. Grimaldi).

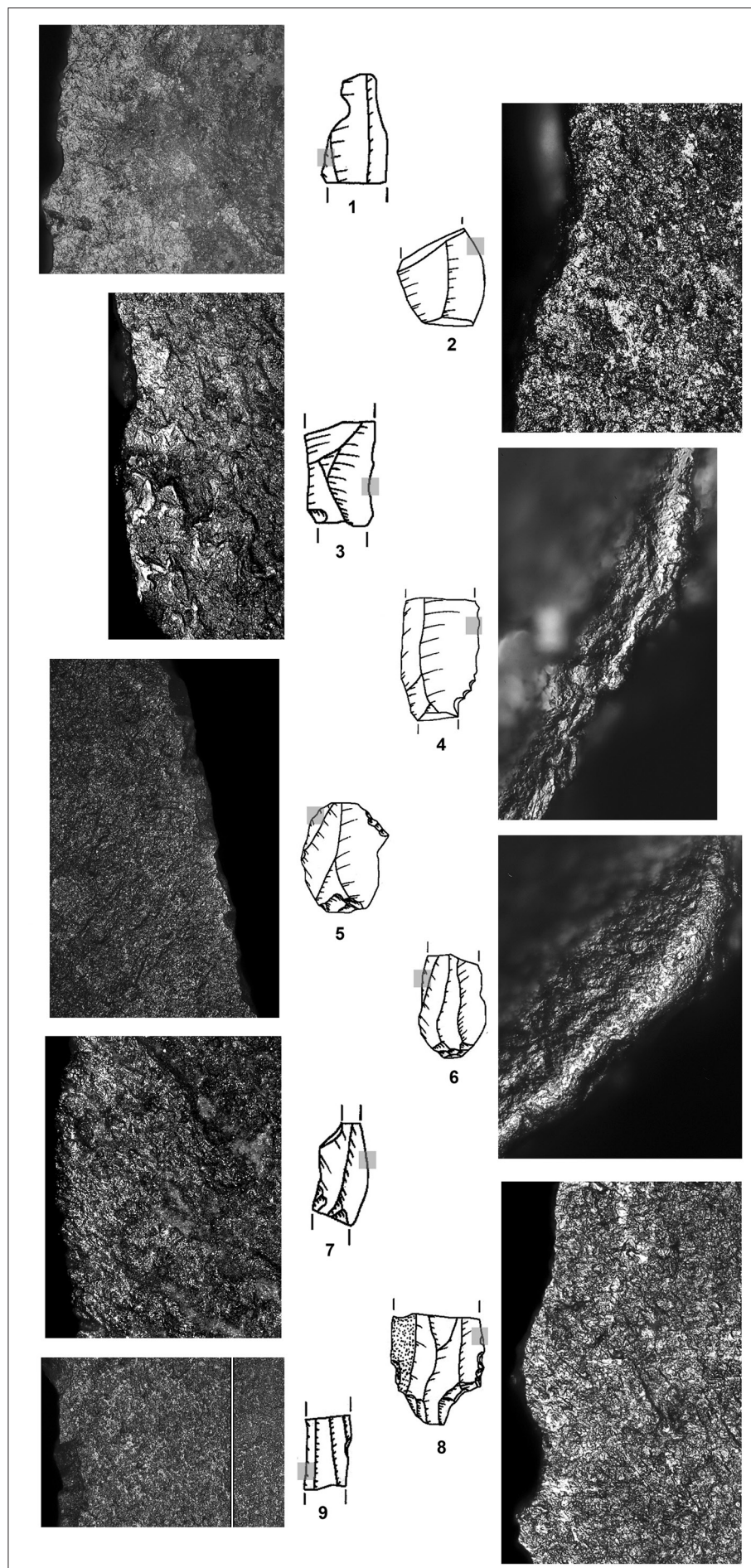


Fig. 11. Riparo Mochi: early Proto-Aurignacian "Knives". Functional analyses. 1 (fig.10, n.12. 200x), 2 (fig.10, n.29. 200x), 3 (fig.10, n.24. 200x), 4 (fig.10, n. 1. 400x), 5 (fig.10, n.48. 100x), 6 (fig.10, n.10. 200x), 7 (fig.10, n.19. 200x), 8 (fig.10, n.44. 200x), 9 (fig.10, n. 56. 200x) (Photos: S. Grimaldi).

Abb. 11. Riparo Mochi: "Messer" des frühen Proto-Aurignacien. Funktionelle Auswertung. 1 (Abb.10, n.12. 200x), 2 (Abb.10, n.29. 200x), 3 (Abb.10, n.24. 200x), 4 (Abb. 10, n. 1. 400x), 5 (Abb.10, n.48. 100x), 6 (Abb. 10, n.10. 200x), 7 (Abb. 10, n.19. 200x), 8 (Abb. 10, n.44. 200x), 9 (Abb. 10, n. 56. 200x) (Fotos: S. Grimaldi)

selection and usage (e.g. the knives). We are inclined to affiliate PA1 to the Proto-Aurignacian and, as a result, we have developed a model to explain the changes observed between PA1 and PA2.

Discussion

The overarching issue tackled in this paper is that, despite the fact that some authors are stressing the importance of social contacts and/or trade/exchange systems (see for instance Bietti & Negrino 2007; Pearce & Moutsiou 2014), knowledge of a large area is essential for hunter-gatherers relying on resources that are dispersed, and which may vary spatially and temporally. A system of long-distance logistic mobility – practiced by individuals or small hunting groups – has been documented in numerous ethnographic contexts (e.g. Binford 1991; Leacock 1969; Lovis et al. 2005, among others) as well as in some archaeological evidence (for instance, Kelly & Todd 1988; Rockmann & Steele 2003).

Here, even if we are well aware that any direct inference from recent periods to the early Upper Palaeolithic time should be considered with caution, we suggest that such adaptive subsistence behaviour could be one of the reasons explaining the rapid early Upper Palaeolithic spread into Europe.

In this regard, the Mediterranean rim represents one of the two hypothetical ways of dispersal that bypass the Alpine range (Broglia 1994), the other one being the “Danube corridor” (Conard & Bolus 2003; Nigst et al. 2014). North of the Alps, only “classic” Aurignacian sites are known, while south of the Alps, the Proto-Aurignacian was developed first (see Teyssandier 2007). Regardless of the way one interprets these two technological manifestations (see Banks et al. 2013; Higham et al. 2013), it appears that Riparo Mochi provides some information for documenting how (and perhaps why) these populations quickly settled in Mediterranean Europe. It is worth remembering that, unlike other regions, the Liguro-Provençal Arc seems to have experienced a gap in human occupation between the last Mousterian and the first Proto-Aurignacian occupations, as suggested by the sterile Unit H of Riparo Mochi; while this gap still needs to be clarified, it is certainly part of the explanation behind the rapid dispersal of Proto-Aurignacian groups.

One of the striking elements of the Riparo Mochi archaeological record concerns the patterns of lithic material management. Unit G of Riparo Mochi (PA3), considered “typical” Proto-Aurignacian, no longer represents the first Upper Palaeolithic occupation on this site. From now on, these are documented by Units G-H (PA1) and G-base (PA2), displaying a lower density of artefacts and a higher proportion of local rocks than Unit G. As previously seen, from PA1 to PA2 (and consequently to PA3) we observe changes, namely the absence/presence of the Dufour bladelets

and the increased frequency of France flints; from a functional standpoint, we observe similar activities by means of similar blank types.

The data of Riparo Mochi - while depicting long distance transportation since the first proto-Aurignacian occupation of the site - support the hypothesis of populations that, while crossing the Liguro-Provençal Arc, gathered and used the available resources in a similar way but with different intensity and effectiveness in time.

Whether or not the site was intended for specialised activities requires more investigation, but these data might be consistent with a long-distance logistic mobility model, assuming that PA1, PA2 (and PA3) represent successive steps in the Proto-Aurignacian implantation. Two interpretations are possible. Either this change in the raw material spectrum reflects a difference in the role played by the Riparo Mochi site within the territory (e.g. the epicentre of the mobility system would have shifted or expanded its radius), or this change documents populations who were better organised to supply rocks of greater suitability (i.e. indicating a higher degree in planning strategies). Between these two extreme cases, we might consider additional nuances relating to the technological system of populations in particular. In our region of study, it appears clearly that the selection of rocks became a critical phase during the Upper Palaeolithic. As an example, the Proto-Aurignacian lithic assemblage of the Grotte de l'Observatoire (Monaco) is composed of more than 50% of exotic rocks (Porraz et al. 2010). The model of an opportunistic selection should probably be diminished within this context.

Even if several other variables should be taken into account when considering the rapid diffusion of the Proto-Aurignacian in southern Europe and of the early Aurignacian in central Europe - such as the exploitation of specific niches requiring different food-acquisition technologies (Nigst et al. 2014) - the raw material spectrum identified at Riparo Mochi mirrors the mobility system of the Proto-Aurignacian groups, but also mirrors a socio-economic organisation that was, for the first time, partly oriented towards the supply of high quality rocks that could be transported and exploited over long distances. In this regard, the relatively small dimension of the Proto-Aurignacian tools - tentatively identified as the by-products of a rapid expansion of the Proto-Aurignacian foraging niches that may have been a response to interactions between rather different hominid populations, namely Neanderthals and modern humans (as suggested by Kuhn 2002) - could be more strongly related to the need to use the high quality raw material sparingly in a long-distance logistic mobility.

Some Western European key sites provide important data, but mainly on a local or regional scale, or without a high-resolution time scale (see Brooke 1999; Miller & Barton 2008; Pike-Tay et al. 1999;

Porraz et al. 2010; Slimak et al. 2006, among others). It is interesting to note that, like Riparo Mochi and the Grotte de l'Observatoire, the site of l'Arbreda in Spain (Ortega 2002) and the rockshelter of Sóllyomkút, in Hungary (Mester 2000) also document rock transportation over long distances. To date, there is no straightforward explanation to clarify the underpinnings of the rapid and supposedly homogeneous expansion of the Proto-Aurignacian in Italy, and along the Mediterranean rim, but it is likely that regional peculiarities (natural paths, human presence/absence and economic opportunities) determined various scenarios and different rhythms of dispersal for the Proto-Aurignacian groups (Porraz et al. 2010). The Liguro-Provençal Arc sheds light on one of these scenarios.

Conclusion

The site of Riparo Mochi shows that distinct occupation phases of the Proto-Aurignacian "colonisation" took place over a short time span. It also shows the existence of groups who were exploiting a large territory since the earliest occupation of the site. Human groups who inhabited Riparo Mochi adapted their raw material provisioning strategies to the geological context, by moving raw materials over long distances. Such a settlement system was certainly influenced by the geomorphology of the Liguro-Provençal Arc, but its role in peopling and interactions should not be minimised.

The very early Upper Palaeolithic incomers into Western Europe were familiar with travelling over distances greater than 100 or 200 km. In that perspective, other evidence such as the marine shells found in the Proto-Aurignacian collection of Grotta di Fumane (Lessini Mounts, northeastern Italy), and most likely collected in the Adriatic sea around 400 km away from the site (i.e. the hypothetical OIS 3 Adriatic coastline, following Bertola et al. 2013), should not be considered as surprising in terms of circulation distance.

These first populations appear to have been very well organised and adapted, "mapping" resources and sharing data in a way that probably contributed to the success of their spreading. While this approach tries to explain the distribution patterns of the Proto-Aurignacian populations along the Mediterranean rim, we hope it also provides insight into other important archaeological issues.

ACKNOWLEDGEMENTS: The study was partly supported by the Dipartimento di Lettere e Filosofia, Università di Trento (Italia). One of us (GP) has been supported by the Programme Collectif de Recherche "ETICALP", piloted by D. Binder (CNRS, CEPAM) and funded by the Provence-Alpes-Côte-d'Azur region and the Alpes-Maritimes department. Permission was granted by the Soprintendenza per i Beni Archeologici della Liguria, in particular we thank Dr. A. Del Lucchese and Dr. E. Starnini. We are grateful to many people, especially A. Spinosi (città di Ventimiglia), M. A. Segré and the staff of the Museo Preistorico

dei Balzi Rossi. We are in debt to A. Segré who generously gave us direct information and original field documentation on the Riparo Mochi excavation. We thank the anonymous reviewers for their comments. We also thank Brian Martin for having reviewed the English text and Evelyn Egger for the German translation. S.G. conceived and directed the "Riparo Mochi Project", and performed technological and functional analysis; G.P. performed petrographical analysis; F.S. performed statistical analysis; all authors wrote the paper.

Literature cited

- Arobba, D. & Caramiello, R. (2009).** Analisi paleobotanica sui sedimenti del riparo Bombrini (Balzi Rossi, Ventimiglia). *Bulletin du Musée d'Anthropologie Préhistorique de Monaco* 49: 41-48.
- Andrefsky, W., Jr. (1994).** Raw-material availability and the organization of technology. *American Antiquity* 59: 21-34.
- Bamforth, D. B. (1986).** Technological efficiency and tool curation. *American Antiquity* 51: 38-50.
- Bamforth, D. B. (1990).** Settlement, raw material, and lithic procurement in the Central Mojave Desert. *Journal of Anthropological Archaeology* 9: 70-104.
- Bamforth, D. B. (1991).** Technological organization and hunter-gatherer land use: a California example. *American Antiquity* 56: 216-234.
- Banks, W. E., D'Errico, F. & Zilhao, J. (2013).** Human-climate interaction during the Early Upper Paleolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian. *Journal of Human Evolution* 64: 39-55.
- Beck, C. & Jones, G. T. (1990).** Toolstone selection and lithic technology in Early Great Basin Prehistory. *Journal of Field Archaeology* 17: 283-299.
- Bertola, S., Broglio, A., Cristiani, E., De Stefani, M., Gurioli, F., Negrino, F., Romandini, M. & Vanhaeren, M. (2013).** La diffusione del primo Aurignaziano a sud dell'arco alpino. *Preistoria Alpina* 47: 17-30.
- Bettinger, R. L. (1987).** Archaeological approaches to hunter-gatherers. *Annual Review of Anthropology* 16: 121-142.
- Bietti, A. & Negrino, F. (2007).** Transitional industries from Neandertals to anatomically modern humans in continental Italy: present state of knowledge. In: J. Riel-Salvatore & G. A. Clark (Eds.) *New approaches to the study of Early Upper Palaeolithic "transitional" industries in Western Eurasia*. BAR International Series 1620:41-60.
- Binder, D. (1994).** Recensement des disponibilités en matières premières lithiques dans la région Provence-Alpes-Côte d'Azur. *Rapport de prospection thématique, Synthèse du programme de recherche 1992-1994. Provence orientale et Provence Alpine*. Service Régional de l'Archéologie PACA. Unpublished Report.
- Binder, D. (1998).** Recensement des disponibilités en matières premières lithiques dans la région Provence-Alpes-Côte d'Azur. *Rapport de synthèse sur les prospections thématiques en Provence Rhodanienne 1995-1997*. Service Régional de l'Archéologie PACA. Unpublished Report.
- Binford, L. R. (1977).** Forty-Seven trips: a case study in the character of archaeological formation processes. In: R. V. S. Wright (Ed.) *Stone tools as cultural markers*. Australian Institute of Aboriginal Studies, Canberra, 24-36.
- Binford, L. R. (1978).** *Nunamiut Ethnoarchaeology*. Academic Press, New York.
- Binford, L. R. (1979).** Organization and formation processes: looking at curated technologies. *Journal of Anthropological Research*. 35: 255-273.
- Binford, L. R. (1980).** Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. *American Antiquity* 45: 4-20.

- Binford, L. R. (1991).** When the going gets tough, the tough get going. In: C. Gamble & W. A. Boisismier (Eds.) *Ethnoarchaeological Approaches to Mobile Campsites*. International Monographs in Prehistory, 25-138.
- Boldarian, A. T. (1991).** Folsom mobility and organization of lithic technology: a view from Blackwater Draw, New Mexico. *Plains Anthropologist* 36: 281-295.
- Bon, F. (2002).** L'Aurignacien entre Mer et Océan. Réflexion sur l'unité des phases anciennes de l'Aurignacien dans le sud de la France. *Mémoire de la Société Préhistorique Française* XXIX, 253 p.
- Broglio, A. (1994).** Il Paleolitico Superiore del Friuli e Venezia Giulia. *Atti della XXIX Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria*: 36-56.
- Brooke, S. B. (1999).** Aurignacian lithic economy and early modern human mobility: new perspectives from classic sites in the Vézère valley of France. *Journal of Human Evolution* 37: 91-120.
- Carr, P. J. (1994).** Technological organization and prehistoric hunter-gatherer mobility: examination of the Hayes Site. In: P. J. Carr (Ed.) *The organization of North American prehistoric chipped stone tool technologies*. International Monographs in Prehistory, Archaeological Series 7, Ann Arbor, Michigan. 35-44.
- Conard, N. J. & Bolus, M. (2003).** Radiocarbon dating the appearance of modern humans and timing of cultural innovations in Europe: new results and new challenges. *Journal of Human Evolution* 44: 331-371.
- Dini, M. & Conforti, J. (2011).** Lo sfruttamento del quarzo nel Musteriano, Uluzziano e Aurignaziano di Grotta la Fabbrica (Grosseto, Italia). *Rivista di Scienze Preistoriche* 61: 21-38.
- Douka, K., Grimaldi, S., Boschian, G., Del Lucchese, A. & Higham, T. (2012).** A new chronological framework for the Upper Palaeolithic of Riparo Mochi. *Journal of Human Evolution* 62: 286-299.
- Grimaldi, S. (in press).** The Proto-Aurignacian "knives" of the Riparo Mochi (Balzi Rossi, Italy). In: J. Marreiros, J. Gibaja & N. Bicho (Eds.) *Proceedings of the International Conference on Use-Wear analysis, Use-Wear 2012*. Cambridge Publishing Scholars, 2014.
- Grimaldi, S. & Santaniello, F. (2014).** New insights into Final Mousterian lithic production in western Italy. *Quaternary International* 350: 116-129.
- Higham, T., Wood, R., Moreau, L., Conard, N. & Ramsey, C. (2013).** Comments on "Human-climate interaction during the Early Upper Paleolithic: testing the hypothesis of an adaptive shift between the Proto-Aurignacian and the Early Aurignacian" by Banks et al. *Journal of Human Evolution* 65: 806-809.
- IBCM - International Bathymetric Chart of the Mediterranean (2014).** *Ocean Mapping Project of the Inter-governmental Oceanographic Commission*. <http://www.ngdc.noaa.gov/mgg/ibcm/ibcm.html>.
- Jones, T. G., Beck, C., Jones, E. E. & Hughes, E. R. (2003).** Archaeology lithic source use and paleoarchaic foraging territories in the Great Basin. *American Antiquity* 68: 5-38.
- Kelly, R. L. (1983).** Hunter-gatherer mobility strategies. *Journal of Anthropological Research* 39: 277-306.
- Kelly, R. L. (1988).** The three sides of a biface. *American Antiquity* 53: 717-734.
- Kelly, R. L. (1992).** Mobility/sedentism: concepts, archaeological measures, and effects. *Annual Review of Anthropology* 21: 43-66.
- Kelly, R. L. & Todd, L.C. (1988).** Coming into the country: early paleoindian hunting and mobility. *American Antiquity* 53(2):231-244.
- Kuhn, S. L. (1991).** "Unpacking" reduction: lithic raw material economy in the Mousterian of West-Central Italy. *Journal of Anthropological Archaeology* 10: 76-106.
- Kuhn, S. L. (2002).** Pioneers of Microlithization: the "Proto-Aurignacian" of Southern Europe. In: R. G. Elston & S. L. Kuhn (Eds.) *Thinking Small: Global Perspectives on Microlithization*. Archeological Papers of the American Anthropological Association, 12, 83-93.
- Kuhn, S. L. & Stiner, M. C. (1998).** The Earliest Aurignacian of Riparo Mochi (Liguria, Italy). *Current Anthropology* 39:175-189.
- Laplace, G. (1977).** Il Riparo Mochi ai Balzi Rossi di Grimaldi (Scavi 1939-1949). Les industries leptolithiques. *Rivista di Scienze Preistoriche* 32: 3-131.
- Lea, V. (2005).** Raw, pre-heated or ready to use: discovering specialist supply systems for flint industries in mid-Neolithic (Chasséen) communities in southern France. *Antiquity* 79:51-65.
- Leacock, E. (1969).** The Montagnais-Naskapi band. In: D. Damas (Ed.) *Contributions to Anthropology: Band Societies* (Bulletin 228). National Museums of Canada, Ottawa, 1-17.
- Lovis, A. A., Donahue, R. E. & Holman, M. B. (2005).** Long-distance logistic mobility as an organizing principle among northern hunter-gatherers: a Great Lakes Middle Holocene settlement system. *American Antiquity* 70:669-693.
- MacDonald, G. F. (1968).** *Debert: a Paleo-indian site in Nova Scotia*. Anthropology Papers 16, National Museum of Canada, Ottawa.
- Maroto, J., Soler, N. & Fullola, J. M. (1996).** Cultural change between Middle and Upper Palaeolithic in Catalonia. In: E. Carbonell & M. Vaquero (Eds.) *The last neandertals, the first anatomically modern humans: a tale about the diversity. Cultural change and humans evolution: the crisis at 40 KA BP*. Universitat Rovira i Virgili, Tarragona, 219-250.
- Mester, Z. (2000).** Sur la présence du silex de Świeciechów dans l'abri de Sölyomkút (montagne de Bükk, Hongrie). *Praehistoria* 1: 83-93.
- Miller, A. & Barton, M. C. (2008).** Exploring the land: a comparison of land-use patterns in the Middle and Upper Palaeolithic of the Western Mediterranean. *Journal of Archaeological Science* 35:1427-1437.
- Morrow, C. A. & Jefferies, R. W. (1989).** Trade or embedded procurement?: a test case from Southern Illinois. In: R. Torrence (Ed.) *Time, energy and stone tools*. University Press, Cambridge, 27-33.
- Negrino, F. (2002).** *Modificazioni tecno-tipologiche ed utilizzo delle materie prime nell'Appennino tosco-emiliano e nell'arco ligure tra il Paleolitico medio recente e Paleolitico superiore antico*. PhD dissertation. Università di Genova.
- Negrino, F. & Starnini, E. (2006).** Modelli di sfruttamento e circolazione delle materie prime per l'industria litica scheggiata tra Paleolitico inferiore ed Età del Rame in Liguria. *Atti della XXXIX Riunione dell'Istituto Italiano di Preistoria e Protostoria*: 283-298.
- Nelson, M. C. (1991).** The study of technological organization. *Archaeological Method and Theory* 3: 57-100.
- Nigst, P. R., Haesaerts, P., Damblon, F., Frank-Fellner, C., Mallol, C., Viola, B., Gotzinger, M., Niven L., Trnka, G. & Hublin, J.-J. (2014).** Early modern human settlement of Europe north of the Alps occurred 43,500 years ago in a cold steppe-type environment. *Proceedings of the National Academy of Science* 111 (40): 14394-14399.
- Normand, C. & Turq, A. (2005).** L'Aurignacien de la Grotte de Isturitz (France): la production lamellaire dans la sequence de la salle de S. Martin. *Archeologiques* 1: 375-392.
- Odell, G. H. (1996).** *Stone tools and mobility in the Illinois Valley. From hunter-gatherer camps to agricultural villages*. International Monographs in Prehistory, Archaeological Series 10, Ann Arbor.
- Onorotini, G. (2004).** Le Proto-Aurignacien: première culture de l'homme moderne de Provence et Ligurie. *L'Anthropologie* 108: 239-249.

- Ortega, D. (2002).** Mobilitat i desplaçaments dels grups caçadors-recol·lectors a inicis del Paleolític superior a la regió Pirinenca oriental. *Cypsela* 14: 11-26.
- Palma di Cesnola, A. (1993).** *Il Paleolitico superiore in Italia*. Garlatti e Razzai Editori, Firenze.
- Parry, W. J. & Kelly, R. L. (1987).** Expedient core technology and sedentism. In: J. K. Johnson & C. A. Morrow (Eds.) *The organization of core technology*. Westview Press, Boulder, Colorado, 285-304.
- Pearce, E. & Moutsiou, T. (2014).** Using obsidian transfer distances to explore social network maintenance in late Pleistocene hunter-gatherers. *Journal of Anthropological Archaeology* 36: 12–20.
- Pike-Tay, A., Cabrera Valdes, A. & Bernaldo de Quiros, F. (1999).** Seasonal variations of the Middle-Upper Palaeolithic transition at El Castillo, Cueva Morin and El Pendo (Cantabria, Spain). *Journal of Human Evolution* 36: 283-317.
- Pons-Branchu, E., Hamelin, B., Losson, B., Jaillet, S. & Brulhete, J. (2010).** Speleothem evidence of warm episodes in northeast France during Marine Oxygen Isotope Stage 3 and implications for permafrost distribution in northern Europe. *Quaternary Research* 74: 246–251.
- Porraz, G. (2005).** *En marge du milieu alpin - Dynamiques de formation des ensembles lithiques et modes d'occupation des territoires au Paléolithique moyen*. PhD, University of Aix-Marseille. Unpublished. 386 p.
- Porraz, G. & Negrino, F. (2008).** Espaces économiques et approvisionnement minéral au Paléolithique moyen dans l'aire liguro-provençale. *Bulletin du Musée d'Anthropologie Préhistorique de Monaco*, suppl. 1: 29-40.
- Porraz, G., Simon, P. & Pasquini, A. (2010).** Identité technique et comportements économiques des groupes protoaurignaciens à la grotte de l'Observatoire (Principauté de Monaco). *Gallia Préhistoire* 52: 33-59.
- Rockman, M. & Steele, J. (ed.) (2003).** *Colonization of unfamiliar landscapes. The archaeology of adaptation*. Routledge, London and New-York.
- Simon, P. (2007).** Aperçu des ressources en matières premières lithiques du Sud-est de la France (Provence et Côte-d'Azur). *Bulletin d'études préhistoriques et archéologiques alpines* 18.
- Slimak, L., Pesesse, D. & Giraud, Y. (2006).** Reconnaissance d'une installation du Protoaurignacien en vallée du Rhône. Implications sur nos connaissances concernant les premiers hommes modernes en France méditerranéenne. *Comptes Rendus Palevol*. 5: 909–917.
- Teyssandier, N. (2007).** L'émergence du Paléolithique supérieur en Europe: mutations culturelles et rythmes d'évolution. *Paléo* 19: 367-389.
- Tomasso, A. (2014a).** *Territoires, systèmes de mobilité et systèmes techniques à la fin du Paléolithique supérieur dans l'arc Liguro-provençal*. PhD Dissertation, Université de Nice/Sophia Antipolis and Università di Pisa.
- Tomasso A. (2014b).** Pérennité et évolution des territoires d'approvisionnement au Paléolithique supérieur: l'exemple de l'Épigravettien de la grotte des Enfants (Ventimiglia, Italie). In: M. Otte (Ed.) *Modes de contacts et de déplacements au Paléolithique eurasiatique*. ERAUL 140, Université de Liège / Archéologiques 5, MNHA-CNRA Luxembourg, 513-532.
- Torrence, R. (1983).** Time budgeting and hunter-gatherer technology. In: G. Bailey (Ed.) *Hunter-gatherer economy in prehistory*. Cambridge University Press, Cambridge, 11-22.
- Torrence, R. (1989).** *Time, energy and stone tools*. Cambridge University Press, New York.
- Watts, W. A., Allen, J. R. M. & Huntley, B. (2000).** Palaeoecology of three interstadial events during oxygen-isotope Stages 3 and 4: a lacustrine record from Lago Grande di Monticchio, southern Italy. *Palaeogeography, Palaeoclimatology, Palaeoecology* 155: 83–93.
- Wood, R., Barroso Ruiz, C., Caparros, M., Jorda Pardo, J. F., Galvan Santos, B. & Higham, T. (2012).** Radiocarbon dating casts doubt on the late chronology of the Middle to Upper Palaeolithic. *Proceedings of the National Academy of Sciences* 110 (8): 2781–2786..