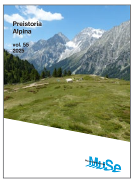

Preistoria Alpina

ISSN 0393-0157

https://www.muse.it/home/ricerca-e-collezioni/editoria-muse/riviste-e-collane/preistoria-alpina/

Museo delle Scienze

Article / Articolo

Mesolithic rock crystal knappers at Staller Sattel (South Tyrol, Italy). Technological know-how, on-site activities and mobility based on the STS 4A lithic industry

Ursula Wierer[1*], Klaus Kompatscher[2], Nandi Maria Hrozny Kompatscher[2], Simona Arrighi[3,4], Stefano Bertola[5]

[1] Soprintendenza Archeologia Belle Arti e Paesaggio della Città Metropolitana di Firenze e della Provincia di Prato, Firenze
[2] Via Leonardo da Vinci 15, Bolzano
[3] Università degli Studi di Siena, Dipartimento di Scienze Fisiche, della Terra e dell'Ambiente, Siena
[4] Centro Studi sul Quaternario odv, Sansepolcro, Arezzo
[5] Università degli Studi di Ferrara, Dipartimento di Studi Umanistici – Sezione di Scienze Preistoriche e Antropologiche, Ferrara

Key words

- Eastern Alps
- Early Mesolithic
- Lithic industry
- Petrographic and micropalaeontological analyses
- Techno-typological study
- Use-wear analysis

Abstract

The rock-crystal and chert assemblage from the Early Mesolithic site of Staller Stattel STS4A (Antholz, South Tyrol, 2,125 m a.s.l) provides insights into the hunter-gatherer lifeways in the inner-Alpine mountain areas. Rock crystal found in the fissures of the Tauern Window was flaked on site. Knappers combined typical Sauveterrian schemes with crystal-specific solutions to reduce this mineral. Use-wear traces on tools indicate butchering, hide- and woodworking, consistent with the mountain-base-camp nature of STS4A. Petrographic and micropalaeontogical analyses conducted on the chert artefacts suggest the provenance of seasonal groups and the territories they traversed before reaching Staller Sattel. Dolomitic Buchenstein chert was knapped on site for producing small armatures. Long-distance mobility is documented by finished artefacts consistent with chert from the Belluno-Friulian Prealps. The suggested south-north direction is discussed, showing complementarity use of lithic raw-materials among coeval sites. Finally, the presence of radiolarite from the Northern Calcareaous Alps further attests to the crossing of the main Alpine ridge by Mesolithic populations.

Parole chiave

- Alpi orientali
- Mesolitico antico
- Industria litica
- Analisi petrografica e micropaleontologica
- Studio tecno-tipologico
- Analisi delle tracce d'uso

Riassunto

L'industria in cristallo di rocca e selce di Passo Stalle STS4A (Anterselva, Sudtirolo, 2.125 m s.l.m.) fornisce nuovi dati sulla frequentazione dei cacciatori-raccoglitori mesolitici dei territori alpini più interni. Il quarzo ialino, presente nelle fessure della Finestra dei Tauri, veniva scheggiato combinando la tecnologia sauveterriana con soluzioni specifiche per il cristallo. Le tracce d'uso sugli strumenti prodotti parlano di macellazione, lavorazione della pelle e del legno, in linea con l'interpretazione del sito come campo base. Analisi petrografiche e micropaleontologiche della componente in selce indicano la provenienza dei gruppi, ovvero i territori attraversati prima che giungessero a STS4A. La selce dolomitica del Buchenstein/Livinallongo era scheggiata nel sito. La mobilità a lungo raggio è documentata da prodotti finiti, ricavati da selce compatibile con gli affioramenti delle Prealpi Bellunesi e Friulane. La direttrice sud-nord viene discussa nel contesto di siti coevi, mostrando un uso complementare delle materie prime litiche. La presenza della radiolarite delle Alpi Calcaree Settentrionali suggerisce contatti verso i territori nordalpini.

* E-mail corresponding Author: ursula.wierer@cultura.gov.it

The petrographic and micropalaeontological analyses were conducted by S.B., the technological study by K.K. and U.W., the typological analysis by U.W., the use-wear analysis by S.A.. The remaining parts were elaborated jointly by S.A., S.B., N.M.H.K., K.K. and U.W..

Ursula Wierer, Klaus Kompatscher, Nandi Maria Hrozny Kompatscher, Simona Arrighi, Stefano Bertola, 2025 – Mesolithic rock crystal knappers at Staller Sattel (South Tyrol, Italy). Technological know-how, on-site activities and mobility based on the STS 4A lithic industry. Preistoria Alpina, 55: 05-52.

1. Introduction

1.1 The use of rock crystal in the Alpine Mesolithic

The exploitation of rock crystal as raw material for the production of lithic artefacts is a well known phenomenon in the Alpine Mesolithic. Initial observations in the 1980s highlighted the presence of hyaline quartz artefacts at several sites in South Tyrol, in association with chert assemblages (Broglio & Lunz 1984; Lunz 1986). In studies about hunter-gatherer settlement and mobility patterns, the co-occurrence of specific lithic raw material varieties in varying percentages has been a key argument in connecting the numerous and wide spread Mesolithic sites of the Adige River basin into a site system. Specifically, the presence of rock crystal artefacts, not only near the primary sources of the Tauern Window but also at mountain sites located further south, and the discovery of individual rock crystal artefacts even in some rock shelters in the distant valley bottom around Trento, has been a significant argument for the seasonal vertical mobility model (Broglio & Lanzinger 1990; Broglio 1994).

In the Eastern Alps, Mesolithic sites with a rock crystal industry are concentrated in the mountain areas along the Italian-Austrian border, geographically near, or not far from the alpine fissures of the Tauern Window. Several sites are documented between Friuli and Carinthia (overview in Pessina 2005) and between South and North Tyrol (Lunz 1986; Mahlknecht 2002, 2007; Hammerschmied 2011; Kompatscher & Kompatscher 2011; Kompatscher et al. 2016). In this latter area the frequency of rock crystal, generally 40-80% of the artefacts per site, quickly decreases moving away from the primary sources (Bagolini et al. 1984; Kompatscher & Kompatscher 2011). Rock crystal mining attributed to the Mesolithic and Neolithic has been identified at Riepenkar, an alpine fissure at 2,800 m a.s.l. on the southern slope of the Olperer in the Tuxer Alps (Leitner & Bachnetzer 2011).

Due to the high abundance of primary sources in the Western Alps, it is not surprising that the use of Mesolithic rock crystal is well attested in those areas. An overview, concerning Swiss and Italian sites, is provided by Crotti et al. (2002). Some excavated sites are of particular interest due to their high percentages, 93-99%, of hyaline quartz (Auf der Maur & Cornelissen 2014; Curdy et al. 2003; Fontana et al. 2000; Raiteri 2017). Two Mesolithic rock-crystal fissures exploited as mines have been identified in Switzerland. At Fourcla da Strem Sut/Stremlücke, located at 2,817 m a.s.l. in the Swiss canton of Uri, two exceptional objects, antler beams interpreted as tools for crystal extraction or flaking hammers, could be recovered along with the extraction waste (Reitmaier et al. 2016; Cornelissen et al. 2022). Excavations at Fiescheralp, at 2,575m a.s.l. in the Swiss canton of Valais, led to the discovery of a rock crystal bearing fissure, with crystals knapped on site and transformed into artefacts (Hess et al. 2021, 2023). Sites with Mesolithic mining known so far are located at high elevation suggesting a profound knowledge of the territory, including its geological features and mineral resources (Hess et al. 2021).

1.2 Aim of the research

The study of the lithic assemblage of the Staller Sattel STS 4A site, mostly constituted by rock crystal, aims to enhance our knowledge about the lifeway of Early Mesolithic hunter-gatherers who frequented the inner-Alpine territories near the main watershed, during seasonal migrations. The interdisciplinary research carried out through lithic raw material analysis, techno-typological studies and use-wear analysis, aims to investigate the procurement and management of minerals and flakable rocks, the intra- and extra-site flaking processes, the technological know-how and the choices of tool production, the activities performed by the inhabitants of the site and their mobility patterns in both the local and wider territory.

2. Study area and site context

2.1 Geographical and geomorphological setting of the study area

The Mesolithic site of Staller Sattel STS 4A is located in the municipality of Rasen-Antholz in the Eastern Alps (South Tyrol, Italy), at 2,125 m a.s.l. The site takes its name from the Staller Sattel/Passo Stalle mountain pass (2,052 m a.s.l.), located a little further north on the Italian-Austrian border (Fig. 1). STS 4A lies on the southern slope of a wide, northeast to southwest oriented high-altitude-valley basin, shaped by glacial and fluvioglacial processes (see also Kompatscher at al. 2016). The entire area has been extensively modelled by active moraines and postglacial rockslides which led to the formation of several wet areas and moraine-dammed lakes, the largest being the Obersee (2,016 m a.s.l.; outline of 1,3 km, Austria). The western margin of the basin is formed by a steep rocky slope along which the paved road leads to the Antholzer/Anterselva Lake (1,641 m a.s.l., Italy) and to the eponymous valley. To the east, the basin gently slopes towards the Defreggen Valley (Austria).

Fig. 1 – *Location of the Staller Sattel Pass (Rasen-Antholz, South Tyrol, Italy) on the Italian-Austrian border (map base Tirol-Atlas, Universität Innsbruck).* / ***Fig. 1 –*** *Localizzazione del Passo Stalle (Rasun-Anterselva, Alto Adige) sul confine italo-austriaco (base cartografica: Tirol-Atlas, Universität Innsbruck).*

2.2 Geological setting of the study area

In order to introduce the lithic raw material study presented below, general information about the geological setting is provided here (see also Kompatscher et al. 2016). The rocky substrate of the Staller Sattel area is part of the Austroalpine domain, primarily constituted by crystalline rocks locally intruded by late Alpine magmatic masses (Fig. 2). The site lies to the south of the northeast-southwest oriented Defreggen-Antholz-Vals tectonic line where the variscan metamorphic basement of Antholz crops out. To the north of this line the variscan metamorphic basement of Tures crops out (gneiss, paragneiss, schists, amphibolites, marbles, phyllites, quartzites), locally intruded by extended Oligocene plutonic bodies (tonalites) crossed by

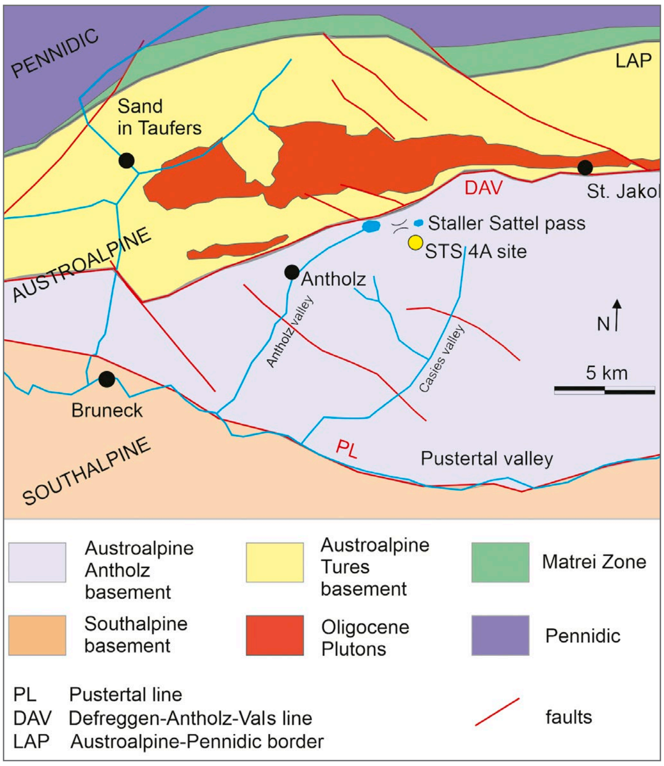

Fig. 2 – *Simplified geologic-tectonic model of the study area (modified from Cesare et al. 2009: 111, fig. 69, Carta Geologica d'Italia 1:50.000 Sheet 009 Anterselva). /* ***Fig. 2 –*** *Schema geologico tettonico semplificato dell'area d'indagine (modificato da Cesare et al. 2009: 111, fig. 69, Carta Geologica d'Italia 1:50.000 Foglio 009 Anterselva).*

both acid and basic dykes (Geological Map of Italy, scale 1:50,000, sheet 009 Anterselva/Antholz). Approximately 15 km to the south of STS 4A the Pustertal/Val Pusteria line, a significant east-west oriented regional tectonic line, separates the Southalpine basement and covers from the Austroalpine basement.

2.3 The site context. Stratigraphy, site formation and chronology

The STS 4A site is located on a flat terrace (2,125 m a.s.l.) where several other Mesolithic find-spots were identified (Fig. 3). The archaeological excavation of *locus* STS 4A covering 18 sqm, took place between 2009 and 2015. Stratigraphy, soil micromorphology and site formation processes have been discussed in the previous paper (Kompatscher et al. 2016). Podsolization, typical of coniferous forested soils in high-altitude environment, is the predominant soil formation process that occurred on sand and gravel deposits. The Mesolithic occupation corresponds to the first of two identified pedogenic cycles called "paleo-podsol" formed in an open-forest environment with an *Larix* and *Pinus cembra* community. Stratigraphic Unit (SU) 10 represents the residual of the Mesolithic living floor, formed by the accumulation of burning residues and flaking waste, and lies above the eluvial horizon of the paleo-podzol SU 11 (Fig. 4). SUs 3 and 4, which also contain lithic artefacts, fill a shallow depression corresponding to a void in the podzolic soil, and are interpreted as the result of anthropogenic reworking of the living floor. Several anthropogenic structures were documented during the excavation. Horizons 1 and 2, at the top of the sequence, belong to the current pedogenic cycle. The lithic artefacts found here originate from upward movement due to post-depositional processes. The results of the C14-AMS dating of seven charcoal samples (Kompatscher et al. 2016) place the stratigraphic sequence between 9137 ± 50 BP and 7861 ± 60 BP, corresponding to 8481-8267 cal. BC and 6866-6588 cal. BC (2 sigma) (Fig. 4). It is unclear whether the older data set referable to the Preboreal (SU 14 and 15), which dates a thin charcoal level at the base of the stratigraphy, originates from natural or anthropogenic fires. The younger dataset corresponding to the Boreal / Boreal-Atlantic boundary and associated with the lithic artefacts, is undoubtly of anthropogenic origin.

The lithic artefacts are found from the top of unit 2 down to unit 11 in the stratigraphy, within a total vertical depth of only 7 cm. The spatial distribution, best shown by the 2,447 three-dimensionally recorded artefacts, shows a ring-shaped concentration surrounding the above mentioned anthropogenic disturbance area (Fig. 5).

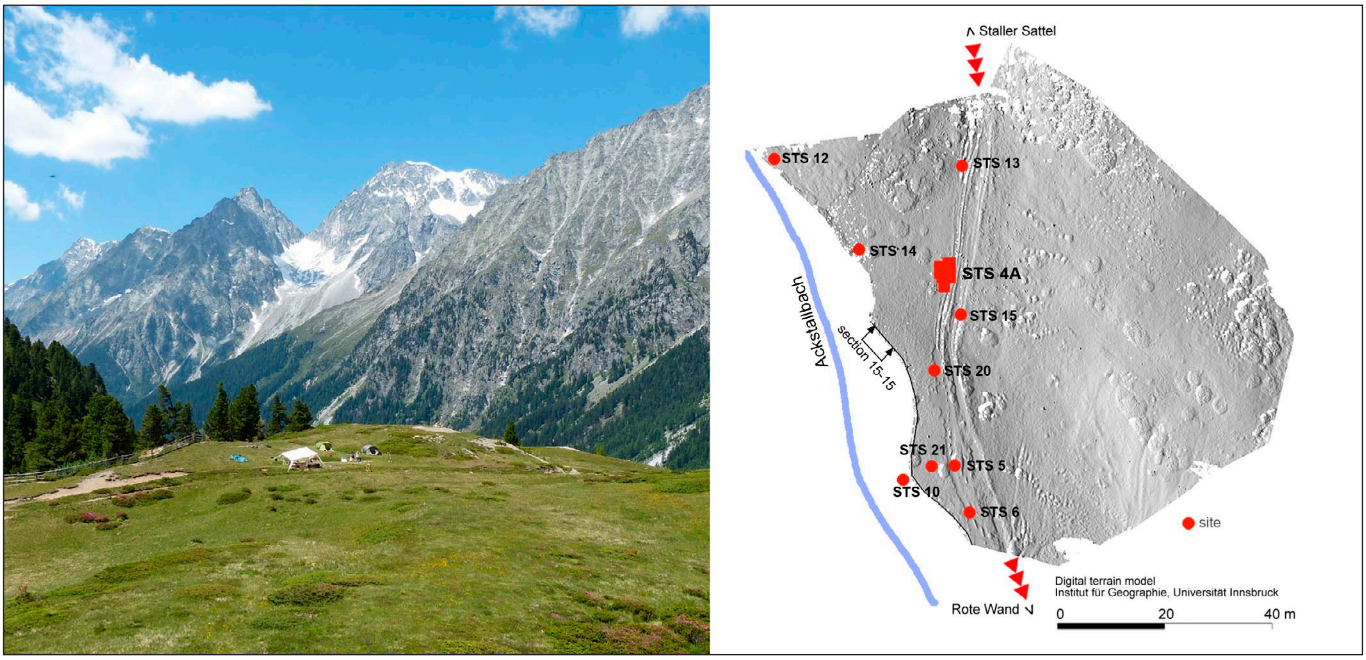

Fig. 3 – *View of the Ackstall terrace with the mesolithic site Staller Sattel STS 4A during excavation (left); digital terrain model and location of the lithic findspots (right). /* ***Fig. 3 –*** *Vista del terrazzo Ackstall con il sito mesolitico Staller Sattel STS 4A in corso di scavo (sinistra); modello digitale terrestre con ubicazione dei ritrovamenti litici (destra).*

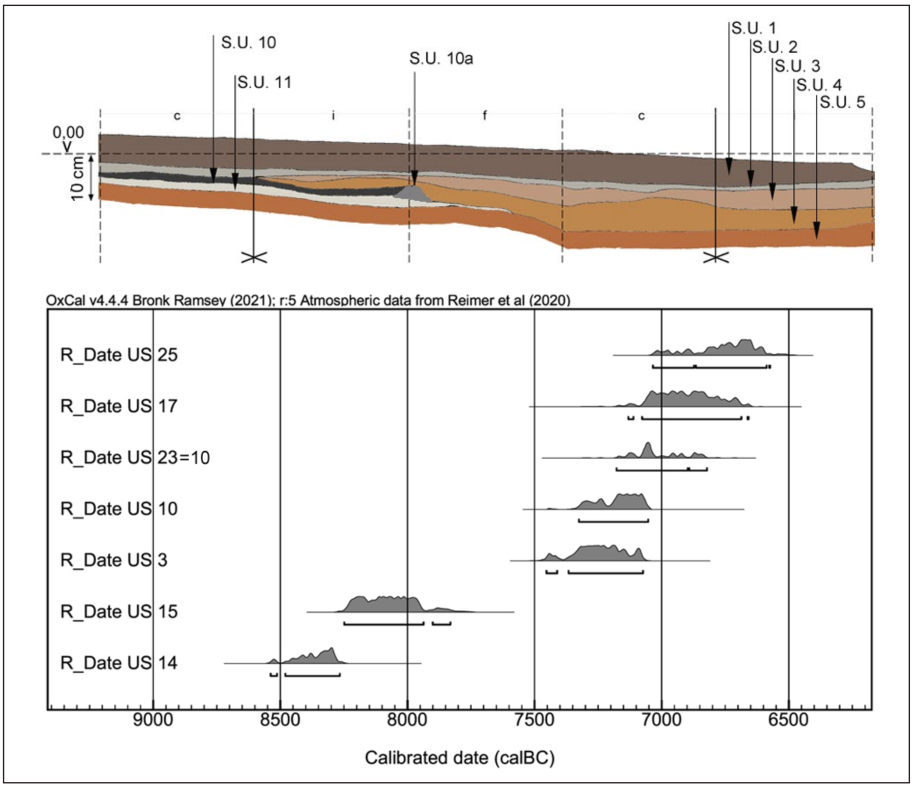

Fig. 4 – *Part of the stratigraphic section 5-5 with main stratigraphic units (above); dendro-chronological curves of the 14C-AMS datings of STS 4A site, calibrated with Oxcal v4.4.4 (below). / **Fig. 4** – Porzione della sezione stratigrafica 5-5 con principali unità stratigrafiche (sopra); curve dendrocronologiche delle datazioni 14C-AMS di STS 4A calibrate con Oxcal v4.4.4 (sotto).*

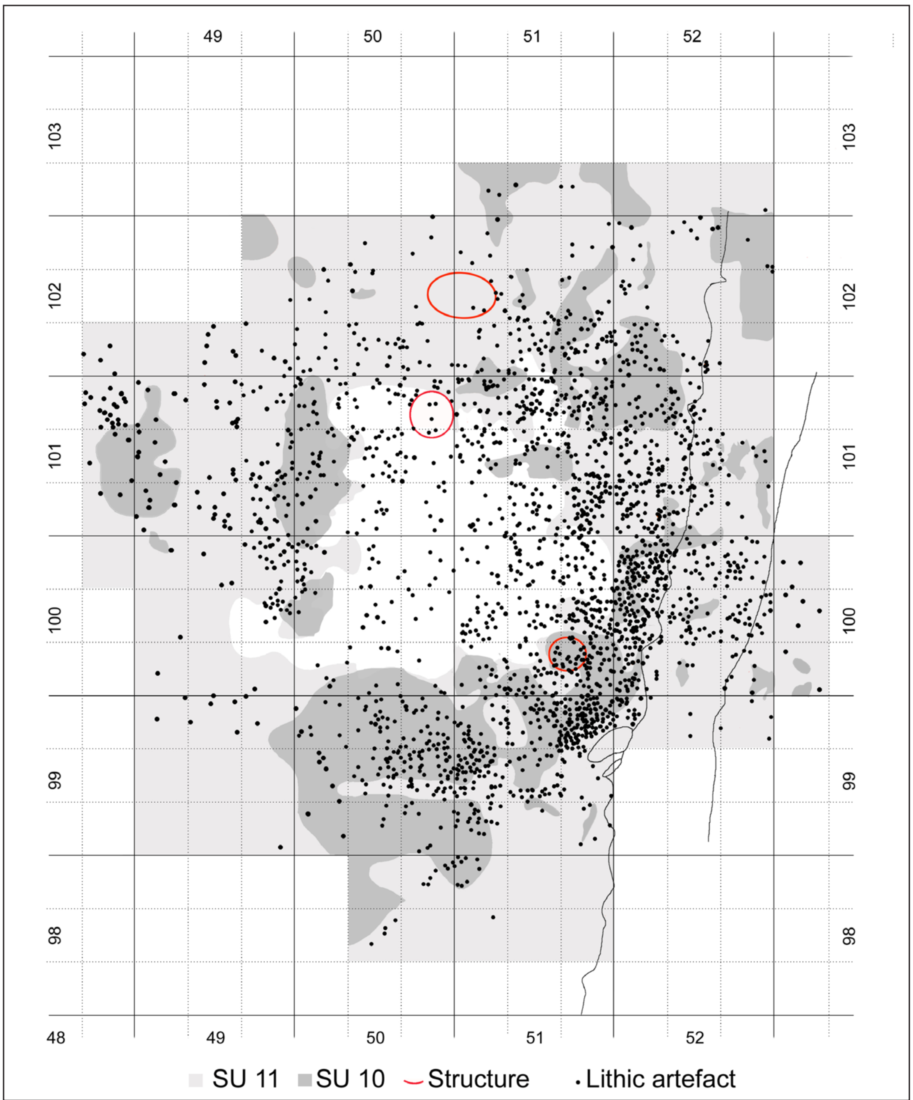

Fig. 5 – *The spatial distribution of the 2,447 lithic artefacts three-dimensionally positioned during excavation. Anthropogenic structures are shown in red / **Fig. 5** – Distribuzione spaziale dei 2.447 reperti litici posizionati in fase di scavo. In rosso le strutture antropiche.*

3. Materials and methods

3.1 Materials

The lithic industry from Staller Sattel STS 4A constits of 10,534 elements, 75% of which is very small flaking waste. A total of 2,447 pieces have been spatially recorded in the three-dimensional excavation grid and numbered separately („RR“ for „Reperti Registrati”). The remaining 8,087 artefacts were collected by water screening the sediment using 1mm meshes; their spatial distribution has been recorded according to the excavation units (33 x 33 cm).

The industry has a fresh appearance. Only 3-4% of the 790 studied artefacts show worn edges, which could be at least partly recent due to the site location next to a hiking trail. About 4-6% of the pieces show fire-induced alteration, a surely underestimated percentage difficult to be recognized on rock crystal. Heat leads to a higher fragility of the artefacts but does not alter their colour. Except very sporadic chert artefacts, the assemblage is not affected by patina. About ten artefacts, made both from rock crystal and from chert, show superficial residues which could be traces of pitch. The fragmentation rate of the analysed artefacts is very high, about 65%. Given the condensed stratigraphy, the sample has been studied as a single assemblage without distinction between stratigraphic units.

3.2 Methods of the techno-typological analysis

The study has been conducted on a selection of 790 artefacts consisting of the technologically diagnostic elements and of the retouched pieces (Tab. 1). About 90% of this selection are registered items and 10% were recovered through sieving*.* Particular attention has been paid to the technological study of rock crystal, as hyaline quartz constitutes about 90% of the industry. Experimental flaking aimed to test the fracture mechanics and knapping properties of this mineral. A significant aspect of the technological study was the analysis of the external crystal surfaces, preserved on 25% of the analysed items, in order to orient the artefacts according to the crystal geometry. The axonometric drawing of selected artefacts within an ideal crystal was useful for reconstructing the crystal reduction methods.

The few refittings (n. 10) and conjoins of ancient fractures are not the result of systematic research. Rock crystal is difficult to refit. It is colourless and transparent, so to the eye confuses the features of opposing faces. The distinction between blades and bladelets (length/width >= 2) is set at a width of 11 mm. This was established after plotting the totality of width values, which revealed a gap in the records between 9 and 11 mm.

The typological analysis has been carried out according to G. Laplace’s typology (1964), except for the splinterd pieces classified according to Crémilleux and Livache (1976). Subtypes of the backed points and geometrics have been classified according to the typology of Broglio and Kozlowski (1984). The definition of diagnostic variants among the microlithic armatures is based on the descriptions published by the G.E.E.M. (1969, 1972).

3.3 Methods of the raw material analysis

The raw material analysis was developed through several steps. First, the entire assemblage was divided into two groups: 1. A group of quartz (hyaline/milky/vein quartz) and quartzites, referable to provenance areas near the site; 2. A group of cherts from different, non-crystalline geological contexts attesting more distant provenance areas. The first group has not been studied in detail to determine precise source areas, assuming their more or less local origin. In contrast, detailed petrographic analyses were carried out on the second, smaller but significant, group of allochtonous chert artefacts (n. 123).

At first, they were grouped according to their macroscopic features, separating those affected by thermal or surface alterations. Then, all the chert artefacts were analysed in detail under a stereomicroscope (Optika SZ series, up to 90X with camera Moticam 3+ USB 3). Diagnostic features such as transparency, lustre, colour, cortex characteristics, textures and structures, fossil content and accessory minerals helped classify the chert types (cherts or radiolarites) and to group and assign each chert lithotype to specific geological formations and/or secondary sources. Microfossils were identified using comparison atlases and other reference works (Robaszynski & Caron 1995; Premoli-Silva & Sliter 1995, 2002; Bolli et al. 1985).

Detailed photos of the microfacies of the chert artefacts were taken and described to support our attributions. The preserved natural surfaces on the artefacts (cortex or neo-cortex) allowed us to determine whether the sourcing occurred near primary outcrops or from secondary sources (slope detritus, soils, torrent pebbles), as well as the morphology of the raw materials exploited (slab, nodule, cobble). The archaeological samples were compared with similar geological samples for definitive formational attribution.

Both Italian and Austrian geological cartography were consulted to hypothesize possible displacements between the site and the source areas (Carta Geologica d’Italia, 1:100.000 e 1:50.000 ISPRA; Mandl 2000; Gawlick et al. 2009; Brandner et al. 2011; Brandner & Gruber 2012).

Tab. 1 – *Techno-typologically analyzed mesolithic artefact assemblage from Staller Sattel STS 4A site, divided by lithic raw material. /*
Tab. 1 – *L’industria mesolitica di Passo Stalle, sito STS 4A, sottoposta ad analisi tecno-tipologica. Divisione per materia prima litica.*

Lithic raw material:	Cores	Unretouched artefacts	Retouched artefacts – armatures	Retouched artefacts – common tools	*Debris* and indeterminate fragments	Natural blocks and slabs	Waste from armature – and toolmaking	Total
Rock crystal	12	379	108	83	58		9	649
Buchenstein chert	6	34	12	3	9	1		65
Rosso Ammonitico chert		3	5					8
Southern Prealpine chert	1	20	5	7	5			38
Filonian “pegmatitic” quartz		3	1	1	4	1		10
Northalpine radiolarite			2					2
Quartz/Quartzite		7			7	1		15
Indeterminable		2	1					3
Total	19	448	134	94	83	3	9	790
% Retouched artefacts (n.228)			59%	41%				100%

3.4 Methods of the use-wear analysis

Use-wear analysis was carried out on a sample of 98 artefacts, selected among retouched tools and unretouched items recovered from stratigraphic units 1, 2, 3, 10 and 14. The analysed artefacts were made on rock crystal (n. 83), Buchenstein chert (n. 4) and other Southalpine cherts (n. 11). The study focused on domestic tasks carried out at the site. The analysis of impact traces on the armatures was not part of the research.

Use-wear analysis of the rock crystal artefacts followed the specific methodology developed for this material (Fullagar 1986; Pignat & Plisson 2000; Knutsson et al. 2015; Ollé et al. 2016). In examining tool surfaces, we focused on scarring, striations, polishing, and abrasions. Regarding scarring, the development of microchipping on rock crystal does not consistently correspond with the morphologies observed for other raw materials (Fernández-Marchena & Ollé 2016). This difference is attributed to specific regions of the crystal artefacts, primarily on the ventral face, which exhibit surface undulations caused by the frequent presence of lancets. These undulations alter the surface of the tool, leading to increased stress on the worked material during use. As a result, when stress causes an edge fracture, the microchipping takes on the morphology of the lancets (Fernández-Marchena & Ollé 2016). In contrast, in areas without lancets, the microchipping exhibits a conchoidal appearance (Knutsson 1988; Fernández-Marchena & Ollé 2016). Therefore, our analysis of edge scarring primarily focuses on the dimensions, localization, and arrangement of the scars, rather than their morphological characterization.

The analysis of implements made of Buchenstein and other cherts was based on the identification of edge damage, rounding, polish, and striations (Tringham et al. 1974; Odell & Odell-Vereecken 1980; Keeley 1980; Vaughan 1985).

All lithic implements were analysed using both low-power (Tringham et al. 1974; Odell & Odell-Vereecken 1980; Odell 1981) and high-power approaches (Keeley 1980; Vaughan 1985; Van Gijn 1990) with the aid of different microscopes:

- a 3D digital Hirox KH 7700 microscope equipped with an MX-G 5040Z body and an AD-5040Lows lens (20x-80x magnifications) for LPA, and equipped with an MXG-10C body and OL 140 II lens (140x-560x magnifications), a polarizing filter and an AD-10S Directional Lighting Adapter for HPA examinations.
- a Zeiss Axio Scope 7 reflected light optical microscope with 10 oculars and three objective lenses (100-400x magnifications), equipped with polarizing filters and DIC for HPA examinations.

Traces on the archaeological lithic tools were interpreted by comparing them with an experimental reference collection, composed of experimental tools made from chert and rock crystal and representing a wide range of uses and activities (see chapter 8.1).

4. Lithic raw material analysis and provenance

4.1 Local lithic resources: Rock crystal primary sources

Rock crystal makes up about 90% of the lithic assemblage recovered at Staller Sattel STS 4A site. Mineralogical investigations and fluid inclusions analysis, which have been conducted elsewhere

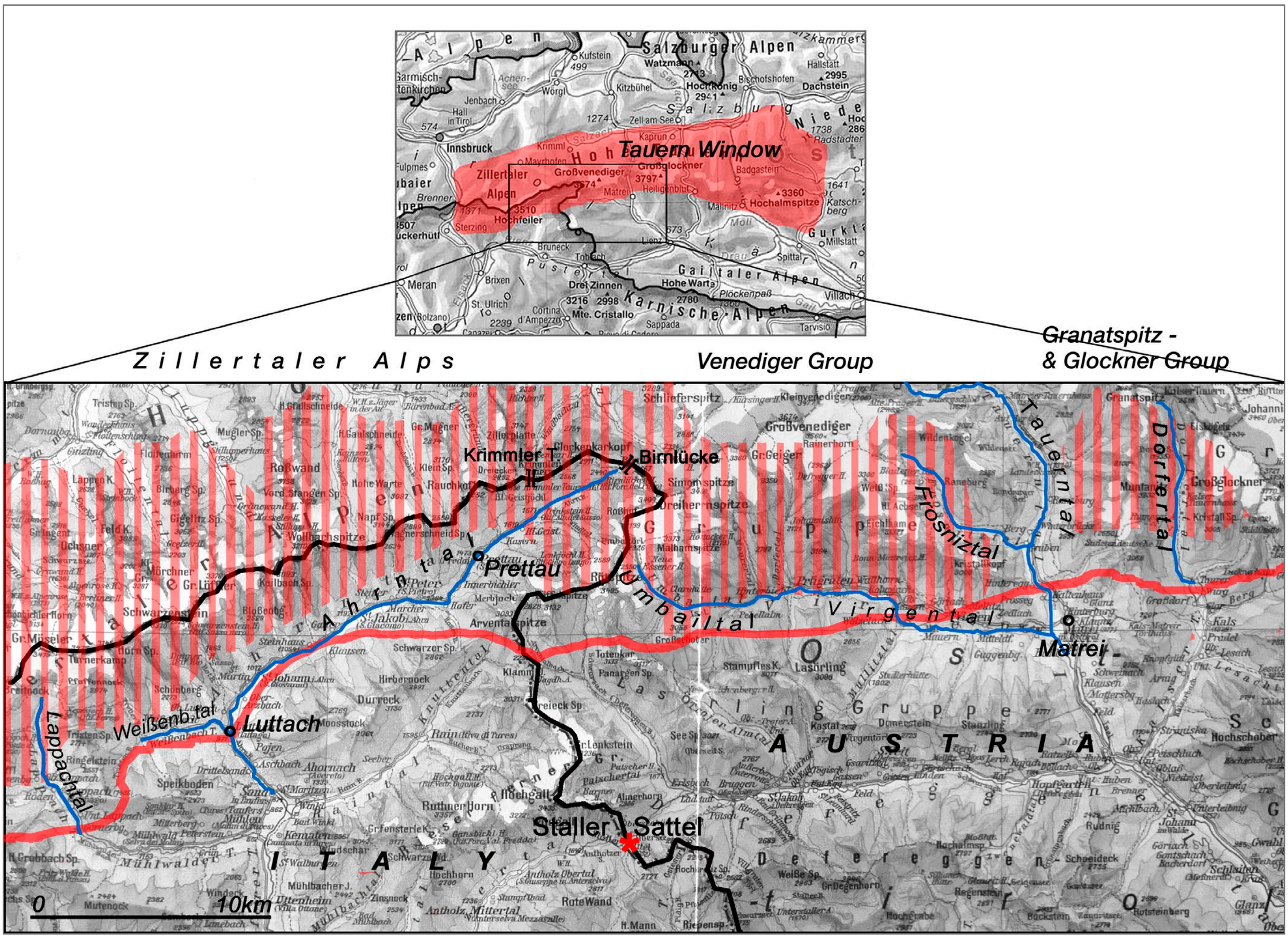

__Fig. 6 –__ Extension of the tectonic Tauern Window in the Eastern Alps (above, according to Seemann, 1994); the distance of the Staller Sattel from the southern margin of the Tauern Window (red line) and from the nearest areas known for alpine fissures (red-striped) (below, according to Exel 1980; 1982). /
__Fig. 6 –__ Estensione della finestra tettonica dei Tauri nelle Alpi Orientali (in alto, secondo Seemann, 1994); la distanza di Passo Stalle dal margine meridionale della finestra dei Tauri (linea rossa) e dalle più vicine aree note per fessure alpine (tratteggio rosso) (sotto, secondo Exel 1980; 1982).

to determine the potential sources of the material (Niedermayr 2011), have not been taken into consideration. The presence of numerous artefacts bearing portions of natural crystal faces, indicating an origin from automorphic minerals, as well as the abundance of transparent elements, is consistent with the hypothesis of its genesis within open alpine fissures (de Lombera Hermida 2008, Niedermayr 2011). The Staller Sattel is located near the southern border of the tectonic Tauern Window. It stretches over 160 km in a west-east direction, from the Brenner Pass to the Katschberg Pass, encompassing the Zillertaler Alps and the Hohe Tauern (Seemann 1994) (Fig. 6 above). The window exposes the deeper-lying subpennidic and pennidic units of the Alps (Schmid et al. 2004; Schmid et al. 2013), traditionally known as the *Zentralgneis* and the *Untere und Obere Schieferhülle*. These tectonic units are rich in alpine fissures that developed during the uplift. The cavities had been filled by hot hydrothermal fluids, which underwent slow cooling during geological time (Niedermayr 1994; Kandutsch et al. 1998). The fluids crystallized, forming the fillings of the fissures. The resulting minerals, frequently in the form of colourless hyaline quartz or smoky quartz crystals, have been object of collection and trade for many centuries.

Based on the geographical proximity, possible provenance areas for the STS 4A hyaline quartz can be hypothesized. Important areas with rock crystal fissures are located north of Staller Sattel, within a belt that stretches from the north-west to the north-east (Fig. 6 below). To the west, one encounters the fissures of the Zillertaler Alps, with areas historically exploited by mineral collectors. On the present-day Italian slope, they are known around Lappach/Lappago, Neves, Weissenbach/Rio Bianco and along the main Alpine ridge up to the Birnlücke/Forcella del Picco (Exel 1980). The Venedigergroup extends from here towards the east, with crystal fissures roughly between Prettau/Predoi and Matrei, delimited by the Umbail-, Virgen- and Frossnitz Valleys. This district is the closest to Staller Sattel, located at a distance of roughly 15 to 30 km in direct line. A further area with primary sources lies to the east of Matrei and the Tauern Valley, between the Granatspitz- and Glocknergroup, today accessible via the Dorfer Valley (Exel 1982).

Modern mineral collectors move in rough terrain at significant altitude. However, it should be kept in mind that the more easily accessible areas may have been extensively exploited in the past. Therefore it can be assumed that the availability of rock crystal was considerably different in the Postglacial, with a higher abundance also at lower altitudes.

4.2 The most local lithic resources: filonian quartz (“pegmatitic quartz”) and quartzites

Ten artefacts were made on meta-magmatic quartz mineralizations (so called “pegmatitic quartz”), often in association with feldspars, tormalina and biotite, crossing the paragneiss of the Tures basement (Pl. 1: 5-6). Close to the Staller Sattel pass, on the northern slope of the valley, these are rather frequent. Quartz mineralizations are also found in the Oligocene plutonites, both in dykes and in the thermal metamorphic aureole.

Other expoitable local lithologies are represented by white or grey metamorphic quartzites which form banks up to 0.5 m thick in the Austroalpine (Antholz and Tures) variscan paragneiss basement (Pl. 1: 7-8). Their use at STS 4A is not proven (see chapter 6.7). In sum, flakable rocks available within a short distance from the site, less than 5 km, are scarce and of poor quality.

4.3. Non-local lithic resources from the Austroalpine

4.3.1 Radiolarites from the Chiemgau/Ruhpolding Group (Upper Jurassic)

Two armatures, a backed fragment and a geometric piece (triangle) are made of light grey radiolarite (Pl. 1: 1-2). The raw material shows strong similarities with the radiolaritic horizons, specifically with the radiolarian marls that are typical of the so called “Chiemgau-Schichten” (Middle Jurassic). The Chiemgau formation has recently been included in the Ruhpolding Group of the Northern Calcareous Alps (Austria/Bavaria) (Gawlick et al. 2009). Artefacts made from these lithotypes are quite frequent at the Mesolithic high-altitude site Ullafelsen (Sellrain, Innsbruck, Austria), located in a side valley, the Fotscher Valley, some tens of kilometers northwest of the Brenner Pass (Pl. 1: 3-4) (Bertola 2011a). Their features are very similar to those observed on the STS 4A-artefacts. The nearest comparable outcrops to Staller Sattel are located in the Karwendel Mountains, particularly near the Achensee, north of the Inn Valley (Fig. 7).

4.4. Non-local lithic resources from the Southalpine

They represent the majority of the non-local flaked artefacts. These cherts originate from the Eastern Southalpine sedimentary covers, extending approximately 100 km south of the Puster Valley (from the Dolomites to the Prealps facing the Po Plain) and about 150 km in an east-west direction (from the Adige Valley to the Tagliamento Valley). Within this large area the features of the cherts recovered at STS 4A allow to hypothesize the most probable provisioning routes and areas. The above mentioned cherts have been grouped and assigned to specific geological formations and provenance areas as described in the following chapters and related macrophotoes. Percentages are reported in figure 8 and table 2.

4.4.1 Dolomites. Buchenstein cherts (Triassic, Ladinian)

The most frequently used chert at STS 4A is the Buchenstein (Neri et al. 2007: 51-54), certainly not for its quality, but because closest to the site and generally frequent in the Dolomites. Among the geological formations different sub-units have been described (*Knollenkalke, Bänderkalke, Plattenkalke*). The STS 4A cherts have been mainly collected from *Plattenkalk*-like horizons. The silicified horizons (layers) or nodules in the pelagic limestone are mostly dark, with less frequent green varieties. The chert microfacies are characterized by the presence of radiolarians, calcisferes, pelagic bivalves and volcanic inputs (Pl. 2: 1-6). Cherts are almost always inhomogeneous, frequently laminated, slightly vitreous and somewhat rough to the touch due to incomplete silicification. Among the STS 4A assemblage, there are also cortical artefacts, not much exploited cores, and fragments of small natural slabs, suggesting that the raw material was procured from not too far from the site. Blocks were collected from the *detritus* near the outcrops or from soils. The nearest outcrops with quite abundant cherts are found in the area of Prags/Braies, between the Pragser Wildsee/Lago di Braies and the Toblacher See/Lago di Dobbiaco, about 22 km in a direct line south of STS4A. These outcrops lie at 1,230 m a.s.l. and therefore easily accessible from the Puster Valley (Fig. 7).

Tab. 2 – *Results of the petrographic analyes of the STS 4A artefacts different from rock crystal (BL-FR = Belluno-Friulian Prealps). /* ***Tab. 2 –*** *Risultati delle analisi petrografiche dell’industria di STS 4A diversa da cristallo di rocca (BL-FR = Prealpi Bellunesi-Friulane).*

Lithology	**Nr**	**%**
Filonian quartz and quartzites	6	5,0
Radiolarites – Chiemgau Group	2	1,6
Buchenstein	64	53,3
Rosso Ammonitico Superiore	8	6,7
Fonzaso – Prealps BL-FR	2	1,6
Soccher/Fadalto – Prealps BL-FR	5	4,2
Maiolica – Prealps BL-FR	8	6,7
Scaglia Variegata Alpina – Prealps BL-FR	8	6,7
Scaglia Rossa – Prealps BL-FR	14	11,7
Non identified	3	2,5
Total	120	100

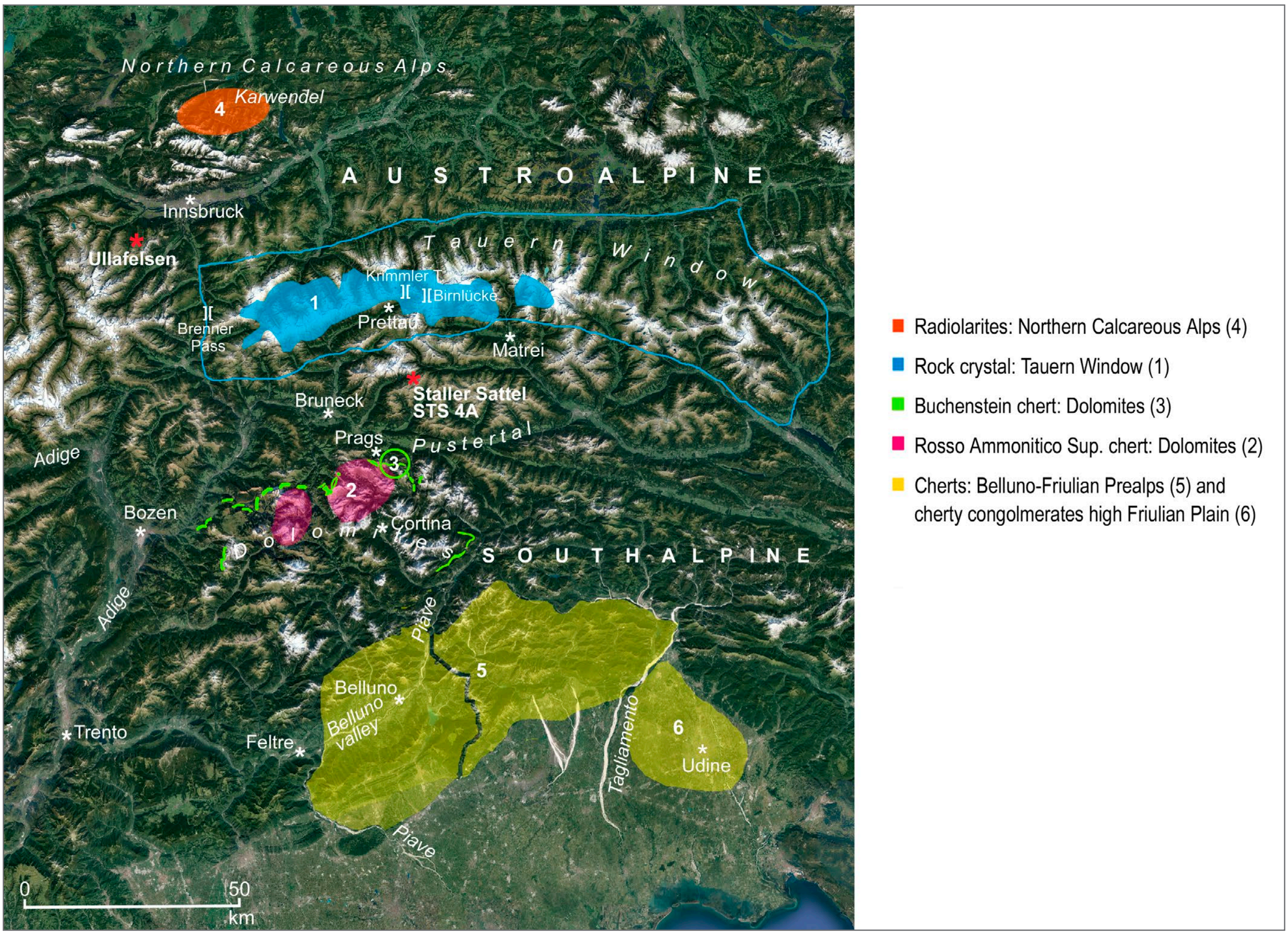

Fig. 7 *– Localization of the sourcing areas of chert and radiolarite compatible with the raw materials identified at Staller Sattel STS 4A(aerial photo from Google Earth). /* ***Fig. 7*** *– Localizzazione delle aree di provenienza delle selci e radiolariti compatibili con le materie prime identificate a Staller Sattel STS 4A (foto aerea da Google Earth).*

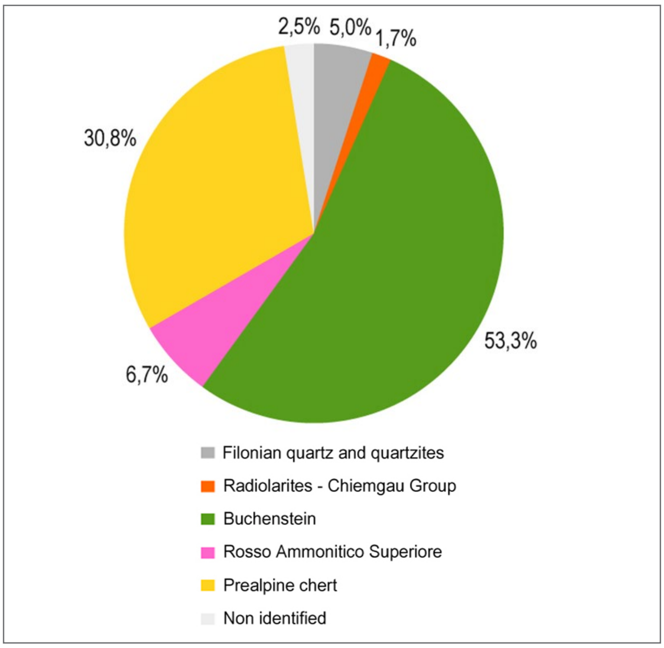

Fig. 8 *– Results of the petrographic analyes of the STS 4A artefacts different from rock crystal (the Prealpine chert comes from the Belluno-Friulan Prealps). /* ***Fig. 8*** *– Risultati delle analisi petrografiche dell'industria di STS 4A diversa da cristallo di rocca (la selce prealpina provine dalle Prealpi bellunesi-friulane).*

4.4.2 Dolomites. Rosso Ammonitico and Maiolica cherts (Upper Jurassic-Lower Cretaceous)

In the Dolomites, the pelagic (Jurassic to Cretaceous) Southalpine series has been nearly completely eroded by the Alpine uplift. Isolated patches are found near Cortina d'Ampezzo, in the Fanes–Sennes–Prags/Braies area, and on top of the Sella and the Puez/Gardenaccia group, at elevations between 2,500 and 3,500 m a.s.l. (Geological Map of Italy 1: 50,000, sheets 028 La Marmolada and 029 Cortina d'Ampezzo; Brondi et al. 1977: 19; Lukeneder 2011). The flakable cherty formations include the Rosso Ammonitico (small nodular micritic Tithonic horizons with red cherts) and the Maiolica, characterized by dark grey cherts (Bini et al. 1995), whilst the outcrops of Marne del Puez, Scaglia Variegata Alpina and Scaglia Rossa (here referred to as "Ruoibes de Inze formation", near Antruilles; Sauro & Meneghel 1995: 16) are very sporadic and highly tectonized. The outcropping series have limited geographic extension, are difficult to access and are often disturbed by tectonics and strongly condensed. The exploitation of these cherts was occasional at STS 4A. A few Rosso Ammonitico artefacts, mostly consisting of armatures, show strong analogies with cherts cropping out in the Fanes area, at about 2000 m a.s.l., where they are characterized by thick wavy microlamination highlighted by thin spiculas alignment (Pl. 2: 7-8). Regarding the Maiolica, a partial provenance from the dolomitic outcrops cannot be completely excluded for STS 4A artefacts, although most of them show clear affinities with the prealpine area (see the following chapter).

4.4.3 Belluno and Friulan Prealps. Fadalto, Soccher, Fonzaso, Maiolica cherts (Upper Jurassic-Lower Cretaceous)

The lithic industry of STS 4A comprises chert lithofacies that can undoubtedly be attributed to geological formations outcropping in the prealpine areas. The presence of silicified bioclastic calcarenites clearly indicates re-sedimented horizons within the Belluno-Carnian slope-to-basin formations. These lithofacies are abundantly found at the margins of the Friulian Platform and are referred to as “Faldalto Calcarenites” (the nearest, Ghetti 1987, 1989) or “Soccher Limestone” (Pl. 3: 1-4). Furthermore, most of the artefacts made of Fonzaso and Maiolica cherts contain fine detrital components, suggesting that these cherts likely originate from the same provenance areas, at least for the majority of the artefacts. Additional evidence supports this hypothesis. One end-scraper displays a small natural surface originating from a strongly rounded pebble with iron oxides in the inner fractures (Pl. 3: 7-8). These pebbles are abundant in the Friulian Plain (Plio-Pleistocene fluvio-glacial pebbles of the Tagliamento amphitheater) and, to the best of current knowledge, have not been recorded elsewhere (Fig. 7) (Fontana & Ferrari 2020).

4.4.4 Belluno Prealps. Upper Scaglia Variegata Alpina (Middle Cretaceous, Cenomanian)

In the Southalpine, the upper part of the Maiolica (Aptian to Cenomanian) is generally referred to as “Scaglia Variegata Alpina”. Although in the Belluno geological sheet (1: 50.000) this formation has not been divided and is mapped as Maiolica, this distinction is made in the present article. A group of Cenomanian artefacts belongs to cherts cropping out within a few tens of metres at the top of the Scaglia Variegata Alpina (yellow varieties). Their micropalaeontological content allows for their stratigraphic placement (Pl. 4: 1-4). We can exclude their occurrence in the Dolomitic areas, where the series are highly condensed or eroded. Possible provenances areas for these artefacts include the Non Valley, near the Adige Valley, where they are frequent (Bertola 2011a), as well as the westernmost part of the Belluno Prealps (municipality of Feltre). Despite some variability within the group, which suggests a certain caution in attribution, their petrographic features suggest stronger affinities with the Belluno Prealps due to the presence of fine microdetritus dispersed in the matrix. These chert types have been collected near prime chert outcrops and never in alluvial contexts.

4.4.5 Belluno Prealps. Scaglia Rossa cherts (Upper Cretaceous, Turonian-Maastricthtian)

In terms of absolute frequency, the second most commonly used chert after the Buchenstein is the Scaglia Rossa (Pll. 4 and 5). The Scaglia Rossa formation of the Belluno Prealps (Costa et al. 1996: 33-35) contains abundant chert nodules and layers throughout the whole formation, not only in the lower part as seen in most Southalpine Scaglia Rossa outcrops (Peresani & Bertola 2010: 91-92). STS 4A artefacts represent various chert types distributed across the entire formation, from the bottom (Pl. 4: 5-8) to the top (Pl. 5: 1-8), ranging from reddish to yellowish brown. Most of these artefacts originate from the upper Scaglia Rossa outcrops (Campanian to Maastrichtian age. Pl. 5: 1-8). In terms of micropalaeontological association, colour and texture, comparable Scaglia Rossa cherts are found only in the Belluno Prealps. This is certainly clear evidence of the provenance of this chert group. Additionally, the Scaglia Rossa cherts used at STS 4A have been collected near optimal chert outcrops.

4.4.6 Considerations about the provenance of the Southalpine cherts in the STS 4A site

A part of the exploited cherts were collected at high altitudes in the Dolomites, attesting movements within the mountain area for hunting or seasonal shifts.

The presence of Jurassic to Cretaceous detrital cherts (Faldalto Calcarenites, Soccher, Fonzaso, Maiolica) suggests their provenance from transitional areas between a platform and a basin. This is particularly the case of the Friulian Platform, which remained active until the end of the Cretaceous, and the adiacent Belluno-Carnian basin (Gnaccolini 1968; Costa et al. 1996: 28-33; Masetti & Bianchin 1987: 199-201; Zanferrari 2008).

These data suggest movements much further south, given that comparable chert outcrops are found in the Belluno-Friulian Prealps, particularly:

- in the lower Piave Valley (Belluno Valley and in the adjacent reliefs bordering the Venetian Plain) (Fig. 7). The best chert outcrops in terms of abundance, accessibility and integrity, are located on the southern slope of the Belluno Valley, between the Alpago and the locality of Mel (Peresani & Bertola 2010: 91-92; Visentin et al. 2016).
- in the lower Tagliamento Valley, extending down to its mouth in the high Friulian Plain. Small and strongly rounded pebbles of various chert lithotypes are frequent in this area. The best in terms of homogeneity and flakability are the pebbles from the Fonzaso and Maiolica formations.

5. Techno-typological analysis of rock crystal

5.1 Rock crystal as knappable raw material

5.1.2 Shape of the quartz crystal

The term “rock crystal” or “hyaline quartz” refers to macro-crystalline quartz in the form of isolated crystals characterized by flat crystalline faces and transparent appearance (automorph quartz) (Mourre 1996; de Lombera Hermida 2008). Quartz belongs to the trigonal-trapezohedral crystal class. Its crystals have four crystallographic axes (Rykart 1989, Fig. 9: 3):

- the c-axis or main axis and
- the three a-axes, which are in a right angle to c and form constant angles of 120° between each other. The shape of a quartz crystal is determined by its ordered atomic structure (crystal grid). Its shape consists of a combination of basic crystallographic forms. The most common combination is:
- the six-sided prism (m) and
- the two main rhombohedra (r and z). These, when combined, form the six-sided terminations of the crystal (Rykart 1989: 43. Fig. 9: 1-2).

The angles between the analogous crystal faces are constant and remain the same even when the size of the crystal faces varies (Fig. 9: 2). They meet at 120° (m to m), 142° (m to r / m to z), 134°(r to z) and finally at 86° at the top of the crystal (r to r / z to z).

5.1.3 Varying habit and adaptations of the real crystals

The progressive growth of rock crystals within a crystal fissure occurs through the deposition of substance from circulating hydrothermal solvents onto the crystal faces (Fig. 10: 1-2). The differing growth rate of the faces (r with respect to z, as well as r-z with respect to m) leads to a variety of shapes, which determine the individual habit of the real crystals (Rykart 1989: 50, Fig. 29A; Mottana et al. 1997). Furthermore, depending on the position and the orientation of the crystal within the fissure, and on the projection of the neighbouring crystals, the growth in a certain direction may be favoured or hindered (Fig. 10: 3) (Mullis 1991). Nevertheless, even the resulting distorted, flattened or elongated crystals maintain the above mentioned angles. In nature quartz crystals generally grow in associations. A typical association of the quartz is twinning, where two or more crystals grow together by contact or by compenetration (Mottana et al. 1997). During their growth crystals may be subjected to diaclases caused by internal flaws and tectonic forces (de Lombera Hermida 2009). Once broken, the fragments may continue to grow within the cavern adapting their shape to the new position („regenerated“ crystal fragment or „healed“ crystals).

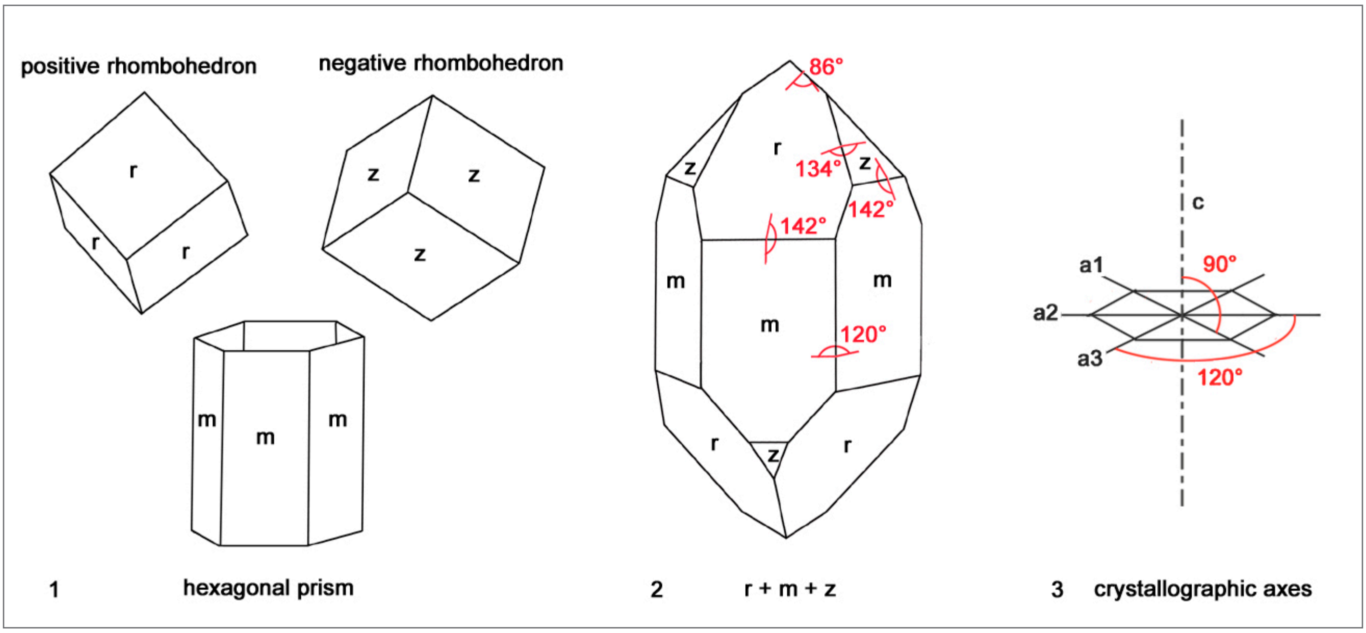

***Fig. 9 –** 1. The most common combination of crystallographic forms found in quartz crystals; 2. Ideal quartz crystal with indication of the angles; 3. Crystallographic axes and angles (modified from Rykart 1989). / **Fig. 9 –** 1. La più comune combinazione di forme cristallografiche nei cristalli di quarzo; 2. Cristallo di quarzo idale con indicazione degli angoli; 3. Assi cristallografiche e angoli (modificato da Rykart 1989).*

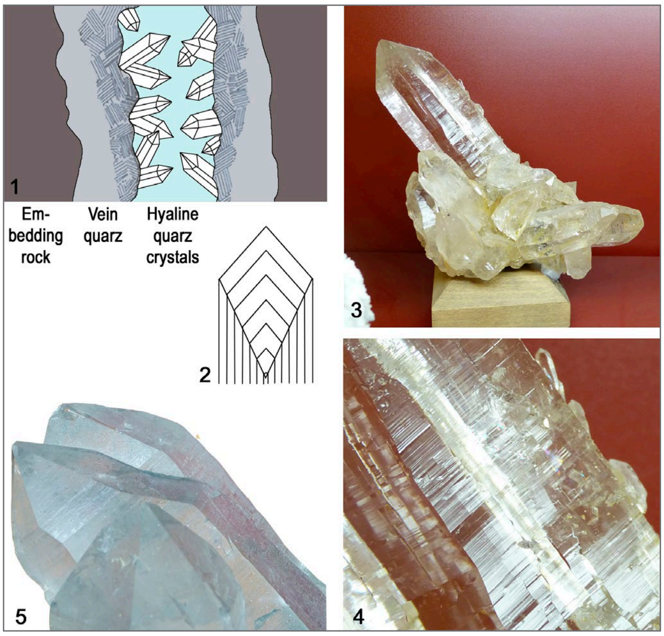

***Fig. 10 –** 1. Rock crystals inside an alpine fissure (modified by Collina-Girard 1997); 2. Growth and growth ratio between rhombohedron and prism (modified by Rykart 1989, Abb 29a); 3. Rock crystal druzy (Mineralienmuseum St. Johann in Ahrn); 4. Prism with horizontally striated surface; 5. Rhombohedron with opaque surface. / **Fig. 10 –** 1. Cristalli di rocca all'interno di una fessura alpina (modificato da Collina-Girard 1997); 2. Crescita e rapporti di crescita tra romboedro e prisma (modificato da Rykart 1989, Abb 29a); 3. Drusa di cristallo di rocca (Museo dei Minerali, San Giovanni - Valle Aurina); 4. Prisma con superficie striata orizzontalmente; 5. Romboedro con superficie opaca.*

5.1.4 Rock crystal colour and surface, size and physical properties

Rock crystals are colourless and can be completely transparent, or range from transparent to translucent, specially at the crystal base attached to the enclosing rock which is more subject to tectonic forces. Due to their exposure to corrosive hydrothermal solvents the surfaces of the r and z may appear more or less matte. In contrast, the prism faces show a parallel striping perpendicular to the c-axis (Fig. 10: 4-5). Contact surfaces between adjacent and intergrown crystals are matte with a rough, ribbed surface.

Rock crystals show a great variety of sizes. Their length can range from less than 1 mm up to several meters. Nevertheless, rock crystals longer than 25 cm represent an exception (Rykart 1989). Currently the largest examples in Southern Tyrol's museum collections are those measuring 50-60 cm (at the Naturmuseum Bozen and at the Mineralienmuseum St. Johann Ahrntal). The ratio between the length and thickness of quartz crystals typically ranges from 3:2 to 4:1 (Rykart 1989: 50).

Hyaline quartz is very brittle. The transparent portions break forming neat concave fractures whereas the fractures on the translucent are uneven (see also de Lombera Hermida 2008). Due to the anisotropy of this mineral, a preferred splitting and cleavage direction runs parallel to the faces of the rhombohedra (Fig. 10: 2) (Mottana et al. 1997, n. 71; Rykart 1989: 50; de Lombera Hermida 2009: 7; Mourre 1996: 206). This is confirmed by the results of the present study, which shows that the preferred direction to open and to reduce the crystals at STS 4A is indeed oblique to the c-axis (see chapters 5.2.2 and 5.2.3).

Hyaline quartz has a hardness value of 7 on the Mohs' scale. According to the results of the experimental work (see chapter 8.1.6) rock crystal has sharper and more resistant edges compared to chert.

5.1.5. Knapping properties and features

Experimental knapping carried out as part of the present study showed that rock crystal exhibits less conchoid fracturing compared to Southalpin chert, particularly in the translucent portions. This results in a generally weaker curvature between the Hertzian cone (bulb and counter curve) and the flat ventral surface (Fig. 11). Only removals from the transparent crystal portions with smooth flaking surface may have pronounced bulbs. In the case of hinging, hinged terminations on rock crystal are rarely rounded, which can again be explained by the less conchoid fracturing (Fig. 12). The distal ends are usually either stepped or normal. Occasionally, due to high internal pressure and low rotation during splitting, the ventral face of the resulting detachment may exhibit a rippled surface. Therefore, when using rock crystal as a lithic

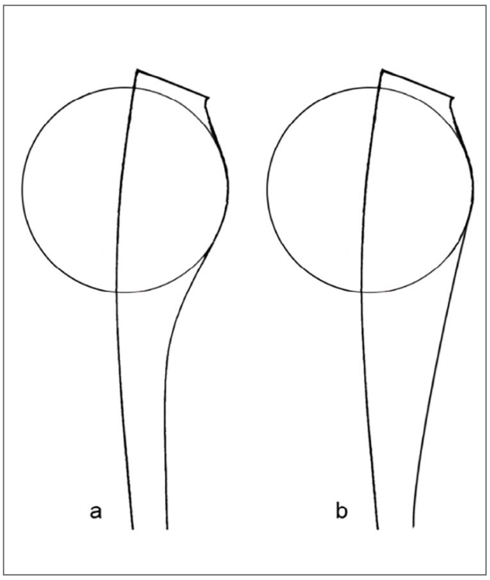

*Fig. 11 – Bulb and countercurve. Comparison between a) chert and b) rock crystal blanks. / **Fig. 11 –** Bulbo e controcurva. Confronto tra supporti in a) selce e b) cristallo di rocca.*

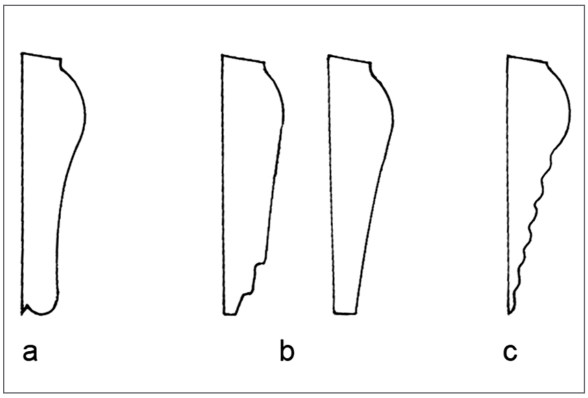

***Fig. 12 –** Pattern of hinged fracture. a) Chert, with rounded fracture; b) Rock crystal, with step or normal fracture; c) rock crystal, with rippled ventral face. / **Fig. 12 –** Andamento della frattura riflessa. a) selce con frattura arrotondata; b) cristallo di rocca con frrattura step o normale; c) cristallo di rocca con faccia ventrale increspata.*

raw material, the optimal preparation of the core to avoid hinging is less compelling than with chert, which has a more conchoidal fracture pattern.

Rock crystal is very brittle and not very flexible, so the detachment of very thin blanks (less than 2 mm) almost always leads to their breakage, unlike with chert. On the translucent portions, the removals are often characterized by unpredictable changes in the direction of the blow. This can hinder or affect the detachment of the desired product and the further reduction of the crystal.

The fracture surfaces of the transparent portions are generally smooth (sometimes also ribbed or rippled), whereas those generated on the translucent or matte portions are never smooth. For this reason, products detached from the basal translucent portion of the crystals are difficult to orient. This is due to the limited development of the bulb, the superimposition of the ripples and the frequent changes in the direction of the propagation wave. In the case of blank fragments, feeling the ventral face with the fingers can help to determine the orientation of the blow.

Rock crystal can be easily retouched. Regular conchoidal retouching is achieved only on the transparent portions whereas the negatives of the translucent portions are generally shapeless. The distinction between natural fractures and negatives is therefore difficult, sometimes recognizable only through small edge splinterings caused by the retoucher.

5.2 Reduction of rock crystal at the site STS 4A

5.2.1 Size of the chosen crystals

The studied rock crystal assemblage from STS 4A does not comprises intact crystals or larger fragments that would allow for the determination of the size and habitus of the exploited minerals. The few artefacts preserving larger portions of the hexagonal prism indicate a minimum width of 20-30 mm for the prism faces.

5.2.2 Reduction scheme of intact rock crystals

Intact crystals show features that allow them to be used as cores without preparation. Due to the smooth surface no decortication was required (see also Visentin 2017: 81). The angle of the apex, lower than 90°, was already suitable for flaking (Figg. 9: 2 and 13: 3a). Production on hyaline quartz crystals began directly from the outer surface, in contrast to chert where the desired blanks were often detached from the inner portion of the block. Intentional breakage of the crystal to obtain useful angles was difficult to control and therefore risky. A first blank detached from the apex could be followed by others in the same direction. After reducing the rhombohedron, the oblique flaking surface could be established on the prism (Fig. 13: 3b). Subsequently, after a horizontal 180° rotation of the crystal, a second surface could be

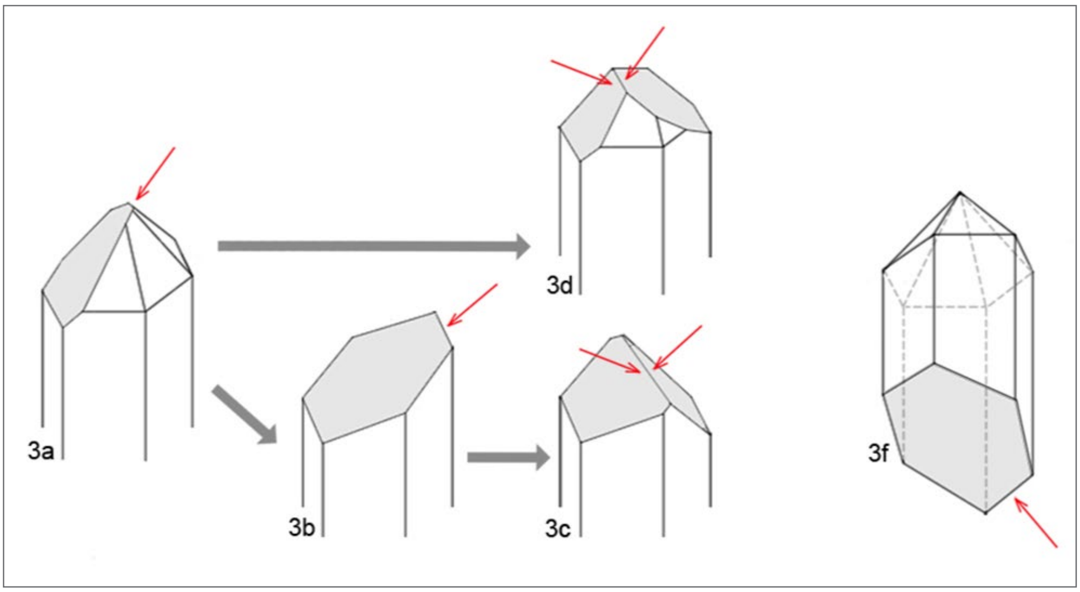

***Fig. 13 –** Possible sequence of reduction of an intact rock crystals at STS 4A. Central arris and flaking surfaces are here represented as flat, although these could be curved or bulged. / **Fig. 13 –** Possibile sequenza di riduzione di un cristallo di rocca intatto a STS 4A. Nervatura centrale e superficie di distacco sono quì rappresentate come piane, ma potevano essere ricurve o bombate.*

created and a central arris formed. In this way, one surface could be used as striking platform and the other as flaking surface (Fig. 13: 3c). This action could also have been performed earlier, already on the rhombohedron (Fig.13: 3d). Depending on the position of the arris, the surfaces created could vary in length and facilitate the production of blanks for different purposes. Additionally, the inclination of the flaking surface could vary according to the desired products. This procedure enabled a flexible and continuous exploitation of the crystal core. The flaking angles had to be kept under control during knapping.

This method of blank production could be continued until the complete reduction of the crystal, unless interrupted by irregularities in the raw material or mistakes during flaking. On the translucent crystal portions unexpected changes in the direction of the blows or hinging on the flaking surface were quite frequent and difficult, if not impossible, to correct. Further reduction could then only be attempted opportunistically, for example by establishing a new oblique flaking surface on the crystal base after a vertical rotation (Fig. 13: 3e. For comparison see also Visentin 2017: 81).

5.2.3 Examples of blank production according to the above described scheme

At STS 4A no “first blank” indicating the opening of the crystal from the apex has been identified, but the extraction of desired products from the rhombohedron is demonstrated by two artefacts, both transformed into tools (Pl. 6: 1-2). The subsequent reduction phase is best observed on some blades and on a laminar flake (Pl. 6: 3-4, 6-7). The *débitage* was carried out in a way that both the striking platform and the flaking surface were oriented obliquely to the crystal c-axis. The angular discontinuity formed by the encounter between the prism face and the negatives acted as longitudinal (Pl. 6: 3, 6) or transversal convexities of the core (Pl. 6: 4, 7). This phase led to the production of the most regular blanks in the assemblage. The systematic use of the above mentioned oblique striking platform is also evident from several flakes, at least one of which was used for core maintenance (Pl. 6: 8-10).

A different method of reduction involved the detachment of blanks transversely to the c-axis. The resulting large and thick flakes had functional potential, as demonstrated by the examples that were transformed into tools (Pl. 6: 5). Several artefacts attest to the initial opening of the crystal from the basal rhombohedron (Pl. 7). Despite the poor quality of this portion of the crystal, such flakes could either be transformed into tools (Pl. 7: 14, from a twinned crystal) or used without retouching (Pl. 7: 11. See chapter 8.2).

5.2.4 Blank production on thick flakes

Besides the reduction of intact crystals or natural crystal fragments, thick flakes have also served as cores. Residual portions of their ventral face (see “+” symbol indicating the positive facet) are clearly visible on 22 artefacts and, with some uncertainity, on additional 18. Large flakes used as cores originated from all parts of a crystal (rhombohedron, the portion between rhombohedron and prism, prism, crystal base). The *débitage* used for their reduction varied as follows:

- unipolar, either half-turning or frontal, aimed at producing bladelets, evidenced on two cores and a refitting (Pl. 8: 7 and 11);
- bipolar versus centripetal, possibly for the production of flakes, attested on a discoidal core (Pl. 8; 2).
- but mostly centripetal, as demonstrated by numerous flakes (Pl. 9: 10-11).

Judging by their shape, some discoidal cores with a biconvex cross-section may also have originated from flakes (Pl. 8: 1 and 6).

5.2.5 Reading the cores. The final phase of rock crystal reduction

Information about the final phase of reduction are obtained from the 11 intact cores (Tab. 3). These cores are all small in size, ranging from 11.9 and 30.4 mm in length. Only half of them show transparent and high-quality crystal, while the remaining ones are translucent. The external crystal portions refer to all parts of the crystal, from the rhombohedron to the base. Exploitation also involved twinned, and therefore irregular, crystals (Pll. 7: 13 and 8: 5), crystals with healed fractures (Pl. 9: 8, 11) and examples showing contact zones with an adjacent crystal (Pl. 8: 7).

During the final exploitation, nearly all cores produced flakes. Judging from the last negatives these were between 16 mm and 23 mm long, with a mean value of 18 mm. Due to the limited convexities of the flaking surfaces and their width, the resulting flakes were thin. The extraction of bladelets and lamellar flakes is evident in three examples, even though they do not display regular negatives (Pl. 8: 7-8, 11).

Core reorientations are frequent. The few crested blanks of the assemblage likely derived from such operations. Core abandonment generally occurred due to hinged scars, loss of flaking angle or size reduction.

The 11 intact cores can be grouped as follows:

a) The simplest cores have a single flaking surface, wide and feebly convex, exploited at its final stage with unipolar (Pl. 8: 8-9), bipolar (Pl. 8: 5) and bidirectional *débitage* (Pl. 8: 2. Phase 2 serving for maintenance). The core back is formed either by an external crystal face or by other natural surfaces. The cores have a discoidal shape (see “oval cores” Broglio & Kozlowski 1984), except for a sub-pyramidal core.
b) More complex cores show two adjacent flaking surfaces exploited from a single striking platform in order to control the transversal convexity. Core RR 2343 has a wide flaking surface adjacent to a narrow one (Pl. 8: 10). The negatives from the opposite striking platform indicate core reorientation. Two adjacent narrow flaking surfaces characterize the only prismatic bladelet core in the assemblage (Pl. 8: 7).
c) The most complex cores have two flaking surfaces exploited from two different striking platforms. Two discoidal cores with a biconvex cross-section (Pl. 8: 1, 6) show alternating reduction from the both faces, with at least 2 reorientations. Another example, irregular in shape, shows successive exploitation of both faces (Pl. 8: 4). Cores RR 1762 and RR 2298, now polyhedral in shape, have two orthogonal flaking surfaces used one after the other (Pl. 8: 3, 11). Core RR 1762 shows frontal exploitation with maintenance from the flanks. After the loss of the flaking angle, the core was rotated. At this point production continued with centripetal detachments from a peripheral striking platform. The small residual core RR 2298 shows initial exploitation on the lateral edge of a flake from a strongly inclined striking platform located on the butt (“burin shaped core” with frontal *débitage)*. After core reorientation *débitage* continued on the ventral face of the flake in a half-turning modality.

In summary, the rock crystal cores which represent the final phase of exploitation show several features typical of Sauveterrian chert technology (Wierer 2008; Flor et al. 2011; Kompatscher 2011; Wierer & Bertola 2016; Visentin 2018). These include:

- the use of thick flakes as cores;
- exploitation of relatively wide and feebly convex flaking surfaces;
- short series of detachments, mostly unipolar (or bipolar to correct flaking mistakes) or centripetal;
- production of thin blanks as an important flaking objective;
- frequent core reorientations;
- core exploitation until the cores become very small.

An important difference, compared to chert assemblages, is the observed rarity of prismatic cores, which could be due to the absence of a specific bladelet production at STS 4A.

Tab. 3 – *Features of the rock crystal cores. /* ***Tab. 3 –*** *Caratteristiche dei nuclei in cristallo di rocca.*

Core number	Plate 8, n.	Morphology of core	Portion of crystal; transparency	Presence of natural crystal surface	Core on flake	Production target	Orientation of detachments	Reorientation of core
Débitage facial on single & wide flaking surface:								
RR 1788 - RR 2447	5	discoidal biconvex	between rhombohedron and and irregular prism; transparent	core back	possible	flakes	bipolar	
RR 691	2	discoidal biconvex	crystal base; transparent	core back	yes		bidirectional vs. centripetal	
RR 1790	9	discoidal plano-convex	crystal base; translucent	core back		flakes	unipolar	
RR 663	8	sub-pyramidal	flat fragment with “healed fracture”; translucent	core back & flaking surface		laminar flakes	unipolar	
Débitage on two adiacent flaking surfaces (wide & narrow) from 1 striking platform:								
RR 2343	10	sub-prismatic	transparent			flakes	bipolar	probably, 180°
RR 2424	7	prismatic	contact zone between crystals; trasparent	core flank	yes. Striking platform on butt of flake	bladelets & flakes	unipolar	
Débitage on two distinct flaking surfaces, from 2 distinct striking platforms:								
RR 133	1	discoidal biconvex	prism; translucent	lateral	possible	flakes (& bladelets?)	a) & b) unipolar	180°
RR 764	6	discoidal biconvex	trasparent		possible	flakes (& bladelets?)	a) unipolar, b) bipolar, a) unipolar	180° 2x
RR 2101	4	irregular & flat	crystal base; traslucent			flakes	a) indet, b) unipolar	180°
RR 1762	3	polyhedral	rhombohedron and prism; transparent	core base		flakes	a) unipola b) centripetal	90°
RR 2298	11	burin-shaped to polyhedral	rhombohedron with “healed fracture”; trasparent	butt & dorsal face of flake used as core	yes	bladelets	a) unipolar frontal b) unipolar half-turning	90°

5.2.6 The bipolar tecnique, part of the final exploitation?

Although no splintered core has been found, some artefacts with reduced width and splintering at the extremities seem to originate from such cores. During the final phase of exploitation, some cores could have been further reduced using the bipolar technique. This technique has been systematically applied to rock crystal reduction at Mont Fallère in Aosta (Raiteri 2017) and is attested also at Casera Lissandri 17 (Visentin et al. 2016).

5.3 Flaking objectives of rock crystal débitage

5.3.1 Few blades of good quality

The assemblage comprises 19 blades, mostly produced during the early stages of crystal reduction (11 of them have portions of external crystal faces). The thick blade detached from a twinned crystal (Pl. 10: 1) further shows that the flaking surface was established obliquely to the crystal c-axis. The longitudinal curvature of the core was achieved through the obtuse angle formed by the intersection of dorsal negatives and the prism face. Thin blades with sharp edges were detached from a rather wide flaking surface (Pll. 6: 4, 6-7 and 10: 7). Proximally they show careful abrasion of the overhang between the striking platform and the flaking surface. The curvature of the flaking surface is maintained through slightly convergent detachments. Another method to produce blades, also in series, involved convergent or centripetal *débitage*, apparently from cores with peripheral faceted striking platform (Pl. 10: 2-4), following careful abrasion of the overhang.

The rather few blades were intended for use as tools, either retouched (n. 7) or unmodified (at least n. 2; see for example Pll. 6: 6 and 10: 5, 7).

During the blade production, fairly thick laminar flakes were obtained as well (Pll. 6: 3 and 10: 6).

5.3.2 Extraction of bladelets

Only two of the cores, both on flakes, show unequivocal bladelet negatives (Pl. 8: 7, 11). Bladelet extraction began from the external crystal faces and was carried out in unipolar sequences (Pl. 11). Cresting for core maintenance is completely absent. Two bladelets show extraction along the natural prism edges, a reduction method that represents an exception in the assemblage (Pl. 11: 4).

Bladelets are rare among the unretouched artefacts (8-9%). The same is observed for the common tools. Only six out of 83 are unequivocally made from bladelets. These are best represented among the truncations. Among the armatures, the identification of bladelets is biased by the backed retouch, which frequently hinders the recognition of the original blanks (see also chapter 5.4.2 and tab. 5, n. 67 indeterminable blanks). Bladelet features can still be recognized on approximately 17% of the items.

Tab. 4 – *Retouched artefacts divided by lithic raw materials. /* ***Tab. 4 –*** *Ritoccati divisi per materia prima litica.*

Typological groups:	**Rock crystal**	**Buchenstein**	**Rosso Ammonitico**	**Prealpine chert**	**Filonian quartz**	**Northalpine radiolarite**	**Indeterminable**	**Total**
Backed points	30	2	1					33
Backed bladelets	6	1						7
Backed pieces with truncation	9	1	1	1				12
Geometrics	13	5	1	2		2		23
Fr. of geometrics or backed pieces with truncation	6	1	1					8
Fr. of backed tools	44	2	1	2	1		1	51
Total Armatures	108	12	5	5	1	2	1	134
Burins	3							3
Endscrapers	17	1		5				23
Truncated pieces	14	2						16
Scrapers (long, short, indet.)	18				1			19
Abrupt indifferenciated pieces	11			1				12
Denticulates	17			1				18
Splintered pieces	3							3
Total Common tools	83	3	0	7	1	0	0	94

Tab. 5 – *Blanks used for armature production. /* ***Tab. 5 –*** *I supporti utilizzati per il confezionamento delle armature.*

Technological category:	**Rock crystal**	**Buchenstein**	**Rosso Ammonitico**	**Prealpine chert**	**Filonian quartz**	**Northalpine radiolarite**	**Indeterminable**	**Total**
Indeterminable	67	8	2	3		1	1	82
Bladelets:	18	3	1		1	1		24
semi-cortical/natural bladelet	*1*							*1*
bladelet from core flank	*1*				*1*			*2*
bladelet from core flank?	*1*							*1*
maintenance bladelet	*4*							*4*
regular bladelet	*11*	*3*	*1*			*1*		*16*
Flakes:	23	1	2	2				28
indeterminable flake	*5*							*5*
cortical/natural flake (51-100%)	*2*							*2*
generic flake	*15*	*1*	*2*	*2*				*20*
maintenance flake	*1*							*1*
Total	108	12	5	5	1	2	1	134

In comparison with coeval industries using Southalpine chert, where bladelets are an important production target, at STS 4A this category represents at most a secondary flaking objective.

5.3.3 Flake production as main flaking objective

The main objective of knapping hyaline quartz was the production of flakes. Flakes with different morphologies were produced for the following purposes:

a) Flakes, typically thin and with one or more cutting edges, used either unmodified or retouched. The dorsal negatives show that they come from centripetal (Pl. 9: 1-6), unipolar convergent (Pl. 9: 9) or, more rarely, bidirectional (bipolar or orthogonal) (Pl. 9: 7) flaking surfaces. The ventral curvature of some items indicates core flaking surfaces with a pronounced distal convexity (Pl. 9: 10). The flaking surfaces had to be wide and oriented slightly oblique to the external prism face. The presence of faceted butts indicates for cores with a peripheral prepared striking platform.
On the contrary no flake production from unipolar *débitage* with parallel detachments is attested (except for the thick laminar flakes mentioned in chapter 5.3.1).

b) Regular and thin flakes (thickness 0.8 – 3.1 mm), which were subsequently transformed into armatures, typically as *Sauveterre* backed points. Due to the extensive modifications the technical features of the original flakes can hardly be reconstructed. The 7 backed points unequivocally extracted from flakes (oriented transversally to the original blank), show orthogonal (n. 3), unipolar (n. 2), unipolar or centripetal (n. 1) and bipolar (n. 1) dorsal scars. Such flakes could have been produced within the context of flaking objective a).
c) Rather thick flakes (thickness > 4 mm), extracted during the initial phases of *débitage* and transformed into common tools. The examples display more or less extended external crystal surfaces. These were transformed into endscrapers and burins, and to a lesser extent, into denticulates and truncations.

5.4 Rock crystal armatures

5.4.1 General information

The production of microlithic armatures was one of the main flaking objectives for rock crystal at STS 4A. The 108 armatures made from hyaline quartz belong to different typological groups (Tab. 4). Besides the most numerous backed fragments, the assemblage is dominated by backed points, followed by geometrics and backed pieces with truncation. Backed bladelets are rare. The size of the intact armatures ranges from 6.2 mm to 16.7 mm.

5.4.2 Blanks used for armature manufacturing

Except for two items made from translucent rock crystal, all armatures are made from transparent material. This indicates a careful selection of the crystal portions with the best flaking properties. About 15% of the armatures display portions of an external crystal face. When extracted from the prism, the blanks were mostly detached obliquely in relation to the c-axis (Pl. 12: 22), and only rarely parallel to it (Pl. 12: 33 along a natural arris). Several armatures were extracted from the crystal rhombohedron (Pl. 12: 24-25). At least one example shows a natural surface resulting from contact with an adjacent crystal.

The invasive backed retouch hinders the reconstruction of the technological features of the original blanks (Tab. 5). Besides the numerous indeterminable blanks, the few identifiable ones indicate that flakes (n. 23) are more frequent than bladelets (n. 18). Among the bladelets, the regular ones predominate. Judging by the dorsal scars, the bladelets mostly belong to unipolar flaking sequences (n. 6). The traces of other sequences (n. 3 orthogonal; n. 2 unipolar or centripetal, n. 2 orthogonal or centripetal, n. 1 bipolar, n. 1 multidirectional) suggest their origin from cores with a wide flaking surface and expanded or centripetal striking platforms.

The flakes used as blanks to produce armatures appear mostly generic (Tab. 5), detached during unipolar (n. 7) and orthogonal (n. 7) flaking sequences. Other orientations of the negatives (n. 1 centripetal, n. 1 bipolar, n. 3 unipolar or centripetal) also suggest in these cases a production from cores with a wide flaking surface and expanded or centripetal striking platforms. Bladelets and flakes for armatures were likely produced from the same cores.

It has to be highlighted that more than a quarter of the armatures (backed fragments, geometrics and backed points) are oriented transversely to the *débitage* axis of the blank (Tab. 6) (n. 29 out of 108, Pl. 12). This demonstrates the systematic use of regular and thin flakes for armature manufacturing.

5.4.3 Techniques used for the backing of rock crystal armatures

The backing of the armatures is typically achieved with abrupt unipolar retouch. Only in exceptional cases (n. 8) the retouch is partially bipolar (Pl. 12: 1, 8, 15-16, 19 and 26-27).

Tab. 6 – *Orientation of the armatures to the* débitage *axis of the blank. /* ***Tab. 6 –*** *Orientamento delle armature rispetto all'asse di distacco del supporto di origine.*

Lithic raw material:	**Orientation to blank:**	**Backed point**	**Backed bladelet**	**Backed tool with truncation**	**Geometrics**	**Fr. backed tools w. truncation or Geometrics**	**Fr. of backed pieces**	**Total**
Rock crystal	longitudinal	19	5	7	9	3	28	71
	transverse	10	2	1	5	1	10	29
	indeterminable					2	6	8
Total Rock crystal		29	7	8	14	6	44	108
Buchenstein chert	longitudinal	1	1		1	1	2	6
	transverse			1				1
	indeterminable	1			4			5
Total Buchenstein chert		2	1	1	5	1	2	12
Rosso Ammonitico	longitudinal	1		1			1	3
	transverse					1		1
	indeterminable				1			1
Total Rosso Ammonitico		1		1	1	1	1	5
Prealpine chert	longitudinal						2	2
	transverse			1	1			2
	indeterminable				1			1
Total Prealpine chert				1	2		2	5
Filonian Quartz	longitudinal						1	1
Indeterminable	longitudinal						1	1
Northalpine radiolarite	longitudinal				2			2
Total		32	8	11	24	8	51	134

***Tab. 7 –** Waste from armature production. / **Tab. 7 –** Residui della produzione di armature.*

Waste from armature production:	**Rock crystal**
Microburins	3
Notch adiacent to fracture	3
Krukowski microburins	2
Total	8
Ratio waste / backed tools	8 / 108 = 0,07

The intentional shortening of blanks using the microburin technique was rare. Only three armatures – a backed point, a scalene triangle on flake and a trapezoidal segment on a bladelet (Pl. 12: 8, 32, 23) – display the typical *piquant trièdre*. The sporadic microburins are represented by two distal examples (Pl. 13: 2) and one proximal example (Pl. 13: 1; Tab.7).

Two "notches adjacent to fracture", a distal and proximal one, refer to intentional shortening (Pl. 13: 3-4). In contrast, the three Krukowski microburins may have resulted from accidents during backing (Pl. 13: 5-6).

This low frequency of microburins cannot be attributed to raw material constraints, as the microburin technique works effectively on rock crystal (Visentin 2017). A possible explanation for the infrequent use of the microburin technique could be related to the preference, observed at STS 4A, for very thin blanks in armature manufacturing. Experimental knapping has shown that about 80% of the blanks thinner than 2 mm break during *débitage*. Such fragments are already suitable for backing, particularly for producing geometric pieces, without any need for further shortening. Furthermore, the absence of a specific bladelet *débitage* could also explain the absence of this technique.

The microburins and *Krukowski* microburins have been found within a radius of only 1m, which may indicate a specific place at the camp where armatures were prepared.

5.4.4 Backed points made of rock crystal

Most of the backed points made of rock crystal have a double back along their entire length (n. 16, Tab. 8). Among these, 9 elongated points can be classified as *Sauveterre* points according to the G.E.E.M. (1972). These points occur as typical *Sauveterre* points, i.e. with a double point (n. 3. Pl. 12: 1, 2, 13), *Sauveterre* points with a single point (n. 4. Pl. 12: 3-4, 6) and *Sauveterre* points with partial backing (n. 1. Pl. 12: 12). One example with complete and bilateral backing can be classifiable as a "short point" (S9 according to Broglio & Kozlowski 1984).

Four backed points show external crystal surfaces: one case from the prism and three from the rhombohedron (Pl. 12: 1, 12). Many backed points are oriented transversely to the *débitage* axis (11 out of all backed points; 4 out of the 9 *Sauveterre* points), in some cases even near the bulbar portion of the flake (Pl. 12: 5). Three bilateral backed points appear to have been abandoned during production (Pl. 12: 7, 10-11), likely due to breakage while making the second back.

***Tab. 8 –** Backed points. / Tab. **Tab. 8 –** Punte a dorso.*

Backed points:	**Rock crystal**	**Buchen stein**	**Rosso Ammonitico**	**Total**
...with marginal back (PD1)			1	1
...with concave back (PD3)	1			1
...with deep total back (PD4)	21	1		22
-with single back	*3*	*1**		
-with double back	*15*			
-with double back & bi-point	*3*			
Indet. fragments	8	1		9
-with single back	*2*			
-with double back	*6*	*1**		
Total	30	2	1	33

* = maybe fragment of a triangle

5.4.5 Backed bladelets made of rock crystal

The six backed bladelets made of rock crystal do not show recurrent features (Tab. 9). Some of them appear to be the result of repairs and re-adaptation of broken armatures, or unfinished armatures, or adaptations of irregular core-maintenance blanks (Pl. 12: 16).

5.4.6 Backed pieces with truncation made of rock crystal

The group is mainly composed of backed bladelets with oblique truncation forming an obtuse angle (Tab. 10), except for one backed blade with orthogonal truncation (Pl. 12: 18) and a backed blade with double truncation, both of them oblique (Pl. 12: 22). Except for this latter, all items have a single back. Retouching of the back is generally unipolar, except for a partially bipolar back (Pl. 12: 19). One example resembles a scalene triangle (long with long base) (Pl. 12: 20).

Two backed blades with truncation show a portion of the external part of the prism, indicating that the original blank was detached obliquely to the c-axis (Pl. 12: 19, 22).

5.4.7 Geometric pieces made of rock crystal

Despite the variety within this typological group, which also includes circle segments (Pl. 12: 28-29), trapezoidal segments (Pl. 12: 23) and isosceles triangles (Pl. 12: 27, 30), the geometric pieces are dominated by the scalene triangles (Tab. 11). Among these, scalene long triangles (represented by the two variants with long and short base) predominate over the scalene short ones. Six out of eight have a back on all three sides (Tab. 12). Due to the low elongation index which is at most 3.2, none can be classified as *Montclus* triangle according to G.E.E.M. (1969). Artefact RR 1931 is not a typical Sauveterrian scalene triangle (Pl. 12: 25). Due to the shape, which is nearly isosceles, and the concave base it reminds the triangles *de Coincy* of the Beuronian (G.E.E.M. 1969). This artefact, together with another triangle, show evident portions of the external crystal faces originating from the rhombohedron (Pl. 12: 24-25). Four geometric pieces (Pl. 12: 25, 30-32) are oriented transversely or obliquely to the *débitage* axis. The abrupt retouch is generally unipolar, except for two examples with partial bipolar retouch (Pl. 12: 26-27).

***Tab. 9 –** Backed bladelets. / **Tab. 9 –** Lamelle a dorso.*

Backed bladelets:	**Rock crystal**	**Buchenstein**	**Total**
...with marginal back (LD1)	2		
-with single back	*2*		
...with deep back (LD2)	4	1	6
-with single back	*3*	*1*	
-with double back	*1*		
Total	6	1	7

***Tab. 10 –** Backed pieces with truncation. / **Tab. 10 –** Dorsi e troncatura.*

Backed bladelets with truncation:	**Rock crystal**	**Buchenstein**	**Rosso Ammonitico**	**Prealpine chert**	**Total**
normal (DT1)	1				1
oblique, with obtuse angle (DT4)	7	1 bilat	1	1	10
double irregular (DT5)	1 bilat				1
Total	9	1	1	1	12

***Tab. 11 –** Geometrics. / **Tab. 11 –** Geometrici.*

Geometric pieces:	**Rock crystal**	**Buchenstein**	**Rosso Ammonitico**	**Prealpine chert**	**Northalpine radiolarite**	**Total**
Circle segment (Gm1)	2					2
Trapezoidal segment (Gm2)	1					1
Scalene triangle (Gm3)	8	4		2	2	16
-2 sides with back	*2*	*1*			*1*	*4*
-3 sides with back	*6*	*3*		*2*	*1*	*12*
Isosceles triangle (Gm4)	2					2
-2 sides with back	*2*					*2*
Fragment of scalene or isosceles triangle (fr. Gm3-4)		1	1			2
-2 sides with back			*1*			
-3 sides with back		*1*				
Total	13	5	1	2	2	23

***Tab. 12 –** Triangles: morphological features and retouch. / **Tab. 12 –** Triangoli: forma e ritocco.*

Morphology & retouch of triangles	**Rock crystal**	**Buchenstein**	**Prealpine chert**	**Northalpine radiolarite**	**Total**
Scalene triangle (Gm3)	8	4	2	2	16
-short, with 2 backs	*1*				*1*
-short, with 3 backs	*2*	*3*	*2*		*7*
-long with short base, with 2 backs	*1*				*1*
-long with short base, with 3 backs	*2*				*2*
-long with long base, with 2 backs		*1*		*1*	*2*
-long with long base, with 3 backs	*2*			*1*	*3*
Isosceles triangle (Gm4)	2				2
-long, with 2 backs	*2*				*2*
Total	10	4	2	2	18

5.4.8 Fragments of geometrics or backed pieces with truncation

Some of the backed fragments could belong to either of the above mentioned groups (Tab. 13). One item has three retouched edges, while another is oriented transversely to the original blank.

5.4.9 Fragments of backed pieces made of rock crystal

Around 40% of the hyaline quartz armatures are unclassifiable fragments (Tab. 4). The high proportion of elements with double back is consistent with the overall armature assemblage, which is rich in bilateral backed points and frequent three-backed triangles (Tab. 14). The same trend is observed in the high rate of backed fragments that are transversely oriented (Tab. 6). An unusual feature is the relatively high number of fragments with marginal back (5 examples), possibly related to the fact that these pieces, typically thinner than others, were more subject to breakage.

Six backed fragments show portions of the external crystal face. One of these derives from the rhombohedron (Pl. 12: 35), another from the prism (Pl. 12: 33), with detachment along the natural crystal arris. A backed fragment displays a natural contact surface between two crystals.

Some items appear to have been broken during the manufacturing process: a fragment with an angular back seems to represent a step in the production of triangles (Pl. 12: 36), while a mesial double-backed fragment could originate from the manufacturing of bilateral backed points (Pl. 12: 34).

***Tab. 13 –** Fragments of geometrics or backed pieces with truncation. / **Tab. 13 –** Frammenti di geometrici o dorsi e troncatura.*

Fragments of Gm-DT:	**Rock crystal**	**Buchenstein**	**Rosso Ammonitico**	**Total**
Frr. Gm3-DT	4	1	1	6
-with 3 backs	*1*	*1*		
Frr. Gm-DT	2			2
Total	6	1	1	8

***Tab. 14** – Fragments of backed pieces. / **Tab. 14** – Frammenti a dorso.*

Fragments of backed pieces:	**Rock crystal**	**Buchenstein**	**Rosso Ammonitico**	**Prealpine chert**	**Indeterminable**	**Filonian quartz**	**Total**
distal	8 (2 with double back; 1 marginal)						8
mesial	18 (4 with double back; 2 marginal)				1		19
proximal	6 (2 marginal)	1	1	2		1	11
transverse	9 (4 with double back)						9
indeterminable	3	1					4
Total	44	2	1	2	1	1	51

5.5 Common tools on rock crystal

5.5.1 Burins made of rock crystal

Compared to the average, burins are larger than other retouched tools. They are made on flakes with large portions of prism faces or natural surfaces. Their *biseau* is always very small. The blank of the simple burin with a single *pan* and *flat biseau* originates from natural fracturing during detachment (Pl. 14: 1; Tab. 15). The other simple burin, with a single *pan* and flat *biseau,* originates from a core on a flake oriented obliquely with respect to the c-axis of the prism (Pl. 14: 2). The arrises of the core had been heavily battered, possibly as a result of some kind of activity. The burin on fracture is made from a maintenance flake detached to correct a large hinged negative on the prism surface (Pl. 14: 3).

***Tab. 15** – Burins, Endscrapers and Truncated pieces. / **Tab. 15** – Bulini, Grattatoi e Troncature.*

Groups/Types:	**Rock crystal**	**Buchenstein**	**Prealpine chert**	**Total**
Burins:				
simple, with single *pan* (B1)	2			2
on break (B5)	1			1
Total Burins	3			3
Endscrapers				
...frontal and long (G1)	1			1
...frontal and short (G3)	5	1		6
...frontal with lateral retouch, fragment (fr. G2/4)	1			1
… frontal and short with lateral retouch (G4)	6		3	9
..with isolated nose (G7), short	1			1
...carinated frontal (G9), short	2		2	4
Indet. fragments	1			1
Total Endscrapers	17	1	5	23
Truncated pieces:				
marginal (T1)	3			3
normal, with deep retouch (T2)	5	2		7
oblique, with deeep retouch (T3)	6			6
Total Truncated pieces	14	2		16

5.5.2 Endscrapers made of rock crystal

Five of the 17 endscrapers are made partly or entirely from translucent rock crystal. The blanks used in their manufacture are mostly flakes; only a single endscaper is made on a laminar blank (Pl. 15: 7). Eleven tools display external crystal surfaces which are located

- on the butt (n. 2), indicating that the striking platform was established on the prism, the rhombohedron or the contact surface between adjacent crystals (Pl. 15: 1, 5-6);
- laterally, further confirming the detachment of elongated blanks at an oblique angle to the c-axis (Pl. 15: 7).
- at the centre of the dorsal face (n. 2), indicating the detachment of flakes parallel to the faces of the prism (Pl. 15: 1) or the rhombohedron (Pl. 6: 1), or along the edge between the rhombohedron and the prism (Pl. 15: 8).
- forming the back of the endscraper (Pl. 15: 2).

The endscrapers originating from the early stages of crystal reduction are thicker. No endscraper is clearly made from core maintenance or rejuvenation flakes.

From a typological viewpont, short frontal endscrapers are predominant, including types with and without lateral retouching (Tab. 15). Some examples are exceptionally small. Only a single frontal endscraper is classified as long (Pl. 15: 7). The general predominance of short types is likely due to the basal fracturing and subsequent adaptation (Pl. 15: 2, 7-8, 10-11). The few carinated endscrapers are also of the frontal types. The assemblage includes a nosed endscraper (Pl. 15: 1).

5.5.3 Truncated pieces made of rock crystal

With the exception of one case, the crystal used for all truncated pieces is transparent. Five truncations display portions of the external crystal faces. One of them was detached transversely to the c-axis of the prism (Pl. 6: 5), while the bladelet for truncation RR 1951 was detached oblique to this axis (Pl. 16: 1). Two truncations show the use of thick blanks with irregular external crystal surfaces (Pl. 16: 2).

Overall, the group of rock crystal truncations is heterogeneous, comprising flakes, bladelets and blades. Length values range from less than 10 mm to more than 33 mm. Several truncations (n. 6) are microlithic and may have functioned as armatures. From a typological viewpoint, orthogonal truncations prevail over the oblique ones (Tab. 15).

5.5.4 Scrapers made of rock crystal (long, short and fragmented)

The hyaline quartz used for the scrapers is transparent, with the exception of two tools made from translucent crystal.

Tab. 16 – *Scrapers (long, short and fragmented), Undifferentiated pieces with abrupt retouch, Denticulates, Splintered pieces. /* ***Tab. 16 –*** *Raschiatoi (lunghi, corti e frammentari), Erti indifferenziati, Denticolati, Pezzi scagliati.*

Groups/Types:	Rock crystal	Filonian quartz	Prealpine chert	Total
Long scrapers:				
...with marginal retouch (L1)	3 (1 fr)			3
...with deep retouch (L2)	1 (fr)			1
Short scrapers:				
...with marginal retouch (R1)	3 (1 fr)	1		4
lateral with deep retouch (R2)	5 (4 fr)			5
transverse with deep retouch (R3)	1			1
latero-transversal with deep retouch (R4)	2 (1 fr)			2
Scraper fragments:				
...with marginal retouch (L-R1)	1			1
...with deep retouch (L-R2)	2			2
Total Scrapers	18	1		19
Undifferentiated abrupt pieces:				
...with marginal retouch (A1)	5 (1 fr.)		1	6
...with deep retouch (A2)	6 (5 fr)			6
Total Undifferentiated	11		1	12
Denticulates:				
Notch (D1)	8		1	9
Denticulated scraper (D2)	7			7
Denticulated endscraper (D4)	1			1
Total Denticulates	17		1	17
Splintered pieces:				
...with modified edge (E1)	2			2
...with modified and knocked off edge (E3)	1			1
Total Splintered pieces	3			3

Most of the long scrapers, which are up to 30 mm in lengthe, have marginal retouch (Tab. 16). Two of these (Pll. 6: 4 and 10: 4) are made on blades detached obliquely to the c-axis of the prism. The same orientation is also observed on a short latero-transversal scraper (Pl. 16: 5).

The short scrapers are made from a variety of blanks: generic flakes, partially natural flakes (Pl. 16: 3), flakes resulting from the correction and maintenance of the flaking surface (Pl. 16: 4, 6) as well as on a former core.

5.5.5 Undifferentiated pieces with abrupt retouch made of rock crystal

Except for two undifferentiated pieces with abrupt retouch which were made from translucent raw material, the remaining are made on transparent and semi-transparent quartz. There is no clear evidence of natural external surfaces. The fragmentation rate is very high, with only a single tool remaining intact. Its size, 14 mm in length, indicates the small dimensions of the group. The still identifiable pieces are all made from flakes or laminar flakes, displaying unipolar (Pl. 16: 7) or bipolar *débitage*.

Marginal retouch (usually partial) is as frequent as deep retouch (Tab. 16). Among the latter, the retouch is often interrupted by fractures (n. 5), preventing the shape of the tool from being determined. This technological group does not provide noteworthy technological and typological information.

5.5.6 Denticulates made of rock crystal

Except for three pieces made from translucent raw material, the other denticulates are transparent. Half of the artefacts bear traces of the external crystal surfaces: from the zone between the base and the prism (Pl. 7: 14), from the prism (Pl. 6: 7) and from the rhombohedron (Pl. 6: 2).

Denticulates were predominantly made from flakes (n. 12), including natural, maintenance or generic flakes. They originate from the initial phase of opening (Pl. 7: 14), with unipolar and centripetal scars (Pll. 10: 2 and 16: 8). Some flakes with centripetal negatives show a ventral curvature clearly attributable to a discoidal core. Among these, RR 1325 attests the use of discoidal cores on flake (Pl. 9: 10). Three denticulates are made on relatively thin blades (Pll. 6: 7 and 10: 2).

From a typological viewpoint, denticulates are predominately notches (D1), all made with deep retouch (Tab. 16). Three examples feature a double notch (Pl. 10: 2).

5.5.7 Splintered pieces made of rock crystal

All splintered pieces are made from transparent hyaline quartz flakes. One piece has a natural butt from the prism face. In two cases, the splintering affects only the transversal edge (E1), while in the last case, it also affects the lateral edges (E3) (Tab. 16).

6. Techno-typological analysis of chert and other flakable rocks

6.1 The reduction of the Buchenstein chert

Technological analysis shows that the Buchenstein chert was knapped on site for tool production. Exploitation began from small slabs and small to very small prismatic blocks, originating from natural fracturing, without preparation (Pl. 17: 1, 3- 4). These natural surfaces are generally smooth and flat, or slightly wavy. Reduction developed along orthogonal planes, with striking platforms established the on a fracture or natural surface in order to initiate extraction along a natural edge (Pl. 17: 4). *Débitage* proceeded with short series of detachments. Bladelet production was carried out using:

1) frontal *débitage*, on a narrow flaking surface (Pl. 17: 3). This technique was used to reduce small slabs, with short flaking sequences, and any mistakes could be corrected by forming a second opposite striking platform (see, for example, the fragmentary bladelet (Pl. 17: 9).
2) a *débitage* on a wide flaking surface, in a half-turning way (Pl. 17: 1). The maintenance of the core convexities was achieved through lamellar detachments converging towards the core base (see pyramidal shape of core RR 843, and the orientation of the dorsal scars of the rejuvenation flake Pl. 17: 7, see slightly plunged bladelet with asymmetric distal end Pl. 17: 6). Another method of maintenance involved the detachment of flakes from the core flanks. The correction of the frequent hinged negatives was achieved by the detachment of plunging flakes (Pl. 17: 7). In an advanced state of reduction the knapper might attempt a core reorientation, a typical behaviour in Sauveterrian technology.

The example (Pl. 17: 1) shows the opening of a new lamellar flaking surface along the edge between the striking platform and the flaking surface, a trial soon abandoned due to hinging.

Buchenstein flake production is attested by a residual discoidal core (Pl. 17: 2). This core, along with the rejuvenation flake Pl.17: 5, similar to a *debordante* flake, indicates flake production with facial *débitage*, again typical of the Sauveterrian *débitage*.

6.2 The retouching of the Buchenstein chert

At Staller Sattel STS 4A the Buchenstein chert was used for few specific tool categories. Twelve out of 15 retouched artefacts are armatures (Tab. 4). These are very small in size, ranging from 6.4 to 12.4 mm length, and generally thin (ranging from 0.6 to 2.8 mm). Several items have a flat dorsal face with no any arris. At least some of the armatures were made from bladelets (Tab. 5), possibly originating also from the early phases of core reduction (Pl. 17: 15 with natural surface).

Typologically, the armature assemblage is dominated by geometric pieces. Nearly all of them are scalene triangles, short and backed on three sides (Tabb. 4, 11-12; Pl.17: 16-18). Examples nn. 17 and 18, found lying near one another, are nearly identical. The backed points made of Buchenstein chert, none of which are intact, are very thin. It cannot be excluded that they are fragmented triangles (Pl. 17: 14). All armatures have a direct unipolar back. The microburin technique is not attested, nor is there any evidence of other intentional shortening techniques. This is likely due to the brittleness of this specific raw material.

The only three common tools made of Buchenstein are an endscraper and two truncated pieces (Tab. 4). The frontal endscraper, which is particularly thin, was made on a rejuvenation flake with a hinged end (Pl. 17: 8). The truncations are very small in size (Pl. 17: 10) thus resembling armatures. Microlithic truncations are frequently attested in Sauveterrian assemblages.

6.3 Artefacts made of Rosso Ammonitico chert

The small artefact assemblage made of Rosso Ammonitico chert is mostly composed of armatures (5 out of 8, Tabb. 1 and 4), very small in size and made either from bladelets or small flakes. From a typological viewpoint the assemblage comprises a backed piece with truncation, a geometric fragment (former triangle) (Pl. 18: 1-2), a backed point with marginal retouch and several backed fragments. Considering the few elements of flaking waste, which are small in size and technologically non-diagnostic, it is likely that they originate from tool maintenance rather than from a production sequence. Therefore, the limited Rosso Ammonitico assemblage seems to be the result of a sporadic arrival, possibly related to the retooling of a hunting weapon.

6.4 The reduction of cherts from the Southern Prealps

The artefacts made of chert varieties originating from the Southalpine formations of the Friulian-Belluno Prealps have a fresh appearance; only three artefacts are covered with patina. Several artefacts are burned (n. 12 out of 41). Three elements – two endscrapers (Pl. 18: 14-15) and a crested bladelet (Pl. 18: 5) – display traces of dark and punctiform substance that further analysis would determinate. The impression of the Authors is that it could be pitch. The assemblage is represented by nearly all technological categories (Tab. 1). Nevertheless, the absence of waste from the initial stages of *débitage*, and the sporadic elements interpretable as flaking waste, excludes systematic knapping activity on the site, except for tool and core maintenance. This is consistent with the importation of finished items (tools, armatures, unretouched blanks with functional potential and cores ready for extraction).

Judging from the natural surfaces observed on some of the core maintenance blanks, the cores were established on cortical blocks, on small blocks with natural surfaces from diaclasis or on pebbles. The only preserved core (Pl. 18: 3) is made from a small prismatic block. It was aimed at producing small flakes by a half-turning *débitage* from a single natural striking platform. The transversal convexity was maintained by lateral detachments, while there is no longitudinal curvature. The carinated endscraper (Pl. 18: 4) is made on a former core-on-flake, probably of pyramidal shape. This former core shows the typical reorientation, an operation useful for prolonging core exploitation. Flaking mistakes, such as hinging, caused by a loss of flaking angle are frequently observed. Several hinged flakes are found both among the unretouched artefacts and among the blanks transformed into armatures. Several flakes with functional potential originate from sequences with centripetal detachments, (Pl. 18: 7, 15-16) from the first phases of *débitage* (Pl. 18: 12). Only one flake clearly originates from a unipolar sequence on a large flaking surface.

Bladelet production is indirectly attested by several unretouched artefacts originating from the maintenance of bladelet flaking surfaces (Pl. 18: 5-6). These artefacts are generally quite thick and show convergent or bipolar negatives. By plunging, they established the longitudinal curvature of the core.

6.5 The transformation of the cherts from the Southern Prealps

Sauveterrian complexes are typically characterized, amongst other features, by a bladelet production aimed at producing armatures. This cannot be stated with certainty for the assemblage of Prealpine cherts at STS 4A as none of the five armatures clearly originate from bladelets. Two of them are made from flakes, oriented transversely to the flaking axis (Pl. 18: 10) (Tabb. 5 and 6). Regarding the chert varieties, up to four out of the five armatures are made of chert from the Soccher Limestone formation (see chapter 4.4.3).

The armatures are very small. The intact specimens range between 7.5 and 8.0 mm in length, with thickness varying between 0.9 and 2.4 mm. No backed points or backed bladelets are present (Tab. 4). The two scalene triangles are short and have three backed sides (Pl. 18: 8, 10). The back of the armatures is always made with direct unipolar retouch, except for one item which has inverse bipolar backing. Notably there is the complete lack of microburins and other backing residuals.

Common tools (Tabb. 4 and 6) were made from flakes, often originating from centripetal *débitage* (see above). Prealpine chert, specifically Maiolica and Scaglia Variegata Alpina (see chapters 4.4.3 and 4.4.4), was preferentially used to make endscrapers (n. 5 out of 7 domestic tools). The types of endscraper are shown in table 15. The two carinated endscrapers, made from thick Maiolica flakes, seem to come from the same reduction sequence (Pl. 18: 4, 14). On both of them the Herztian cone is exposed, indicating that their detachment occurred with an over-sized hard hammerstone.

6.6. The sporadic use of local filonian "pegmatitic" quartz

The use of filonian or pegmatitic quartz is attested by sporadic artefacts (10 among the spatially recorded finds: a backed fragment, a short scraper, three unretouched artefacts, a raw material bloc and four small items of flaking waste). The small sample comprises artefacts of notable size compared to the average size of the lithic industry from STS 4A, which can be explained by a minor geographical distance from its outcrops (see chapter 4.2). According to refit n. 7 (Pl. 18: 19), this raw material was also collected in the form of small slabs. The technological features of the artefacts indicate a reduction process consistent with Sauveterrian lithotecnics. The cores' flaking surfaces were rejuvenated through thick flakes in the case of hinging (Pl. 18: 17, 20). Such thick blanks could be transformed into common tools, as in the case of n. 17. Its dorsal negatives show core reduction with two striking platforms for producing flakes and bladelets. Bladelets made of filonian quartz were used for armature production (Pl. 18: 18 on lateral bladelet).

In general, products and flaking waste suggest that the *débitage* of filonian quartz does not differ from the chert varieties found at the site. Despite the small number of artefacts, all major lithic categories are represented. While it cannot be proven, this raw material could have been knapped on site.

6.7 Quartz and local grey quartzite – knapped or not?

Among the elements from quartz and local grey quartzite recovered from the site (Tab. 1) only a single piece can be identified as a flake. It remains doubtful whether the others are artefacts or not. Two conjoined quartzite elements form a natural fragment. Another item represents a portion of a quartz pebble. It cannot be proven that this material was used for knapping.

6.8. Radiolarite armatures from the Northern Calcareous Alps

The two armatures made from radiolarite, most probably of northern Alpine provenance, are both scalene triangles (Tab. 12; Pl. 18: 21-22). The intact example (n. 21) is made from a bladelet. Its shortest side is slightly concave. Both items show retouching also on the long side, but only on n. 22 this forms a third back. The similarity between these two armatures, both of comparable size (width: 3 and 3.2 mm; thickness 1.4 e 1.2 mm) and morphology, suggests that they arrived as finished products, possibly mounted on the same weapon.

From a typological viewpoint, the two armatures, while not inusual in Sauveterrian typology, also show similarities with armature types reported in northern Alpine Beuronien contexts, namely some strongly scalene triangles of "Beuronian C", the most recent phase of the ancient Mesolithic in Southern Germany (Taute 1973-74: 14-16, fig. 3). These triangles are attested in the lithic assemblage of Sarching '83 near Regensburg (Eastern Bavaria), in the Danube sands, with C14 datings between 8340 ± 60 BP and 7752 ± 48 BP (Heinen 2001). The assemblage comprises abundant small and strongly scalene triangles, some with concave base, including specimens with long sides partly or entirely retouched (Heinen 2001: 470, Fig. 218 nn. 1, 3, 7, 28, 31). The author suggests that such features may have originated form contacts with the Sauveterrian techno-complex of Northern Italy (Heinen 2001: 536 and following).

7. An overview on retouched artefacts across raw material varieties

7.1. Armatures

At STS 4A the microlithic armatures show the highest raw-material variety among the different artefact categories (Tab. 1). Rock crystal is the most commonly used material for making armatures (80%), with transparent crystal portions systematically selected to ensure high-quality mineral. The second most common raw material is Buchenstein chert (13%). The production of armatures apparently did not involve the microburin technique, as this typical manufacturing waste is sporadic among rock crystal artefacts and totally absent among all chert varieties (Tabb. 1 and 7). Elsewhere, such waste from armature manufacturing is very abundant, especially in the Sauveterrian high-altitude sites of the Southern Alps (Lanzinger 1985). A possible explanation could be both the absence of systematic bladelet production with rock crystal, as well as the easier breakage of the blanks. This latter aspect is also valid for the Buchenstein blanks, which are particularly thin. The absence of microburins has also been observed in the lithic assemblage of Mont Fallère dominated by rock crystal (Raiteri 2017).

The dimensional analysis of all the 40 intact armatures highlights their very reduced size, concentrated within a length range of 5.8 - 16.7 mm (measuring the longest axis) and a width range of 1.6 - 5.2 mm (Fig. 14). Thickness, measured across the entire sample, ranges from 0.5 - 3.8 mm, with a clear predominance of the 1.1-2 mm class (Fig. 15). The size differences observed between the two most exploited raw materials has a typo-technological explanation. Rock crystal was preferably used for backed points, mostly with double back, both right and left, representing variants of the *Sauveterre* point (Tab. 8). In several cases, these points were made on thin flakes that were backed transverely to combine the necessary length with robustness. This explains the larger size of the hyaline quartz

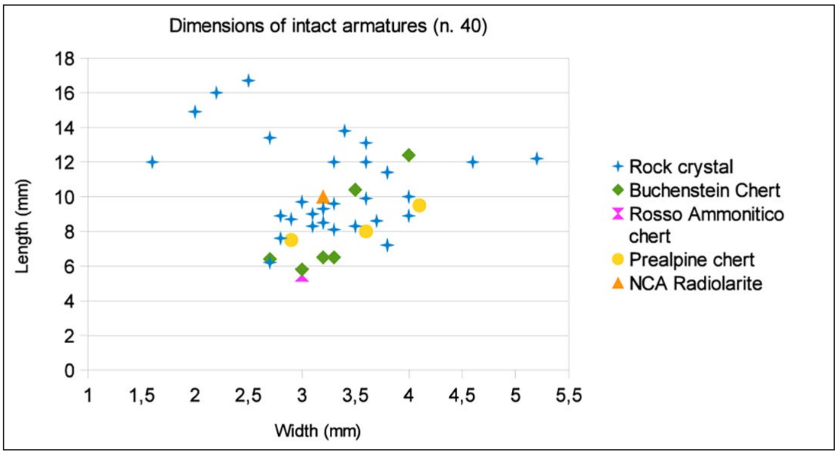

Fig. 14 – *Size of the intact armatures divided by lithic raw material. /* ***Fig. 14 –*** *Dimensione delle armature integre divise per materia prima.*

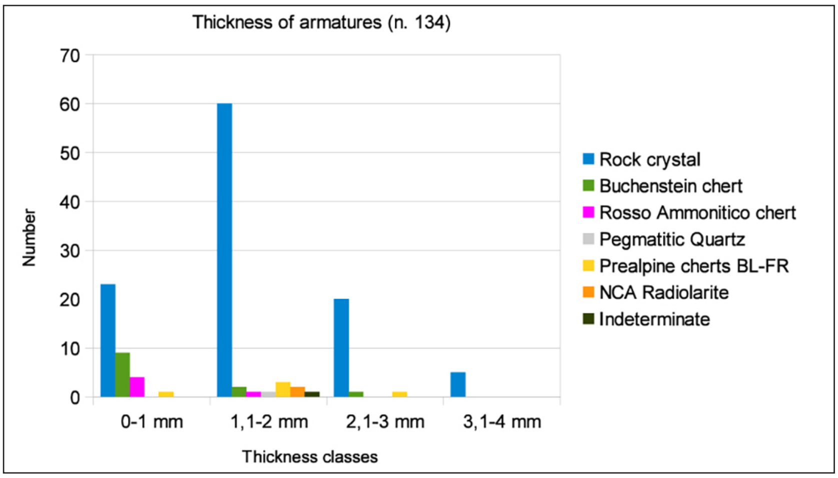

Fig. 15 – *Thickness classes of the armatures divided by lithic raw materials. /* ***Fig. 15 –*** *Classi di spessore di tutte le armature divise per materie prime litiche.*

armatures (Figg. 14 and 15). In contrast, the production of backed points played no role among the Buchenstein and the other lithic raw materials. These are either absent, fragmentary or atypical. Such differentiation could be explained by the large size of quartz crystals compared to the Buchenstein chert blocks.

The production of geometrics (such as triangles) and backed tools with truncation, two groups that are morphologically and dimensionally very similar to each other, used all raw materials, but is percentage-wise, most frequent among the Buchenstein and the Prealpine cherts (Tabb. 4, 10-11).

The geometric pieces are dominated by scalene triangles, produced with all the different raw materials (Tabb. 11-12). The long scalene triangles are made exclusively of rock crystal and radiolarite, whereas the short scalene triangles are preferably made of Buchenstein and Prealpine cherts. Scalene triangles with a third back are well represented across all raw material varieties. However, due to the low elongation index (3.2 at most), none can be classified as *Montclus* triangle (according to G.E.E.M 1969).

In general, a higher rate of generic backed fragments is noted among the rock crystal armatures compared to the other raw materials (Tab. 14), which is consistent with the preferential use of this mineral in the hafting-and-retooling process of hunting weapons carried out on site.

7.2. Retouched domestic tools

The proportion of domestic tools among the retouched artefacts shows a fairly balanced ratio, with 41% of domestic tools compared to 59% of armatures (Tab. 1). A percentage of less than 70-75% for the latter is considered typical for base camps where a variety of subsistence tasks were carried out (Lanzinger 1985; Bagolini & Dalmeri 1987).

At STS 4A the common tools made from chert have been preferably chosen among the core-maintenance and core-correction blanks due to their major thickness. This is a common feature in Sauveterrian industries. In contrast, thick rock crystal blanks used for domestic tools do not originate from maintenance but rather from crystal opening and other operations made on the natural crystal surface. Retouched tools made from flakes and blades are mostly represented by endscrapers, scrapers and denticulates (Tab. 4). Among these, endscrapers show a greater variety of raw-material, and also a higher technical investment in production and maintenance (Tab. 15). The predominance of this typological group is also due to several endscrapers made from Prealpine chert (5 out of 23).

8. Use-wear analysis

8.1 Experimenting the functionality of rock crystal as raw material

An experimental protocol was developed to characterize use-wear on rock crystal surfaces and assess the functionality of artefacts made from this mineral. A series of 16 tool replicas were produced, and then used to perform different tasks (Tab. 17).

Tab. 17 – *Experimental artefacts and activity carried out for the use-wear study. /* ***Tab. 17 –*** *Pezzi sperimentali e attività eseguite nell'ambito dello studio funzionale.*

Exp. n.	Tool type	Active edge, morphology	Active edge angle	Task	Motion	Worked material	Contact angle	Contact surface	Working time (min)
1	Unretouched flake	Pointed	25°	Butchering (skinning)	Longitudinal	Meat+skin	80°/90°	Ventral + dorsal	5
2	Unretouched flake	Pointed	25°	Butchering (evisceration)	Longitudinal + transverse	Meat	60°/80°	Ventral + dorsal	5
3	Unretouched flake	Rectilinear	25°	Butchering (disarticulation)	Longitudinal + transverse	Meat+bones	60°/90°	Ventral + dorsal	10
4	Unretouched flake	Rectilinear	30°	Butchering (defleshing)	Transverse	Meat+bones +tendons	60°	Ventral	15
5	Unretouched flake	Convex	30°	Butchering (defleshing)	Transverse	Meat+bones +tendons	30°	Ventral	5
6	Unretouched flake	Rectilinear	20°	Hide processing (removal of subcutaneous fat) without abrasives	Transverse	Skin	30°	Ventral	20
7	Unretouched flake	Rectilinear	30°	Hide processing (removal of subcutaneous fat) without abrasives	Transverse	Skin	30°	Ventral	20
8	Endscraper	Rectilinear (Retouched)	40°	Tanned hide processing	Transverse	Skin	30°	Ventral	45
9	Unretouched flake	Sinuous	30°	Bone working	Transverse	Bone	30°	Ventral	7
10	Unretouched flake	Convex	25°	Bone working	Longitudinal	Bone	80°/90°	Ventral + dorsal	60
11	End scraper	Rectilinear retouched	40°	Bone working	Transverse	Bone	30°/40°	Ventral	15
12	Unretouched flake	Rectilinear	30°	Wood working	Longitudinal	Wood	90°	Ventral + dorsal	15
13	Unretouched flake	Concave	25°	Wood working	Transverse	Wood	40°	Ventral	10
14	Side scraper	Rectilinear retouched	40°	Wood working	Transverse	Wood	30°	Ventral	10
15	Unretouched flake	Rectilinear	30°	Antler working	Longitudinal	Antler	90°	Ventral + dorsal	15
16	Unretouched flake	Concave	35°	Antler working	Transverse	Antler	40°	Ventral	15

8.1.1 Butchering

Experimental butchering, in particular skinning, evisceration, disarticulation, and defleshing, was performed on some portions of rabbit. The activities were carried out using only small artefacts (5 unretouched flakes), as the archaeological sample under consideration consists exclusively of small objects. One of the tools was hafted to a wooden handle using pitch and sinew. During these operations, both transverse and longitudinal movements (uni- and bidirectional) were executed. Butchering requires tools with relatively sharp, active cutting edges. The most effective tools are those with a straight profile and an angle of 20°-30°. Retouched edges are inadequate for this type of activity.

During butchering the tool may come into contact with bone, which leads to significant changes to the resulting traces. Therefore, it is essential to distinguish between alterations caused by exclusive contact with meat tissues and those caused by contact with both meat and bone.

Traces resulting from the processing of soft animal tissues are poorly developed, mainly consisting of small, isolated scars accompanied by slight edge rounding and occasional, shallow, fine striations (Fig. 16: a).

When a tool comes into contact with bone, the traces become more pronounced. They consist of some small, discontinuously arranged scars along the used edge. These traces are associated with fine abrasion and narrow, irregular striations (Fig. 16: b-c). Butchering did not result in polished areas on the tools' surface.

8.1.2 Antler working

Two unmodified tools were used for this task performing actions both parallel to the active edge and perpendicular to it. Unlike chert tools, where unmodified active edges with a low angle are not effective because they lose functionality after a few minutes of use due to excessive fracturing, rock crystal tools, even with unmod-

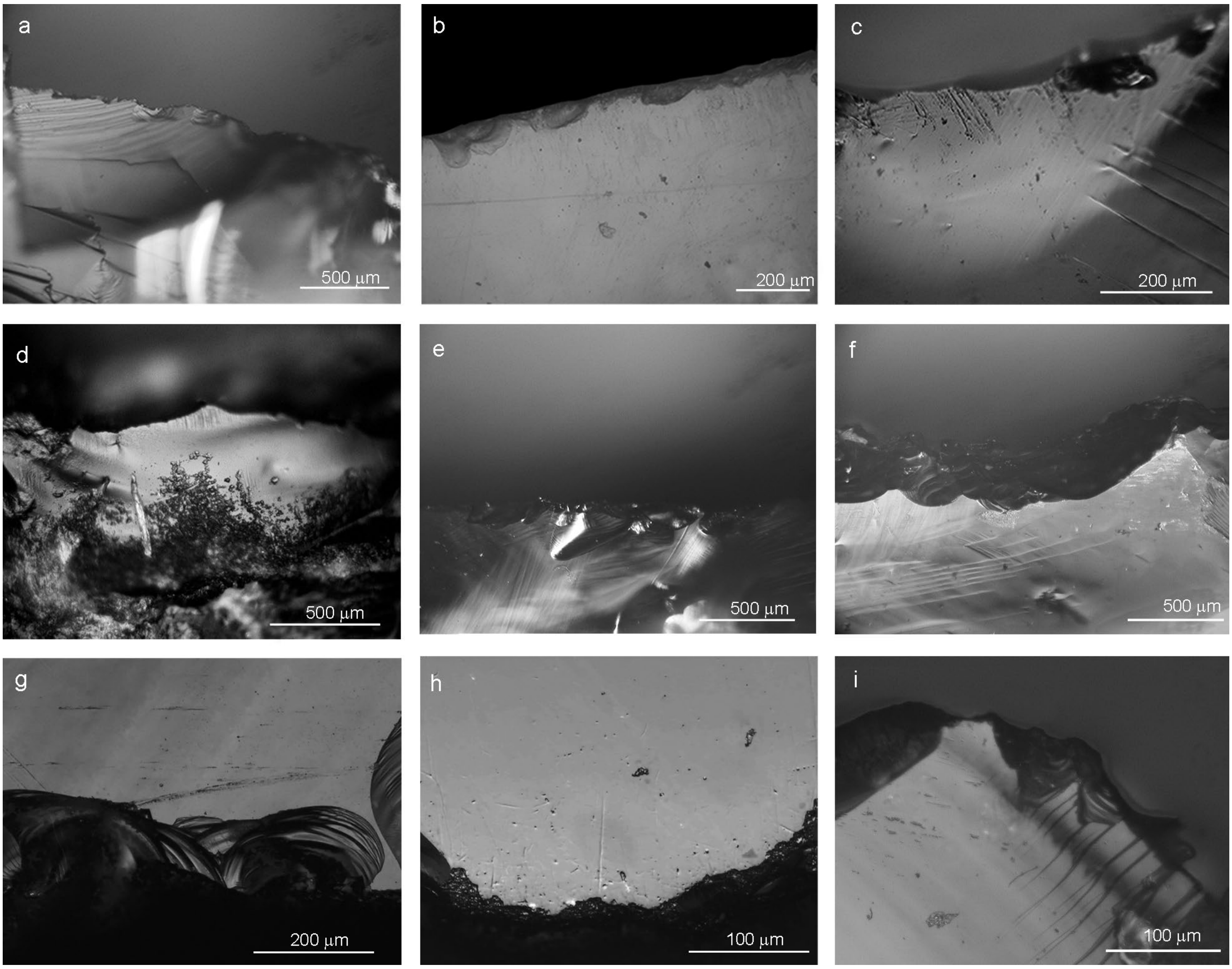

Fig. 16 – *Experimental use-wear traces. a) Isolated scars produced by skinning (exclusive contact with soft animal tissues); b) Edge rounding and fine abrasion in association with scars from evisceration (mainly contact with soft tissues and occasionally with hard animal tissues); c) Scars and narrow striations produced by disarticulation (due to contact with both soft and hard animal tissues); d) Intense abrasion and short striations produced by scraping antler; e-f) Intense micro-scarring produced by sawing antler; g) Large scarring and wide striations produced by sawing wood; h) Pronounced abrasion and light smooth polish associated with pits and short striations produced scraping wood; i) Large and short striations associated with scarring produced by scraping wood. /* ***Fig. 16 –*** *Tracce d'uso sperimentali. a) Isolati distacchi prodotti da spellamento (contatto solo con tessuti animali morbidi); b) Arrotondamento degli spigoli, leggera abrasione e sbrecciature risultanti da operazioni di eviscerazione (principalmente contatto con tessuti morbidi e occasionalmente con tessuti animali duri); c) Sbrecciature e sottili striature derivanti da attività di disarticolazione (contatto sia con tessuti animali morbidi che duri); d) Abrasione intensa e corte striature prodotte da raschiamento di palco; e-f) Sbrecciature evidenti prodotte segando palco; g) Ampi distacchi e larghe striature prodotti segando legno; h) Abrasione marcata e politura omogenea e poco sviluppata associate a "pits" (cavità) e brevi striature risultanti dalla raschiatura del legno; i) Striature larghe e corte associate a sbrecciature prodotte dalla raschiatura del legno.*

ified edges, are well-suited for antler working. Antler processing causes the formation of many scars on the rock crystal artefacts, often large and medium sized, frequently arranged on multiple levels associated with marked abrasion (Fig. 16: d-f). Striations are large and short (Fig. 16: d). Edge rounding is not recorded. The antler processing did not result in the formation of polishing.

8.1.3 Woodworking

The experimental activity was conducted on holm oak *(Quercus ilex*) wood, using an endscraper and two unmodified flakes, with the tools employed in both transverse and longitudinal movements. Good results, in terms of efficiency, were achieved with cutting edges that had a straight profile and an active edge angle of less than 35°/40°. The concave profile proved well-suited for transverse movements, as it conformed to the shape of the branch. Woodworking results in medium and large sized scars on the active edge. Additionally, regular, wide, and superficial striations, along with faint smooth polishing, are observed, often accompanied by small craters (pits) on the tools' surface (Fig. 16: g-i).

8.1.4 Bone working

Bone working may include all activities related to the transformation of this raw material into various artefacts, such as ornamental objects, tools, tool handles, etc. Unlike butchering the lithic tool comes into contact exclusively with bone. Three tools were experimentally used for these tasks (two unmodified artefacts and a sidescraper). For motions carried out transversely to the active edge, straight or slightly concave cutting edges, both retouched and unmodified, with an active edge angle measuring less than 40°, proved to be effective. For actions performed parallel to the active edge, straight or slightly convex edges with an angle between 20° and 35° were found to be suitable.

Use-wear produced by hard materials typically affects only the outermost edge (Knutsson 1988). The traces developed during bone working consist of medium to large sized scars, which may be arranged on one or more levels, along with predominantly irregular striations, associated with extensive abrasion (Fig. 17: a-c). Bone working also produces frequent deep and large striations. In our experimental tests, bone working did not cause the polishing of rock crystal surfaces, differently from what other experimental studies report (Fernández-Marchena & Ollé 2016).

8.1.5 Hide processing

This phase of the experimentation focused on the processing of rabbit hide using three artefacts (two unmodified and one endscraper). The first stage involved cleaning the hide of subcutaneous fat and flesh residues. This was done both with the addition of sand (to facilitate fat removal) and without any additives. Unmodified edges, with a straight profile and an edge angle of less than 30°, proved to be particularly effective, especially during fat removal. The subsequent step involved treating the leather after tanning. In this phase, modified edges with a relatively large active edge angle (40°) were found to be suitable for breaking the dermal fibres of the leather, softening and thinning it.

The hide-working process causes minimal alterations to the rock crystal artefacts. Significant traces were only found when abrasives (sand) were used on fresh hide, resulting in edge rounding, abrasion of the area in contact with the worked material, and abundant, short and narrow striations, in association with some small-sized scars (Fig. 17: d). Cleaning the hide of fat without the use of abrasive substances and processing the leather after tanning did not produce diagnostic traces, except for small, isolated scars and some irregular striations (Fig. 17: e). Processing tanned hide produced a marked abrasion, nar-

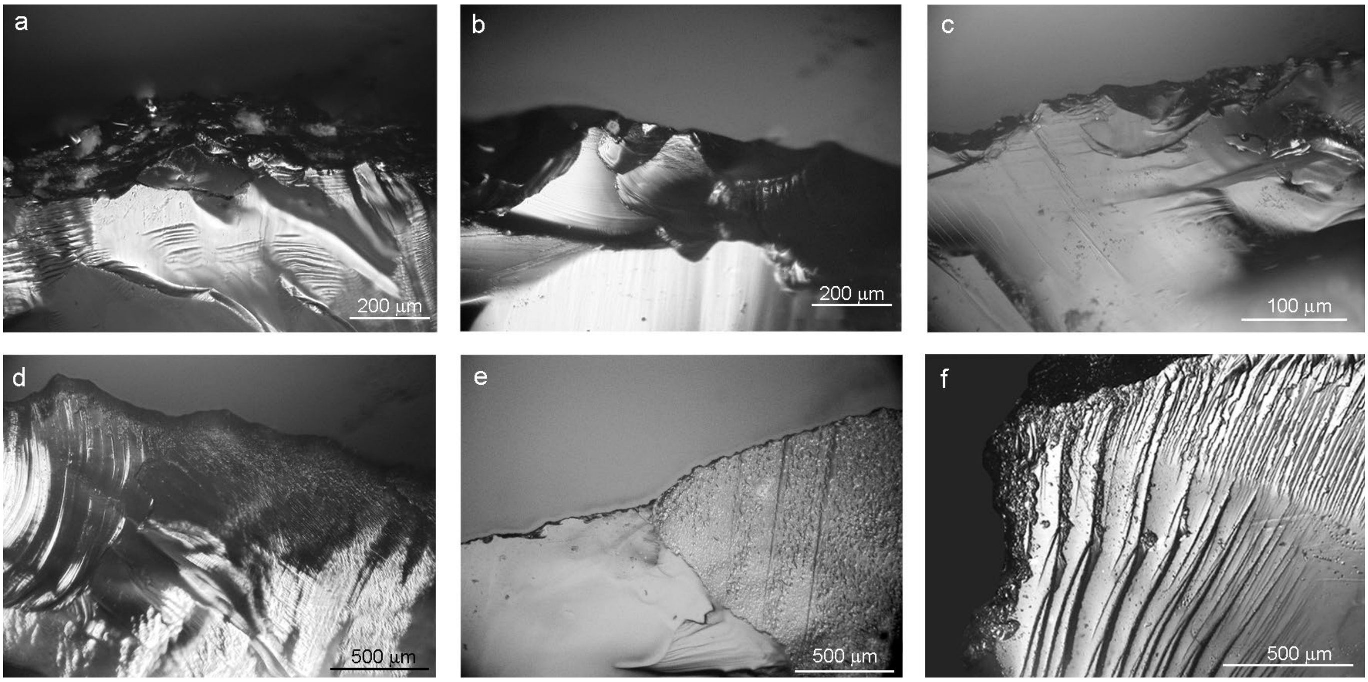

Fig. 17 – *Experimental use-wear traces: a) Abrasion and large scars on multiple levels, accompanied by faint striations produced by transverse movements on bone; b) Medium sized scars and irregular striations produced by sawing bone; c) Large and medium sized scars produced by sawing bone; d) Extended and marked abrasion, along with numerous striations, produced by removing fat from skin using sand; e) Slight edge damage due to cleaning the skin of fat without the use of abrasive substances; f) Pronounced abrasion, edge rounding and short striations produced by the processing of tanned hide. /* ***Fig. 17 –*** *Tracce d'uso sperimentali: a) Abrasione e ampi distacchi organizzati su più ordini, accompagnati da leggere striature prodotte da movimenti trasversali su osso; b) Distacchi di media dimensione e striature irregolari prodotte segando osso; c) Distacchi di media e grande dimensione prodotti segando osso; d) Abrasione estesa e marcata, accompagnata da numerose striature, prodotte dalla rimozione di grasso dalla pelle con l'utilizzo della sabbia; e) Sbrecciature poco marcate sui margini dovute alla pulitura della pelle dal grasso senza sostanze abrasive; f) Abrasione marcata, arrotondamento dei margini e corte striature prodotte dalla lavorazione di pelle conciata.*

row, fine striations, and edge rounding (Fig 17: f). No polishing occurred on the surface of the tools during any of the hide-processing stages.

8.1.6 Insights on the functionality of rock crystal

Though not exhaustive, our experimental program has provided some interesting insights:

a) The development of traces on rock crystal is very slow. When working with resilient materials such as wood and antler, noticeable traces begin to form after approximately 15 to 20 minutes of use. Tools employed on less resilient materials, such as meat and hide, generally did not develop significant traces—particularly when used for short durations, as was the case in most experiments (e.g., 5 to 15 minutes for butchering). In instances where use-wear was observed, it was often associated with the presence of abrasive substances such as bone, ash, or sand. These observations are consistent with previous studies (Gibaja & Carvalho 2005; Araujo et al 2007), which report the development of butchering- and soft-material-related traces only after extended use. This suggests that the absence of use-wear on tools used to process softer animal materials – especially during short tasks – may not necessarily indicate a lack of use. Further experiments involving longer use durations are required to better understand the conditions under which traces develop on this raw material.
b) Rock crystal tools have very sharp cutting edges that lose their effectiveness more slowly compared to other raw materials as chert and jasper. This makes rock crystal particularly well-suited for all types of work, especially in butchery.
c) Rock crystal's active edges, when in contact with hard material (such as antler, bone and wood), fracture much less than those on chert and other knappable rocks, making micro-scars almost invisible without magnification.

Tab. 18 *– The archaeological sample with use-wear-traces. /* ***Tab. 18*** *– Il campione archeologico con tracce d'uso.*

Artefact categories:	Rock crystal	S. Prealpine chert	Buchenstein	Total
Endscrapers	4	1		5
Burins	2			2
Truncated pieces	1			1
Undifferentiated Abrupt retouched pieces	1			1
Denticulates	3			3
Scrapers (long, short and fragmented)	3			3
Subtotal retouched	14	1	0	15
Unretouched flakes	11	1		12
Unretouched laminar flakes	2			2
Unretouched blades	2			2
Indeterminable fragments	1			1
Slab			1	1
Subtotal unmodified	16	1	1	18
Total	30	2	1	33

8.2 Results of the use-wear analysis on the archaeological artefacts

Use-related traces have been identified on 33 artefacts of the studied sample (98 in total), 30 of which are made of rock crystal, one of Buchenstein chert and two of prealpine Maiolica and Scaglia Rossa chert, respectively (Tab. 18). Surface modifications caused by post-depositional phenomena mainly affect artefacts made of Buchenstein chert (two items show a gloss patina) and a few elements made of other types of chert (five artefacts exhibit a light glossy appearance). Finally, five rock crystal objects show traces of dubious origin. The remaining items do not show any surface modification.

The identified use-wear (Tab. 19) mainly consists of edge

Tab. 19 *– Analyzed archaeological sample with use-wear traces, divided both by type of action and processed material. /* ***Tab. 19*** *– Il campione archeologico con tracce d'uso, diviso sia per tipo di attività che per materiale lavorato.*

Artefact categories	Action			Processed materials							
	Longitudinal	Transverse	Indeterminable	Hide	Meat	Wood	Hard	Semi-hard	Soft	Indet.
Endscrapers		5		2		1?				2
Burins	1	1				1				1
Truncated pieces		1								1
Undifferentiated abrupt retouched pieces			1							1
Denticulates	3						1	2		
Scrapers (l, s, fr)	3						3			
Unretouched flakes	7	5		1	1?		3	4	1	2
Unretouched laminar flakes	1	1						1		1
Unretouched blades	1	1			1			1		
Indeterminable		1								1
Small slab		1							1	
Subotals	16	16	1	3	2	2	7	8	2	9
Total		33					33			

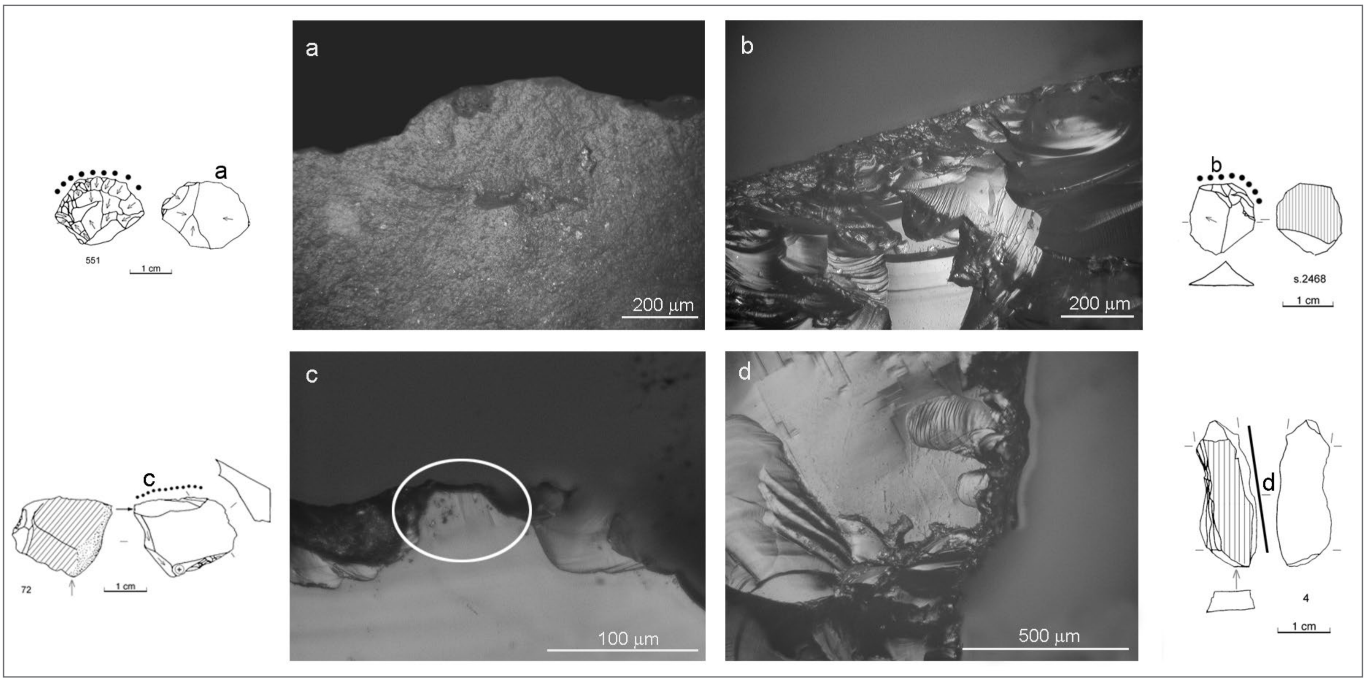

Fig. 18 – Archaeological sample from Staller Sattel STS 4A: a) Polish and edge rounding consistent with hide processing, on a chert endscraper; b) Pronounced abrasion and edge rounding attributable to hide processing on a rock crystal endscraper; c) Abrasion and micro-scarring associated with a weakly polished area, characterized by short striations and pits, on a burin, interpreted as the result of wood scraping; d) Edge damage, abrasions, and narrow striations on a unretouched blade, interpreted as the result of butchering, likely disarticulation. / ***Fig. 18 –*** *Campione archeologico da Staller Sattel STS 4A: a) Politure e arrotondamento dei margini compatibili con la lavorazione della pelle su un grattatoio in selce; b) Abrasione marcata e arrotondamento dei margini attribuibili alla lavorazione della pelle su un grattatoio in cristallo di rocca; c) Abrasione, sbrecciature e zona con leggera politura, caratterizzata da brevi striature e "pits", su un bulino, interpretate come conseguenza della raschiatura del legno; d) Sbrecciatura del margine, abrasioni, e striature sottili su una lama non ritoccata, interpretate come il risultato di operazioni di macellazione, probabilmente disarticolazione.*

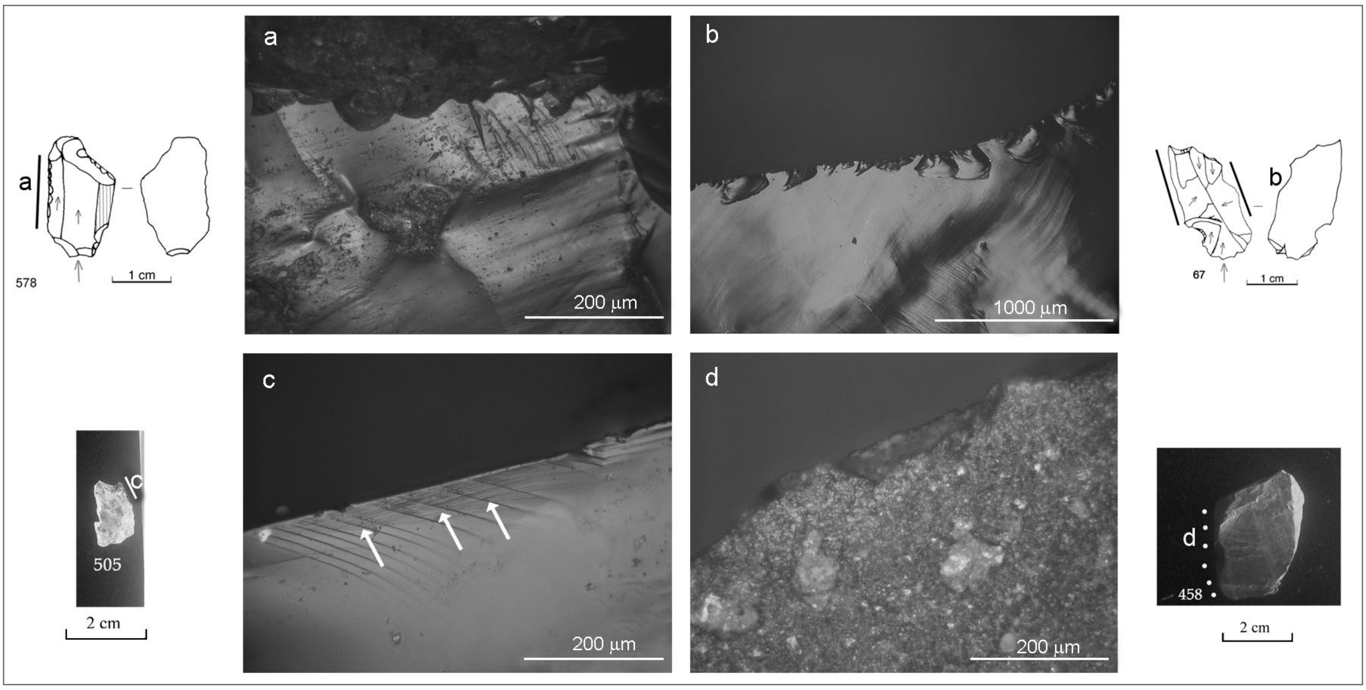

Fig. 19 – *Archaeological sample from Staller Sattel STS 4A. a) Abrasions associated with irregular and longitudinal striations on a rock crystal sidescraper, interpreted as the result from cutting hard material; b) Edge damage on a rock crystal denticulate, interpreted as the result of cutting semi-hard material; c) Thin longitudinal striations on an unretouched flake, interpreted as the result of cutting soft material (likely meat); d) Weak rough polish and edge rounding on a Buchenstein slab, interpreted as the result of scraping soft material. /* ***Fig. 19 –*** *Campione archeologico da Staller Sattel STS 4A. a) Abrasioni associate a striature irregolari e longitudinali su un raschiatoio in cristallo di rocca, interpretate come prodotte dal taglio di materiale duro; b) Sbrecciatura del margine su un denticolato in cristallo di rocca, interpretata come il risultato del taglio di materiale semiduro; c) Sottili striature longitudinali su una scheggia non ritoccata, interpretate come conseguenza del taglio di materiale morbido (probabilmente carne); d) Politura poco sviluppata e irregolare accompagnata da arrotondamento del margine su una placchetta in selce del Buchenstein, interpretati come il risultato del raschiamento di materiale morbido.*

scarring, located on one or both sides of the tool, in association with striations and abrasions. Polishing is generally absent or weakly developed and does not allow to identify the processed material, except in a few cases.

Cutting motion was identified on 16 pieces, associated with butchering (1 flake), processing indeterminate materials of various consistency, soft (n. 1), medium/hard (n. 4) and hard (n. 6), as well as unidentifiable materials (n. 3). Transverse actions were identified on n. 16 artefacts, related to hide processing (n. 2), woodworking (n. 1), processing indeterminate materials of various consistencies, such as soft (n. 1), medium/hard (n. 4) and hard (n. 3), and unidentifiable materials (n. 5). In one case, both the type of motion and processed material remain unknown.

Among the retouched artefacts, use-wear was detected on five endscrapers (four made of rock crystal and one from chert), three scrapers (in rock crystal), three denticulates, two burins, one abrupt piece, and one truncation. Endscrapers were used for processing hide with transverse motions (n. 2) (Fig. 18: a-b) and for scraping hard material, likely wood, and unidentified material (n. 2) (Pl. 19: 1-3). Scrapers and denticulates were used for cutting hard, or medium/hard material (Pl. 19: 6-7), burins for processing wood (Fig. 18: c) and hard material (Pl. 19: 4), the truncation for scraping non-identifiable material (Pl. 19: 5). The abrupt piece displays not recognizable traces. Sixteen unretouched artefacts, primarily flakes, an indeterminable blank and a small Buchenstein slab exhibit clear use-wear (Fig. 19: d). These were used for butchering (n. 1) (Fig. 18: d) and cutting materials of various consistencies, namely hard (n. 2), semi-hard (n. 2), soft (n. 1), as well as unidentified materials (n. 3). Furthermore unretouched artefacts were used for scraping hide (n. 1) and material of various consistency (hard, n. 2; semi-hard, n. 4; soft, n. 1), as well as unidentified material (n. 1).

Used artefacts display only a single working edge, except for one flake with two active edges. This may suggest that the tools were not extensively used. The active edges are mainly rectilinear (n. 24), with fewer exhibiting a convex (n. 8), sinuous (n. 1), and pointed (n. 1) delineation. Rectilinear edges were used equally for longitudinal (n. 13) and transverse (n. 12) motions, whereas convex edges were mainly used for transverse actions (n. 4 transverse, n. 2 longitudinal). The sinuous edge was used transversely and the pointed edge longitudinally.

The retouched edges served as active portions on five endscrapers and one sidescraper, while the remaining nine formal tools were used along their unretouched edges.

8.3 Discussion on use-wear and functionality

Microscopic analysis revealed that the examined artefacts were used to process materials of various consistencies: hard, medium, and soft. However, the processed material could only be identified for a few specific artefacts (n. 5) which were used in processing hide and wood, as well as in butchering. This difficulty in identifying the worked material may be attributed to the high resistance of rock crystal to use-wear formation (Araújo Igreja et al. 2007; Fernández_Marchena & Ollé 2016). Moreover, the presence of a single working edge per artefact suggests that the tools were likely non-intensively used at the site.

The scenario provided by the functional results demonstrates that various activities were carried out at Staller Sattel STS 4A. This is supported by the heterogeneous composition of the toolkit and the varied consistency of the processed materials, which suggest a range of different domestic tasks.

Use-wear has been detected on both formal tools and on unretouched flakes and blades. We observed that artefacts used for butchering or processing soft materials, with the exception of endscrapers, which merit a separate discussion, are unretouched blades or flakes. Butchering primarily requires cutting tools with very sharp edges (see chapter 8.1), so unretouched edges facilitate the dismemberment of the animal (e.g. Walker 1978). Retouched edges may be employed in such operational contexts when potential contact with hard materials, such as bone, would benefit from more durable edges.

Endscrapers are typically regarded as specialized tools for processing hide with transverse action (e.g. Gavrit Roux & Beyries 2018), and this seems to be the case for at least two specimens from Staller Sattel STS 4A. However their employment in other tasks, to a lesser extent, has been recorded in several archaeological contexts, such as for scraping wood (e.g. Jardón Giner 2000), scraping mineral materials (e.g. Porraz et al. 2018) or processing hard animal tissues (e.g. Porraz et al. 2010). Despite its rarity, the sample from Staller Sattel seems to reflect this trend, as one endscraper shows traces possibly associated with wood processing. The use of this tool type for either a specialized function or a wider range of activities may depend on various circumstances, such as the site function and environmental constraints (Andrefsky 1997).

The morphology of the working edges reveals a clear preference for rectilinear and unretouched edges, suitable for both scraping and cutting. Such preference is also documented by the majority of formal tools, which display use-wear on an unretouched edge rather than on the retouched margin (with the exception of endscrapers and a side scraper). This evidence suggests that retouching on certain artefacts may have served to facilitate hafting or tool-handling. No hafting traces have been identified in the archaeological sample. Given that rock crystal tools have more durable cutting edges compared to chert tools (see chapter 8.1, see Araújo Igreja 2009), the need to retouch them for sharpening to increase their resistance to hard material may have been less significant.

9. Discussion and conclusions

9.1. Site function and activities

The previous interpretation of Staller Sattel STS 4A as a mountain base camp, in line with its central location at the conjunction between adjacent hunting territories and its strategic position within the reconstructed route network (Kompatscher et al. 2016, chapter 5), is consistent with the character of the lithic industry. The reduction of rock crystals and, to a much lesser extent, small Buchenstein chert slabs, was carried out on site. Blanks, mainly flakes, were produced and partly transformed into armatures and domestic tools according to Sauveterrian technology.

The frequency of common tools (41%), which is high compared with other Sauveterrian assemblages from mountain sites (Lanzinger 1985), further supports the interpretation of the site as a base camp, where logistics and subsistence tasks would have played an important role. Use-wear studies indicate the processing of materials with various consistencies through cutting and scraping actions. The working of wood, a raw material available in the immediate surroundings (Kompatscher et al. 2016), is attested by wear traces. Use-wear traces observed on several lithic artefacts provide evidence of butchering and hide working which can be linked to the processing of hunted prey. Repeated use-wear traces found on the endscrapers suggest systematic hide-working tasks carried out by the dwellers at the camp. In this regard, five of the endscrapers, all intensely exploited, are made from cherts sourced from the distant Belluno-Friulian Prealps. This suggests that groups embarking on long-term migrations equipped themselves with tools or blanks made from high-quality raw materials not available along their route. It seems that retooling and repairing hunting weapons were tasks commonly carried out at the site, given that broken and intact microliths make up 59% of all retouched artefacts. *Sauveterre* points were primarily made of rock crystal, whereas smaller armatures (such as triangles and backed pieces with truncation) were mostly made of Buchenstein chert. Small projectiles show the highest raw-material variety of the assemblage, also including items made from high-quality Prealpine chert. There is no evidence for an on-site manufacturing of this raw material, which makes their arrival as finished armatures highly probable.

9.2. Rock crystal as lithic raw material in the Alpine Mesolithic

Our study shows that the transparent portions of crystals, which were preferentially worked at STS 4A, respond to *débitage* in a most similar way to high-quality chert. The disadvantages associated with the anisotropy of rock crystal, such as the higher brittleness and a less flexible breaking behaviour of this mineral, could be controlled by the knappers. In contrast, the translucent portion of the crystals, which may exhibit unpredictable changes in the direction of detachments, allow for less predetermination of the desired blanks and result in higher raw material waste. The *débitage* of hyaline quartz is conditioned by the given angles and faces. The extremities of the rhombohedra offer the only suitable angle to open an intact crystal. To obtain the desired thin blanks, mostly flakes, knappers at STS 4A positioned the flaking surface obliquely to the c-axis. Without any need for prior preparation, the longest and most regular blanks could be extracted during the first phase of *débitage.* Core management followed the Sauveterrian reduction schemes commonly observed on small chert blocks: maintenance of a wide and only slightly convex flaking surface, detachment of short series of unidirectional convergent or centripetal blanks, frequent core reorientations, as well as the use of large flakes as cores.

Despite the differences compared to chert, the latter being isotropic and therefore more flexible during *débitage*, the technical expertise of the Mesolithic knappers allowed them to obtain the desired end products from such unusual raw material by successfully combining original crystal-specific solutions with typical Sauveterrian reduction schemes. Indeed, the realized end products do not differ from the characteristic Sauveterrian armature and tool assemblages made from chert. Regarding the functionality of hyaline quartz tools, our experimental tests yield positive results, showing greater sharpness and durability of the working edges compared to chert. This offers advantages in specific tasks such as butchering and processing hard materials. The variable outlining of the edges, depending on the quality of the crystal – straight in the transparent part and wavy or saw-shaped in the translucent portions – could have been useful on this behalf. In sum, rock crystal is suitable for Early Mesolithic production and can not, therefore, be considered *tout court* a replacement material. Furthermore, a certain versatility of this raw material emerges from experimental work carried out using techniques and methods different from those identified at Staller Sattel (Chelidonio 1990; Visentin 2017).

It is a fact, however, that sites with an abundant rock crystal industry, as a result of on-site reduction of this mineral, are sporadic. In general, these sites are located not too far from the primary sources and in regions where high-quality chert is absent. Comparisons between Staller Sattel STS 4A and other excavated Mesolithic sites dominated by hyaline quartz artefacts (93-99%) are found in the Western Alps. Moving from east to west, two swiss sites can be identified: Andermatt Hospental-Moos, a valley bottom site at 1,475 m a.s.l. in the Canton Uri attributed to the Late Mesolithic (Auf der Maur & Cornelissen 2014), and Zermatt Alp Hermettij, a high-altitude rockshelter at 2,600 m a.s.l. at the foot of the Matterhorn in the Canton Valais, with fireplaces dating to the Early Mesolithic (Curdy et al. 2003). Further west, two Italian sites can be cited: Alpe Veglia/Cianciavero in Piedmont, at 1,750 m a.s.l. at the head of the Val d'Ossola, identified as Sauveterrian base camp with nearby quartz outcrops (Fontana et al. 2000) and MF1 Mont Fallère site in Aosta, at 2,240 m a.s.l., with an industry in secondary deposition attributed to the Sauveterrian (Raiteri 2017). For the first three sites, the authors emphasize their location along or near routes leading to important inner-Alpine passes.

In the Eastern Alps, the already noted rapid decrease of the rock crystal component when moving away from the primary sources (see chapter 1.1), does not fully align with the distribution of the Cretaceous chert varieties from the Southern Alps. These latter have a wider distribution pattern, extending northwards beyond the outcrops. It can therefore be deduced that rock crystals and crystal cores were not systematically transported as raw material reserve, as appears to have been the case with Southalpine chert. One reason for this could be the higher quality and better flaking properties of this latter. Another explanation for this behaviour might be related to the logistics of seasonal mobility. In early summer groups moving towards high altitudes, would be equipped with necessary goods, including high-quality chert. In contrast, by late summer or autumn, when returning to lower altitudes, where winter territories were likely located, additional transport of rock crystals, especially when moving towards territories with sufficient high-quality chert outcrops, would have been an unnecessary fatigue.

9.3. Considerations about seasonal mobility and contacts

The considerations in this chapter are summarized in figure 20. Based on the proximity of territories with rock-crystal bearing fissures, we can infer that the Sauveterrian hunter-gatherers who frequented Staller Sattel STS 4A covered one or more mountain ranges along the main Alpine ridge (the Venedigergroup, flanked by the Zillertaler Alps and the Granatspitz- and Glocknergroups) during their seasonal migrations. They could have accessed them during their stays at Staller Sattel STS 4A, a site with base-camp character, or, hypothetically, by crossing the Alpine divide on their way back south. The direct minimum distances, as the crow flies, between the hyaline-quartz sources and Staller Sattel, are approximately 15-20 km, but the real distances had to be greater, due to the mountain barriers.

Also, the Dolomites were among the mountain ranges exploited during the seasonal hunting-and-gathering circuits that the Staller Sattel area was part of, as shown by the artefacts made of Buchenstein and Rosso Ammonitico cherts. Whereas the latter is represented by sporadic armatures, likely imported as finished artefacts, the *châine opératoire* of the Buchenstein chert is nearly complete. The nearest known primary sources lie approximately 22 km south in a direct line, near Prags/Braies, and are easily accessible. The best routes to and from STS 4A, crossing the Puster Valley, have been reconstructed (Fig. 21). Although Buchenstein chert is a raw material of low flaking quality, its widespread outcrops across the Dolomites (Fig. 20) might have been advantageous for an embedded procurement during seasonal migrations.

Interesting hints about long-distance mobility result from the other high-quality Southalpine chert types. Their petrographic features and the overall characteristics indicate an origin from the Fadalto calcarenites, the Soccher limestone, and the formations of the Fonzaso, Maiolica, Scaglia Rossa and Scaglia Variegata Alpina cropping out in the Belluno-Friulian Prealps, with a particular focus on the Belluno Valley. Another likely source area is the high Friulian Plain of the Tagliamento River. Both areas are located at a distance of approximately 90-100 km and 110 km respectively in a direct line from the Staller Sattel. It is therefore no wonder that none of these varieties seem to have been knapped at STS 4A but were instead imported as single finished artefacts.

Early Mesolithic exploitation of cherts from the Belluno-Friulian Prealps is well known for the Veneto region. Petrographic analyses carried out at Mondeval de Sora, a Mesolithic rock shelter located in the Belluno Dolomites, indicate that cherts used during the Sauveterrian site occupation of sector III were mostly collected from the Belluno Valley, around Alpago and Longarone, areas located about 40-50 km to the south (Valletta et al. 2016). Further parallels with STS 4A are seen in the exploitation of the Triassic Buchenstein formations, which are locally available (Valletta et al. 2016, referred to as "Livinallongo"). Finally, a few rock crystal artefacts are also part of the industry, attesting to contacts between the Belluno Dolomites and the Tauern Window.

The southernmost occurrence of rock crystal though, most likely sourced from the Tauern Window, is represented by sev-

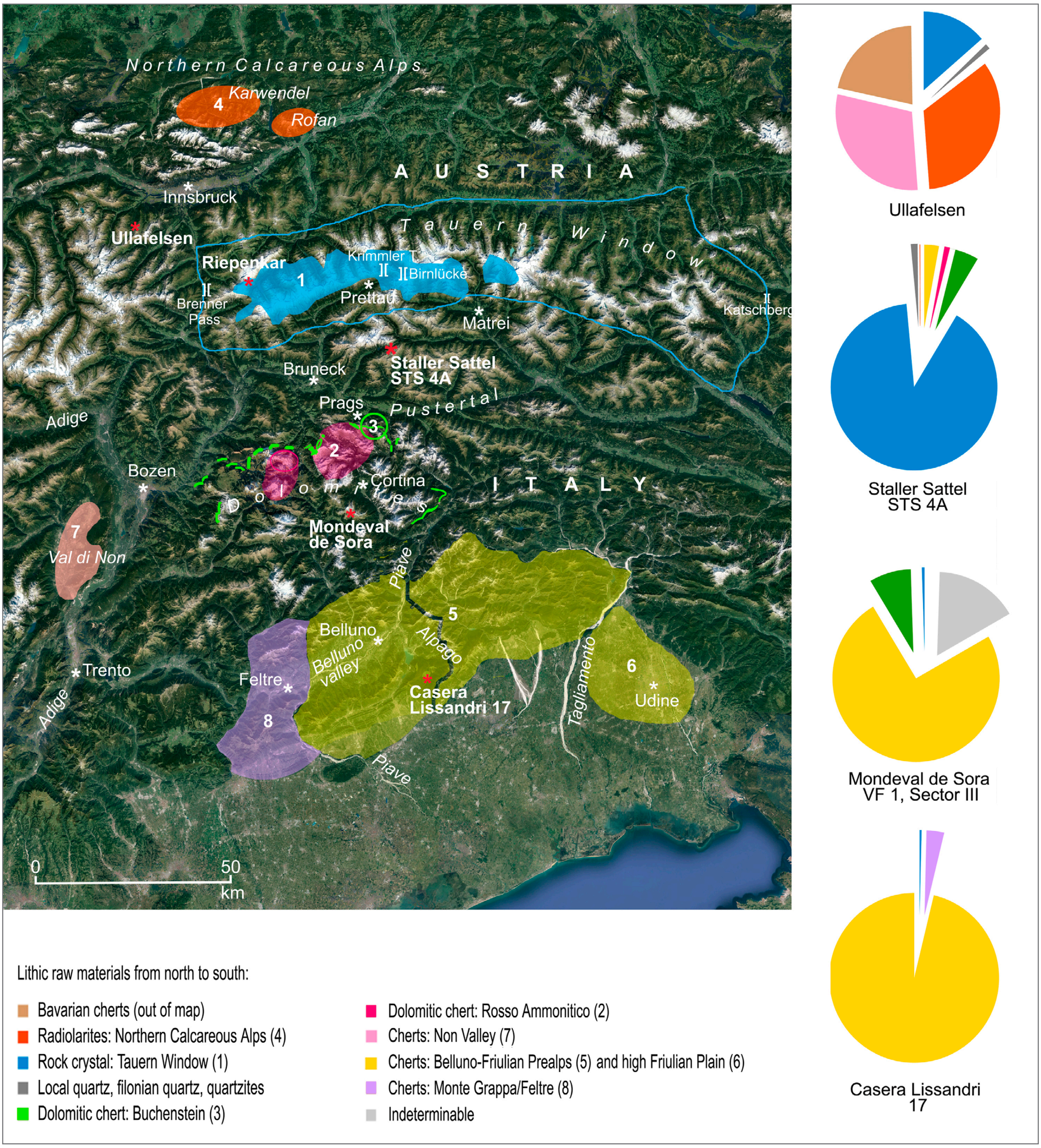

*Fig. 20 – Mapping of the provenance of lithic raw materials identified at several Early Mesolithic sites. Graphs show the quantitative ratio of the different lithologies encountered per site (aerial photo: Google Earth). / **Fig. 20 –** Mappatura delle provenienze delle materie prime litiche identificate in alcuni siti del Mesolitico antico. I grafici indicano i rapporti quantitativi delle diverse litologie riscontrate (foto aerea: Google Earth).*

en artefacts found at the Sauveterrian site Casera Lissandri 17 on the Cansiglio Plateau in the Venetian Prealps (Visentin et al. 2016). Aside from this allochtonous mineral, the groups primarily relied on chert varieties from the Venetian Prealps, mainly collected from the nearby Belluno Valley (30 km to the west), the area around Alpago and the Cansiglio itself. A few Maiolica artefacts suggest provisioning from at least 45 km to the west of the site, given their similarities to the so-called Trento-Plateau condensed facies.

In addition to these excavated sites, interesting raw-material similarities with STS 4A are found among the surface sites of the Comelico in the Carnian Prealps (Bertola 2023, fig. 37). The wide variety of lithic material comprises cherts both from the Belluno-Friulian Prealps and the high Friulian Plain, dolomitic Buchenstein cherts and sporadic rock crystal artefacts.

In sum, there is a complementarity of lithic raw material varieties between Staller Sattel STS 4A, Mondeval de Sora and Casera Lissandri 17. The available data indicate a south to north trajectory,

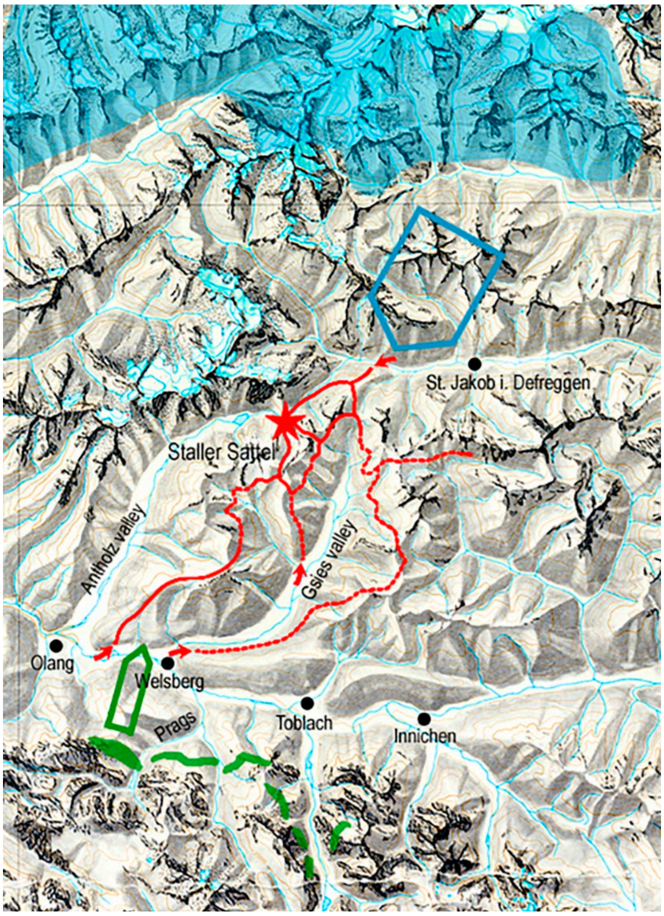

Fig. 21 – Proposed routes from and to Staller Sattel STS 4A in relation to the nearest procurement areas of Buchenstein chert (green) and of rock crystal (light blue), both knapped on site (map base: Tirol-Atlas, Universität Innsbruck). / Fig. 21 – Proposta dei percorsi da e per Passo Stalle STS 4A rispetto alle più vicine aree di approvvigionamento di selce del Buchenstein (verde) e di cristallo di rocca (azzurro), le litologie scheggiate nel sito (base cartografica: Tirol-Atlas, Universität Innsbruck).

connecting the southern Alpine fringe, namely the Belluno- and Friulian Prealps, via the Dolomites, or the adjacent Carnian Prealps, with the mountain ranges north of the Puster Valley. If we accept that Sauveterrian hunter-gatherer groups organized their logistic nomadism according to distinct territorial units (Fontana & Visentin 2016; Fontana et al. 2021, 2023), Staller Sattel STS 4A might be connected to the logistic system proposed for the territory covered by the Piave River hydrographic basin. In this context, the Venetian-Friulian Plain, located at the foothills of the mentioned Prealps, would have provided ideal wintering ground for these Mesolithic groups.

Finally, the identification at STS 4A of two artefacts made of radiolarite from the Northern Calcareous Alps, consistent with the varieties found in the Karwendel Mountains north of Innsbruck (about 80 km in a straight line from Staller Sattel), necessitates considering some form of connections with territories or populations beyond the main Alpine watershed. We are unable to contextualize the arrival of these two microlithic armatures: were they leftovers from a hypothetical Beuronian site use, or did they somehow enter the equipment of Sauveterrian nomads, while they were moving through northern Alpine territories? This latter interpretation would be more cautious, also supported by the fact that the territories on the present-day Austrian slope of the Alpine divide were exploited by both Sauveterrian and Beuronian groups. This aspect has been documented at the open-air Ullafelsen site, located in the Stubai Alps in North Tyrol (Austria). The long-term seasonal hunting camp was used by groups with both techno-cultural backgrounds, as shown by the lithic industry, especially by the provenance of the raw material (Fig. 20; Schäfer 2011).

In addition to Southalpine Cretaceous chert from the Italian Non Valley and Franconian chert from the Kehlheim district in Lower Germany, also radiolarite from the Chiemgau and Ruhpolding formations, cropping out in the Karwendel and Rofan Mountains, was introduced (Bertola 2011a, 2011b; Bertola & Schäfer 2011; Bertola et al. 2020). There is evidence that the radiolarite was rather processed by knappers with Beuronian techno-cultural background. In contrast, the use of rock crystal at Ullafelsen, representing 13,7% of the lithic assemblage, was most likely knapped by Sauveterrian dwellers (Schäfer 2011: 317; Bertola et al. 2020). Mineralogical studies indicate pennidic localities of the Zillertaler as well as the Tuxer Alps as the most probable provenance (Niedermayr 2011). On base of the raw material data of Ullafelsen and of STS 4A, a partial overlap of exploited territories cannot be excluded.

Staller Sattel STS 4A represents a further site attesting the north-south crossing of the main Alpine divide, a phenomenon already documented for the Early Mesolithic in the region (Bertola 2011b; Schäfer 2011; Bertola et al. 2020; Kompatscher & Kompatscher 2005, 2011). Nevertheless, the co-occurrence at STS 4A of artefacts, specifically armatures, made of lithic raw materials originating from both the southern and northern fringes of the Alps constitutes new evidence. These data contribute to widen the picture of long-distance contacts and mobility of Early Holocene alpine populations.

Acknowledgements

We thank Beatrice Vacca Bertini for correcting the text, Benno Baumgarten for providing information on rock crystal, Elisabetta Flor and the anonymous reviewer for their observations and corrections. We are grateful to the Amt für Archäologie Bozen/Bolzano for granting the excavation permit.

Bibliography

Andrefsky W., 1997 – Thoughts on stone tool shape and inferred function. *Journal of Middle Atlantic Archaeology*, 13: 125-143.

Araújo Igreja M., 2009 – Use-wear analysis of non-flint stone tools using DIC microscopy and resin casts: a simple and effective technique. In: Clemente I. & Araújo Igreja M. (eds.), Proceedings of the Workshop, Lisbon, 23-25/05/2008, *Recent Functional Studies on Non-flint Stone Tools: Methodological Improvements and Archaeological Inferences* (CD-ROM).

Araújo Igreja M., Moreno García M. & Pimenta C.M., 2007 – Un exemplo de abordagem experimental da interface traceologia, arqueozoologia: esquartejamento e tratamento da pele de um corço (*Capreolus capreolus*) com artefactos de pedra lascada. *Revista Portuguesa de Arqueologia,* 10 (2): 17-34.

Auf der Maur C. & Cornelissen M., 2014 – Die spätmesolithische und bronzezeitliche Fundstelle Hospental-Moos. Ein Einblick in das urgeschichtliche Urserntal. *Historisches Neujahrsblatt,* 68/1/103 (2013): 37-83.

Bagolini B., Broglio A. & Lunz R., 1984 – Le Mesolithique des Dolomites. *Preistoria Alpina*, 19 (1983): 15-36.

Bagolini B. & Dalmeri G., 1987 – I siti mesolitici di Colbricon (Trentino). Analisi spaziale e fruizione del territorio. *Preistoria Alpina,* 23: 7-188.

Bertola S., 2011a – Northern alpine radiolarites in the lithic assemblage of the Ullafelsen. In: Schäfer D. (ed), *Das Mesolithikum-Projekt Ullafelsen (Teil 1), Mensch und Umwelt im Holozän Tirols, Band 1*, Philipp von Zabern, Darmstadt: 509-519.

Bertola S., 2011b – The flints of Southern Alps (Non Valley, Italy) provenance found in the mesolithic site Ullafelsen. In: Schäfer D. (ed.), *Das Mesolithikum-Projekt Ullafelsen (Teil 1), Mensch und Umwelt im Holozän Tirols, Band 1*, Philipp von Zabern, Darmstadt: 463-505.

Bertola S., 2023 – Studio delle materie prime scheggiate. In: Bertola S., Fontana F. & Visentin D., *Frequentazioni preistoriche sui monti del Comelico*, Dario De Bastiani Editore, Vittorio Veneto: 77-109.

Bertola S., Fontana F. & Schäfer D., 2020 – Attraversare le Alpi 11.000 anni fa: il Mesolitico antico di alta quota nel settore orientale delle Alpi e il sito di Ullafelsen (Sellrain, Innsbruck, Austria). *Rivista di Scienze Preistoriche*, LXX – S1: 57-69.

Bertola S. & Schäfer D., 2011 – Jurassic cherts from the Kehlheim district (Bavaria, Germany) in the Lower Mesolithic assemblage of the Ullafelsen. In: Schäfer D. (ed.), *Das Mesolithikum-Projekt Ullafelsen (Teil 1), Mensch und Umwelt im Holozän Tirols, Band 1*, Philipp von Zabern, Darmstadt: 523-534.

Bini A., Meneghel M., Mietto P., Sauro U. & Siorpaes C., 1995 – *Altopiani Ampezzani: geologia, geomorfologia, speleologia,* con 1 carta geomorfol. f.t. a scala 1:25.000. La Grafica Editrice, Vago di Lavagno (VR), 156 pp.

Bolli H.M., Saunders J.B. & Perch-Nielsen K., 1985 – *Plankton Stratigraphy, vol. 1 Planktic foraminifera, calcareous nannofossils and calpinellids*. Cambridge Earth Science Series, Cambridge University Press, 608 pp.

Brandner R., Lotter M., Gruber A. & Ortner H., 2011 – Exkursion E3, Achental – Bächental. In: Gruber A. (ed), *Arbeitstagung 2011, Geologie des Achenseegebietes, Geologisches Kartenblatt 88 Achenkirch, Geologische Bundesanstalt*, Wien: 199-224.

Brandner R. & Gruber A. (eds), 2012 – *Geologische Karte der Republik Österreich 1:50.000, Blatt 88 Achenkirch*. Geologische Bundesanstalt, Wien.

Broglio A., 1994 – Mountain sites in the context of the North-East Italian Upper Palaeolithic and Mesolithic. *Preistoria Alpina*, 28 (1992): 293-310.

Broglio A. & Kozlowski S.K., 1984 – Tipologia ed evoluzione delle industrie mesolitiche di Romagnano III. *Preistoria Alpina*, 19 (1983): 93-148.

Broglio A. & Lanzinger M., 1990 – Considerazioni sulla distribuzione dei siti tra la fine del Paleolitico superiore e l'inizio del Neolitico nell'Italia nord-orientale. In: Biagi P.*, The Neolithisation of the Alpine Region, Monografie di Natura Bresciana*, 13: 53-69.

Broglio A. & Lunz R., 1984 – Osservazioni preliminari sull'utilizzazione del cristallo di rocca nelle industrie mesolitiche del Bacino dell'Adige. *Preistoria Alpina*, 19 (1983): 201-208.

Brondi A., Mittempergher M., Panizza M., Rossi D., Sommavilla E., Vuillermin F., 1977 – *Note esplicative del foglio 028 La Marmolad*a. Servizio Geologico d'Italia, Litografia Artistica Cartografica, Firenze, 35 pp.

Carta Geologica d'Italia, 2009 – *1: 50.000, foglio 009 Anterselva.* ISPRA – Servizio Geologico d'Italia, Litografia Artistica Cartografica, Firenze.

Carta Geologica d'Italia, 2007 – *1: 50.000, foglio 028 La Marmolada*. ISPRA – Servizio Geologico d'Italia, Università di Ferrara, Ferrara.

Carta Geologica d'Italia, 2007 – *1: 50.000, foglio 029 Cortina d'Ampezzo.* APAT – Servizio Geologico d'Italia, Systemcart S.r.l., Roma.

Carta Geologica d'Italia, 2000 – *1: 50.000, foglio 063 Belluno.* ISPRA – Servizio Geologico d'Italia, Istituto poligrafico e Zecca dello Stato, Roma.

Cesare B., Cucato M., Furlanis S., Keim L., Mair V., Mazzoli C., Meli S., Morelli C., Moretti A., Peruzzo L., Piccin G., Sassi R., Spiess R., 2009 – *Note Illustrative della Carta Geologica d'Italia alla scala 1:50.000, foglio 009 Anterselva*. ISPRA e Provincia Autonoma di Bolzano – Alto Adige, 165 pp.

Chelidonio G., 1990 – Preliminary approach to quartz crystals technology and its meaning as "environmental translation". In: Actes du V° Colloque international sur le Silex, Bordeaux, 17/09-02/10/1987, "Le silex, de sa genèse à l'outil". *Cahiers du Quaternaire*, 17: 489-494.

Collina-Girard J., 1997 – Les outillages sommaires sur supports natureles tenaces (quartz et quartzites). Technomorphologie et evolution psychique. In: Premiere Table Ronde sur l'Exploitation du Quartz au Paleolithique, Aix-en-Provence, 18-19/04/1996. *Préhistoire Anthropologie Méditerranéennes,* 6: 210-226.

Cornelissen M., Auf der Maur C. & Reitmaier T., 2022 – A glacially preserved Mesolithic Rock Crystal Extraction Site in the Swiss Alps. *Norwegian Archaeological Review:* 1-7. https://doi.org/10.1080/00293652.2022.2052747.

Costa V., Doglioni C., Grandesso P., Masetti D., Pellegrini G.B. & Taracanella S., 1996 – *Note illustrative della Carta Geologica d'Italia alla scala 1: 50.000, foglio 063 Belluno*. Roma, Servizio Geologico d'Italia, 76 pp.

Cremillieux H. & Livache M., 1976 – Pour le classement des pièces écaillées. Dialéktiké, *Cahiers de typologie analytique*: 1-5.

Curdy Ph., Leuzinger-Piccand C. & Leuzinger U., 2003 – Zermatt Alp Hermettji et les cols secondaires de Valais. In: Besse M., Stahl Gretsch L.I. & Curdy P. (dir.*),* Constella-Sion. Hommage à Alain Gallay, *Cahiers d'archéologie romande*, 95: 73-88.

Crotti P., Pignat G. & Rachoud-Schneider A.M. (eds), 2002 – *Die ersten Menschen im Alpenraum von 50.000-5.000 vor Christus*. Katalog zur Ausstellung, Verlag Neue Zürcher Zeitung, Zürich & Walliser Kantonsmuseen, Sitten, 199 pp.

de Lombera Hermida A., 2008 – Quartz morphostructural groups and their mechanical implications. *Annali dell'Università degli Studi di Ferrara, Sezione Museologia Scientifica e Naturalistica*. Volume speciale: 101-104.

de Lombera Hermida A., 2009 – The scar identification of lithic quartz industries. In: Sternke F., Eigeland L. & Costa L.-J., Non-Flint Raw Material Use in Prehistory. Old Prejudices and New Direction, *British Archaeological Reports*, Oxford, Series 1939: 5-12.

Exel R., 1980 – *Die Mineralien Tirols. Band 1. Südtirol und Trentino.* Athesia, Bozen, 216 pp.

Exel R., 1982 – *Die Mineralien Tirols. Band 2. Nordtirol, Vorarlberg und Osttirol.* Athesia, Bozen, 200 pp.

Fernández-Marchena, J.L. & Ollé A., 2016 – Microscopic analysis of technical and functional traces as a method for the use-wear analysis of rock crystal tools. *Quaternary International,* 424: 171-190.

Flor E., Fontana F., & Peresani M., 2011 – Contribution to the study of Sauveterrian technical systems. Technological analysis of the lithic industry from layers AF-AC1 of Romagnano Loc III rockshelter (Trento). *Preistoria Alpina,* 44: 207-226.

Fontana A., & Ferrari A., 2020 – Interazione tra processi tettonici, alluvionali, eolici e pedogenetici nell'area di Sammardenchia e Pozzuolo del Friuli/Interaction between tectonic, alluvial, aeolian and pedogenetic processes in the area of Sammardenchia and Pozzuolo del Friuli. *Gortania. Geologia, Paleontologia, Paletnologia*, 41 (2019): 43-60.

Fontana F. & Visentin D., 2016 – Between the Venetian Alps and the Emilian Apennines (Northern Italy): Highland vs. lowland occupation in the early Mesolithic. *Quaternary International*, 423: 266-278.

Fontana F., Visentin D. & Bertola S., 2021 – The Early Mesolithic of the Piave River basin: Mountain tops, riverbanks, and seashores? In: Boric D., Antonivic D., Mihailovic B., *Foraging Assemblages vol. 1*, Serbian Archaeological Society, Belgrade, The Italian Academy for Advanced Studies in America, New York, Columbia University: 102-109.

Fontana F., Visentin D., Bertola S., Cristiani E., Dipino N., Flor E. & Fontana A., 2023 – Investigating the Early-to-Late Mesolithic Transition in Northeastern Italy: A Multifaceted Regional Perspective. *Open Archaeology*, 9: 1-24. https://doi.org/10.1515/opar-2022-0284.

Fontana F., Guerreschi A. & Vullo N., 2000 – Le site mésolithique de l'Alpe Veglia (Alpi Lepontine, Italia): analyse techno-typologique et spatiale. In: Crotti P. (ed.), *MESO 97, Actes de la Table ronde*, Lausanne, 21-23/11/1997, "Epipaléolithique et Mésolithique". Cahiers d'archéologie romande, 81: 259-265.

Fullagar R., 1986 – Use-wear on quartz. In: Ward G.K. (ed), *Archaeology at ANZAAS Canberra.* 54th ANZAAS Congress 1984. Canberra Archaeology Society, Canberra: 191-197.

Gavrit Roux E., & Beyries S., 2018 – Le travail de la peau au Magdalénien moyen ancien. *Bulletin de la Société Préhistorique Française*, 115(4): 647-676.

Gawlick H.-J., Missoni S., Schlagintweit F., Suzuki H., Frisch W., Krystyn l., Blau J. & Lein R., 2009 – Jurassic Tectonostratigraphy of the Austroalpine Domain, *Journal of Alpine Geology,* 50: 1-152.

G.E.E.M. Groupe d'étude de l'Épipaléolithique-Mésolithique, 1*969* – Epipaléolithique – Mèsolithique. Les microlithes géometriques. *Bulletin de la Société Préhistorique Française, 66: 355-366.*

G.E.E.M. Groupe d'étude de l'Épipaléolithique-Mésolithique, 1972 – Epipaléolithique – Mèsolithique. Les armatures non géometriques – 1. *Bulletin de la Société Préhistorique Française, 69, fasc. 1: 364-375.*

Ghetti S., 1987 – *Evoluzione cretacica del margine settentrionale della Piattaforma Friulana*, Tesi di Dottorato, Dottorato di Ricerca in Scienze della Terra, Consorzio delle Università di FE, FI, PR e PV, Ferrara, 180 pp.

Ghetti S., 1989 – Chemical features of a platform to basin carbonate succession (Late Jurassic – Eocene, Friulian Alps, Northern Italy). *Studi Trentini di Scienze Naturali, Acta Geologica*, 65: 141-160.

Gibaja J.F. & Carvalho A.F., 2005 – Reflexiones en torno a los útiles tallados en cuarcita: el caso de algunos asentamientos del Neolítico Antiguo del macizo calcáreo extremeño (Portugal). *Zephyrus*. 58: 183-194.

Gnaccolini M., 1968 – Sedimentologia del Calcare di Soccher nella regione compresa tra la valle del T. Vajont (Pordenone) e l'Alpago (Belluno). *Rivista Italiana di Paleontologia e Stratigrafia,* 74 (3): 829-864.

Hammerschmied J., 2011 – *Bergkristall als Rohmaterial für prähistorische Geräteherstellung. Ressourcen und Funde in Westösterreich, Südtirol und Trentino.* Magisterarbeit, Historisch-Philosophische Fakultät, Leopold-Franzens-Universität Innsbruck.

Heinen M., 2001 – S*arching '83 und '89/90. Untersuchungen zum Spätpaläolithikum und Frühmesolithikum in Südostdeutschland.* PhD Thesis, Faculty of Philosphy, Universität Köln.

Hess T., Mullis J. & Franz L. – 2023. The first petrographic characterization of a prehistoric rock crystal mine in the Swiss Alps. *Scientific Reports* 13: 23107. https://doi.org/10.1038/s41598-023-48914-8.

Hess T., Turck R., de Vries G. & Della Casa P. – 2021. A Prehistoric Rock Crystal Procurement Site at Fiescheralp (Valais, Switzerland). *Lithic Technology*, 46 (3): 209-220. https://doi.org/10.1080/01977261.2021.1899626.

Jardón Giner P., 2000 – *Los raspadores en el Paleolítico Superior. Tipología, tecnología y función en la Cova del Parpalló (Gandía, España) y en la Grotte Gazel (Salleles-Cabardes, Francia).* Diputación Provincial de Valencia, Servicio de Investigación Prehistórica. Serie de trabajos varios, 97, 182 pp.

Kandutsch G., Hasenberger K., Kirchner E.C., 1998 – Neue Daten zur Genese alpiner Zerrklüfte. *Wissenschaftliche Mitteilungen aus dem Nationalpark Hohe Tauern*, 4: 7-17.

Keeley L.H., 1980 – *Experimental determination of stone tool uses*. A microwear analysis. University of Chicago Press, 226 pp.

Knutsson K. 1988 – *Patterns of tool use. Scanning electron microscopy of experimental quartz tools.* AUN Societas Archaeologica Upsaliensis Series, 10, 114 pp.

Knutsson H., Knutsson K., Taipale N., Tallavaara M. & Darmark K., 2015 – How shattered flakes were used: Micro-wear analysis of quartz flake fragments, *Journal of Archeological Science Reports*, 2: 517-531. https://doi.org/10.1016/j.jasrep.2015.04.008.

Kompatscher K., 2011 – Microburins and fracture mechanics: the experimental production of Sauveterrian microliths. *Preistoria Alpina,* 45: 293-307.

Kompatscher K. & Kompatscher N., 2005 – Steinzeitliche Feuersteingewinnung, Prähistorische Nutzung der Radiolarit- und Hornsteinvorkommen des Rofangebirges. *Der Schlern,* 79: 24-35.

Kompatscher K. & Kompatscher N.M., 2011 – Mitelsteinzeitliche Fernverbindungen über den Alpenhauptkamm. In: Schäfer D. (ed), Das Mesolithikum-Projekt Ullafelsen (Teil 1), *Mensch und Umwelt im Holozän Tirols,* Band 1, Philipp von Zabern, Darmstadt: 205-241.

Kompatscher, K., Hrozny Kompatscher N., Bassetti M., Castiglioni E., Rottoli M. & Wierer U., 2016 – Mesolithic settlement and mobility patterns at high altitudes. The site of Staller Sattel STS 4A (South Tyrol, Italy). *Quaternary International,* 423: 23-48. https://doi.org/10.1016/j.quaint.2015.12.090.

Lanzinger M., 1985 – Ricerche nei siti mesolitici della Cresta di Siusi (auf der Schneide), siti XV e XVI dell'Alpe di Siusi nelle Dolomiti. Considerazioni sul significato funzionale espresso dalle industrie mesolitiche della regione. *Preistoria Alpina,* 21: 3-48.

Laplace G., 1964 – Essai de typologie systématique. *Annali dell'Università di Ferrara,* n.s., sez. XV, suppl. 2(1): 1-85.

Leitner W. & Bachnetzer T., 2011 – Steinzeitliche Gewinnung von Bergkristall in den Tuxer Alpen. In: Oeggl K., Goldenberg G., Stöllner T. & Prast M. (eds), Proceedings zum 5. Milestone-Meeting des SFB.HiMAT, Mühlbach, 7-10/10/2020, *Die Geschichte des Bergbaus in Tirol und seinen angrenzenden Gebieten*, Innsbruck University Press: 193-198.

Lukeneder A., 2011 – The Biancone and Rosso Ammonitico facies on the northern Trento Plateau (Dolomites, Southern Alps, Italy). *Annalen des Naturhistorischen Museums in Wien,* Serie A, 113: 9-33.

Lunz R., 1986 – Vor- und Frühgeschichte Südtirols mit Ausblick auf die alpinen Nachbargebiete, Band 1 Steinzeit, Bruneck, 128 pp., 56 tt.

Mahlknecht, M., 2002 – Der "Murmelstein" im Burgumer Tal in Pfitsch. *Der Schlern,* 76 (1/2): 70-81.

Mahlknecht M., 2007 – Mesolithische Funde aus de*m Ursprungtal (Rein). Der Schlern*, 81: 17-19.

Mandl, G.W., 2000 – The Alpine sector of the Tethyan shelf – examples for Triassic to Jurassic sedimentation and deformation from the Northern Calcareous Alps. *Mitteilungen der Österreichischen Geologischen Gesellschaft*, 92: 61–77.

Masetti D. & Bianchin G., 1987 – Geologia del gruppo della Schiara (Dolomiti bellunesi): suo inquadramento nella evoluzione giurassica del margine orientale della piattaforma di Trento. *Memorie di Scienze Geologiche,* 39: 187-212.

Mottana A., Crespi R. & Liborio G., 1997 – *Minerali e Rocce*. Orsa Maggiore Editrice, 604 pp.

Mourre V., 1996 – Le industries en quartz au Paléolithique. Terminologie, méthodologie et technologie. *Paléo*, 8: 205-233.

Mullis J., 1991 – Bergkristall. *Schweizer Strahler*, 9 (3): 127-161.

Neri C., Gianolla P., Furlanis S., Caputo R. & Bosellini A., 2007 – *Carta Geologica e Note illustrative della Carta Geologica d'Italia alla scala 1:50.000 foglio 029 Cortina d'Ampezzo*, vol. 1. APAT, Roma: 1-208.

Niedermayr G., 1994 – Die Mineralvergesellschaftungen der Hohen Tauern. In: Seemann R., Mineral & Erz in den Hohen Tauern. *Ausstellungskatalog Naturhistorisches Museum*, Wien: 55-88.

Niedermayr G., 2011 – Mineralogische Untersuchungen an Quarzartefakten aus dem Bereich des Ullafelsens im Fotschertal, Stubaier Alpen/Tirol, Österreich. In: Schäfer D. (ed.), Das Mesolithikum-Projekt Ullafelsen (Teil 1), *Mensch und Umwelt im Holozän Tirols, Band 1,* Philipp von Zabern, Darmstadt: 539-542.

Odell G.H., 1981 – The Mechanics of Use-Breakage of Stone Tools: Some Testable Hypotheses, *Journal of Field Archaeology*, 8: 197–209. https://doi.org/10.2307/529414.

Odell G. & Odell-Vereecken F., 1980 – Verifying the reliability of lithic use wear assessment by 'blind tests': the low power approach. *Journal of Field Archaeology,* 7 (1): 87-120. https://doi.org/10.2307/529584.

Ollé A., Pedergnana A., Fernández-Marchena J.L., Martin S., Borel A. & Aranda V., 2016 – Microwear features on vein quartz, rock crystal and quartzite: a study combining Optical Light and Scanning Electron Microscopy. *Quaternary International,* 424: 154-170. https://doi.org/10.1016/j.quaint.2016.02.005.

Peresani M., Bertola S., 2010 – Approvvisionnement des materiaux lithiques, ressources locales et economie du débitage dans le Sauveterrian: un exemple du Haut Plateau de Cansiglio (Alpes Orientales Italiennes). *Prehistoires Mediterraneennes*, 1: 87-99.

Pessina A., 2005 – Pramollo-Dosso Confine: Ricerche 2004-2005. Un accampamento stagionale di cacciatori preistorici. *Gortania, Atti del Museo Friuliano di Storia Naturale*, 27: 49-67.

Pignat G. & Plisson H., 2000 – Le quartz pour quel usage? L'outillage mésolithique de Vionnaz (CH) et l'apport de la tracéologie. In: In: Crotti P. (ed.), MESO 97, Actes de la Table ronde, Lausanne, 21-23/11/1997, Epipaléolithique et Mésolithique. *Cahiers d'archéologie romande*, 81*:* 65-78*.*

Porraz G., Simon P. & Pasquini A., 2010 – Identité technique et comportements économiques des groupes proto-aurignaciens a la grotte de l'Observatoire (principauté de Monaco). *Gallia préhistoire*, 52: 33–59. http://doi.org10.3406/galip.2010.2470.

Porraz G., Val A., Tribolo C., Mercier N., de la Peña P., Haaland M.M., Igreja M., Miller C.E. & Schmid V.C., 2018 – The MIS5 Pietersburg at '28' Bushman Rock Shelter, Limpopo Province, South Africa. *PLoS ONE*, *13* (10): 1-45. https://doi.org/10.1371/journal.pone.0202853.

Premoli-Silva I. & Sliter W.V., 1995 – Cretaceous planktonic foraminiferal biostratigraphy and evolutionary trends from the Bottaccione Section, Gubbio, Italy. *Palaeontographia Italica,* 82: 2–90.

Premoli-Silva I. & Sliter W.V., 2002 – Practical manual of Cretaceous Planktonic Foraminifera. In: Premoli-Silva I. & Rettori R. (eds.), *International School of Planktonic Foraminifera, 1° course: Cretaceous*, Perugia, 18-22/02/2002, Università degli Studi di Perugia, Centro Stampa XBS, Milano.

Raiteri L.V.M. (ed), 2017 – *Storie di paesaggi e uomini alle pendici del Mont Fallère nell'Olocene antico e medio (Saint-Pierre, Valle d'Aosta, Italia),* British Archaeological Reports, Oxford, International Series 2866, 146 pp.

Reitmaier, T., Auf der Maur, C., Reitmaier-Naef, L., Seifert, M. & Walser, C., 2016 – Late Mesolithic Rock Crystal Mining 2800 m Above Sea Level near Fuorcla da Strem Sut (Kt. Uri / Graubünden / CH). *Archäologisches Korrespondenzblatt*, 46: 133-148.

Robaszynski F. & Caron, M., 1995 – Foraminifères planctoniques du Crétacé: commentaire de la zonation Europe-Méditerranée. *Bulletin de la Société géologique de France*, 166: 681-692.

Rykart R., 1989 – *Quarz-Monographie: Die Eigenheiten von Bergkristall, Rauchquarz, Amethyst, und anderen Varietäten*. Ott Verlag, Thun, 1. Auflage, 410 pp.

Sauro U., & Meneghel M., (eds), 1995 – *Altopiani Ampezzani.* La Grafica Editrice, Vago di Lavagno (VR), 156 pp.

Schäfer D., 2011 – Das Mesolithikum-Projekt Ullafelsen – Landschaftlicher Rahmen und archäologische Befunde. Arbeitsstand 2009/2010. In: D. Schäfer (ed.), *Das Mesolithikum-Projekt Ullafelsen (Teil 1), Mensch und Umwelt im Holozän Tirols, Band 1*, Philipp von Zabern, Darmstadt: 245-351.

Schmid S.M., Scharf A., Hardy M.R. & Rosenberg C.L., 2013 – The Tauern Window (Eastern Alps, Austria): a new tectonic map, with cross-sections and a tectonometamorphic synthesis. *Swiss Journal of Geosciences*, 106: 1-32.

Schmid S.M., Fügenschuh B., Kissling E., & Schuster R., 2004 – Tectonic map and overall architecture of the Alpine orogen. *Eclogae geologicae Helvetiae*, 97: 93-117.

Seemann, R., 1994 – Einleitung. Zum Begriff der Hohen Tauern und des Tauernfensters. In: Seemann R., Mineral & Erz in den Hohen Tauern. *Ausstellungskatalog. Naturhistorisches Museum Wien*: 11-14.

Taute W., 1973-74 – Neue Forschungen zur Chronologie von Spätpaläolithikum und Mesolithikum in Süddeutschland. *Archäologische Informationen*, 2-3: 59-66.

Tringham R., Cooper G., Odell G., Voytek B. & Whitman A., 1974 – Experimentation in the formation of edge damage: A new approach to lithic analysis. *Journal of Field Archaeology*, 1: 171-196. https://doi.org/10.1179/jfa.1974.1.1-2.171.

Van Gijn A., 1990 – The wear and tear of flint. Principles of functional analysis applied to Dutch Neolithic assemblages. *Analecta Praehistorica Leidensia,* 22: 1-181.

Vaughan, P.C., 1985 – *Use-wear analysis of flaked stone tools.* University of Arizona Press, Tucson, 204 pp.

Valletta F., Fontana F., Bertola S. & Guerreschi A., 2016 – The Mesolithic lithic assemblage of site VF1-sector III of Mondeval de Sora (Belluno, Italy). Economy, technology and typology. *Preistoria Alpina*, 48, 73-81.

Visentin D., 2017 – 4.2 Le serie sperimentali in cristallo di rocca. In: Raiteri L.V.M. (ed), Storie di paesaggi e uomini alle pendici del Mont Fallère nell'Olocene antico e medio (Saint-Pierre, Valle d'Aosta, Italia). *British Archaeological Reports*, Oxford, International Series 2866: 79-84.

Visentin D., 2018 – *The Early Mesolithic in Northern Italy and Southern France. An investigation into Sauveterrian technical systems.* Archaeopress, Oxford, 330 pp.

Visentin D., Peresani M., Bertola S. & Ziggiotti S., 2016 – "Going off the beaten path?" The Casera Lissandri 17 site and the role of the Cansiglio plateau (North- eastern Italy) for human ecology during the Early Sauveterrian". *Quaternary International*, 423: 213-229.

Walker, P. L., 1978 – Butchering and stone tool function. *American Antiquity*, 43 (4): 710-715.

Wierer U., 2008 – Which blanks for which tools? Techno-typological analyses of the Sauveterrian industry at Galgenbühel (Italy). In: Aubry T., Almeida F., Araùjo A.C., & Tiffagom M. (eds.), Proceedings of the XV UISPP World Congress, Lisbon, 04-09/09/2006, Space and Time: Which Diacronies, Which Synchronies, Which Scales / Typology vs. Technology. *British Archaeological Reports*, Oxford, International Series 1831: 197-206.

Wierer U. & Bertola S., 2016 – The Sauveterrian Chert Assemblage of Galgenbühel/Dos de la Forca (Adige Valley, South Tyrol, Italy): Procurement Areas, reduction Sequences, Tool Making. In: Tomasso A., Binder D., Martino G., Porraz G., Simon P. & Naudinot N. (eds.), *Actes de la Journée de la Société Préhistorique Francaise*, Nice, 28-29/3/2013, Ressources lithiques, productions et transferts entre Alpes et Méditerranée, Paris: 229-258.

Zanferrari A., 2008 – La successione cretacea della Piattaforma Friulana. In: Zanferrari A., Avigliano F., Grandesso P., Monegato G., Paiero G., Poli M.E. & Stefani C. (eds), *Note illustrative della Carta Geologica d'Italia alla scala 1: 50.000, foglio* 065 Maniago, ISPRA, Servizio Geologico d'Italia, Roma: 47-51.

Appendix/Appendice

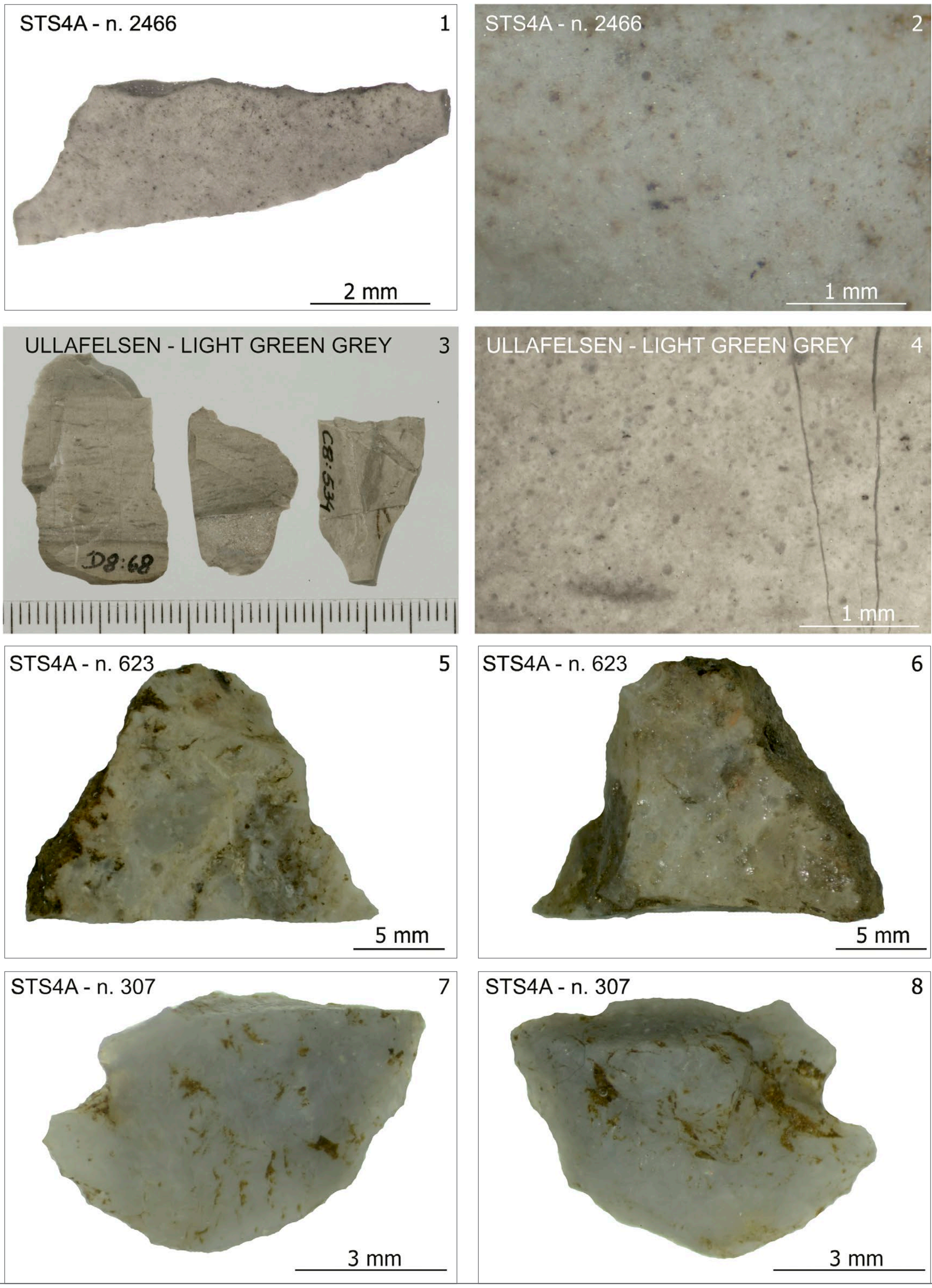

Plate 1 – *Radiolarites, filonian "pegmatitic" quartz and quartzites. 1. Geometric armature of northalpine radiolarite (upper Jurassic, Chiemgau/Ruhpolding Group) of white-light grey colour, slightly metamorphosed (cleavage); 2. Detail of the microfacies with an association of small radiolarians and rare dark sponge spicules in a silicified marl matrix. Microfossils are generally deformed and badly preserved; 3. Chiemgau radiolarite artefact found at the mesolithic site Ullafelsen (Sellrain, Innsbruck, Austria); 4. The microfacies is very similar to the sample from Staller Sattel STS 4A; 5-6. Flake made of local "pegmatitic" quartz, likely originating from the Tures/Anterselva gneiss basement; 7-8. Flake made of local grey quartzite. Multi-decimetric quartzite horizons are frequently found within the gneiss. /* ***Tav. 1 –*** *Radiolariti, quarzo filoniano "pegmatitico" e quarziti. 1. Armatura geometrica in radiolarite nordalpina (Giurassico Superiore, Chiemgau/Ruhpolding Group) di aspetto bianco-grigio chiaro, leggermente metamorfosata (clivaggio); 2. Dettaglio della microfacies con una associazione a piccoli radiolari e rare spicole di spugna di aspetto scuro in matrice marnosa silicizzata; i microfossili sono generalmente deformati e mal preservati; 3. Manufatto in radiolarite Chiemgau proveniente dal sito mesolitico di Ullafelsen (Sellrain, Innsbruck); 4. La microfacies è molto simile al campione di STS 4A; 5-6. scheggia in quarzo filoniano ("pegmatitico") locale, probabilmente proveniente dal basamento gneiss Tures/Anterselva; 7-8. scheggia in quarzite grigia locale. Orizzonti quarzitici pluridecimetrici sono frequenti entro gli gneiss.*

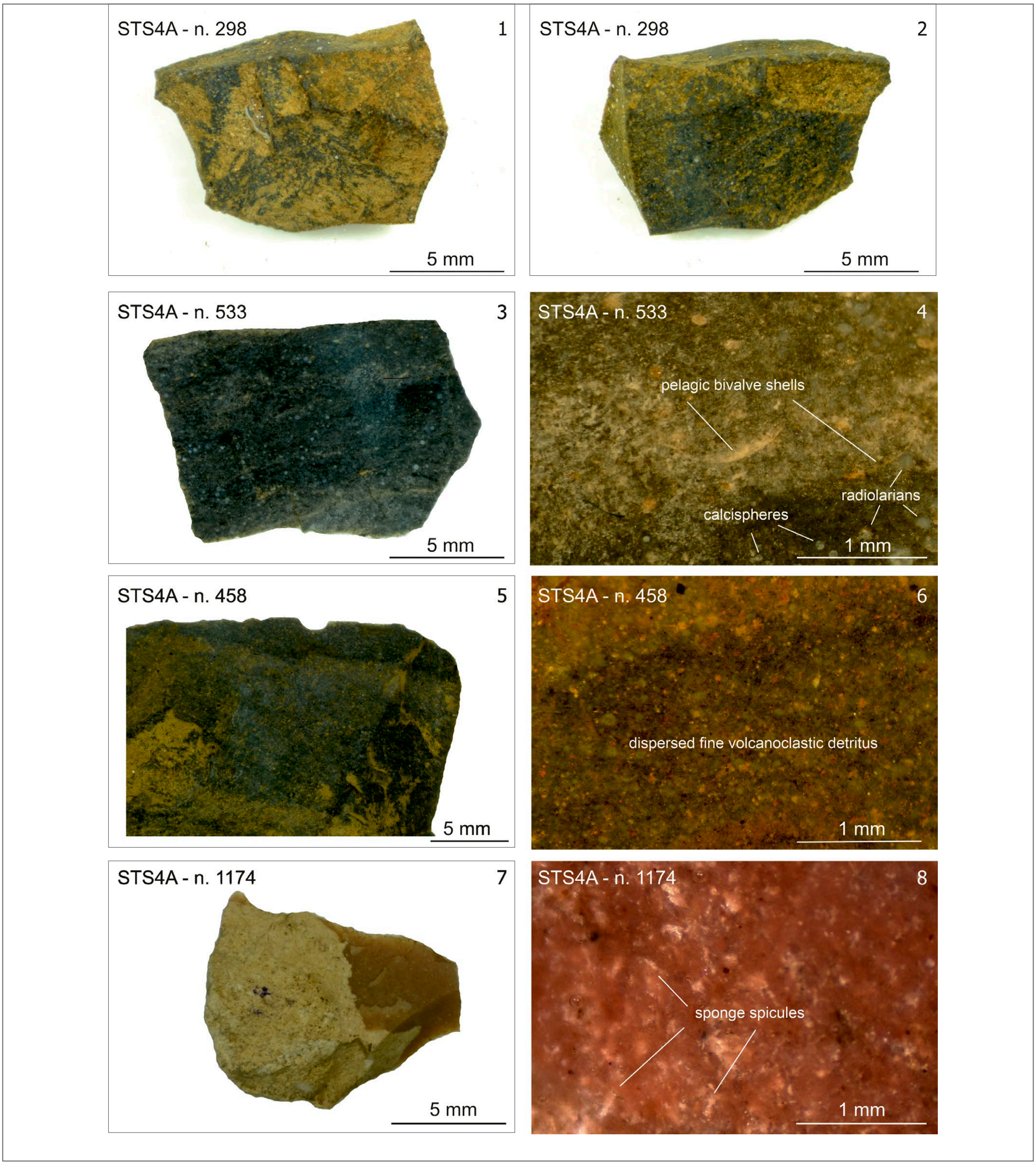

Plate 2 – *Buchenstein and Rosso Ammonitico Veronese cherts, Dolomites. 1-2. Fragment with ventral and dorsal negatives in black chert from Buchenstein (Ladinan age, Dolomites); 3. Blade fragment on black chert from Buchenstein (Ladinan age, Dolomites) with slight laminations; 4. Detail of the microfacies showing the cavities of the radiolarians filled with milky quartz or calcite, and pelagic lamellibranchs with concave morphologies and thin shell; 5. Black chert flake from a Buchenstein plate. The cortical areas are impregnated with clay sediments and iron oxides (collected from soils); 6. The microfacies shows abundant presence of fine volcaniclastic debris; 7. Chert flake from the Rosso Ammonitico Veronese (Dogger-Malm, Dolomites) with white-ivory cortex, collected from outcrops; 8. The whitish microfossils are mainly composed of sponge spicules and subordinate radiolarians, with scattered iron oxides also present. /* ***Tav. 2 –*** *Selci del Buchenstein e del Rosso Ammonitico Veronese - Dolomiti. 1-2. Frammento con negativi ventrali e dorsali in selce nera del Buchenstein (Ladinico, Dolomiti); 3. Frammento di lama su selce nera del Buchenstein (Ladinico Dolomiti) con leggere laminazioni; 4. Dettaglio della microfacies che mostra le cavità dei radiolari riempite di quarzo latteo o da calcite, e lamellibranchi pelagici a morfologie concave e guscio sottile; 5. Scheggia in selce nera su placchetta di Buchenstein con aree corticali impregnate da sedimento argilloso e da ossidi (raccolta da suoli); 6. La microfacies evidenzia un abbondante presenza di fine detrito vulcanoclastico; 7. Scheggia in selce del Rosso Ammonitico Veronese (Dogger-Malm, Dolomiti) con cortice bianco-avorio, raccolta presso affioramenti; 8. I microfossili biancastri sono costituiti prevalentemente da spicole di spugna e da subordinati radiolari; sono presenti anche ossidi di ferro sparsi.*

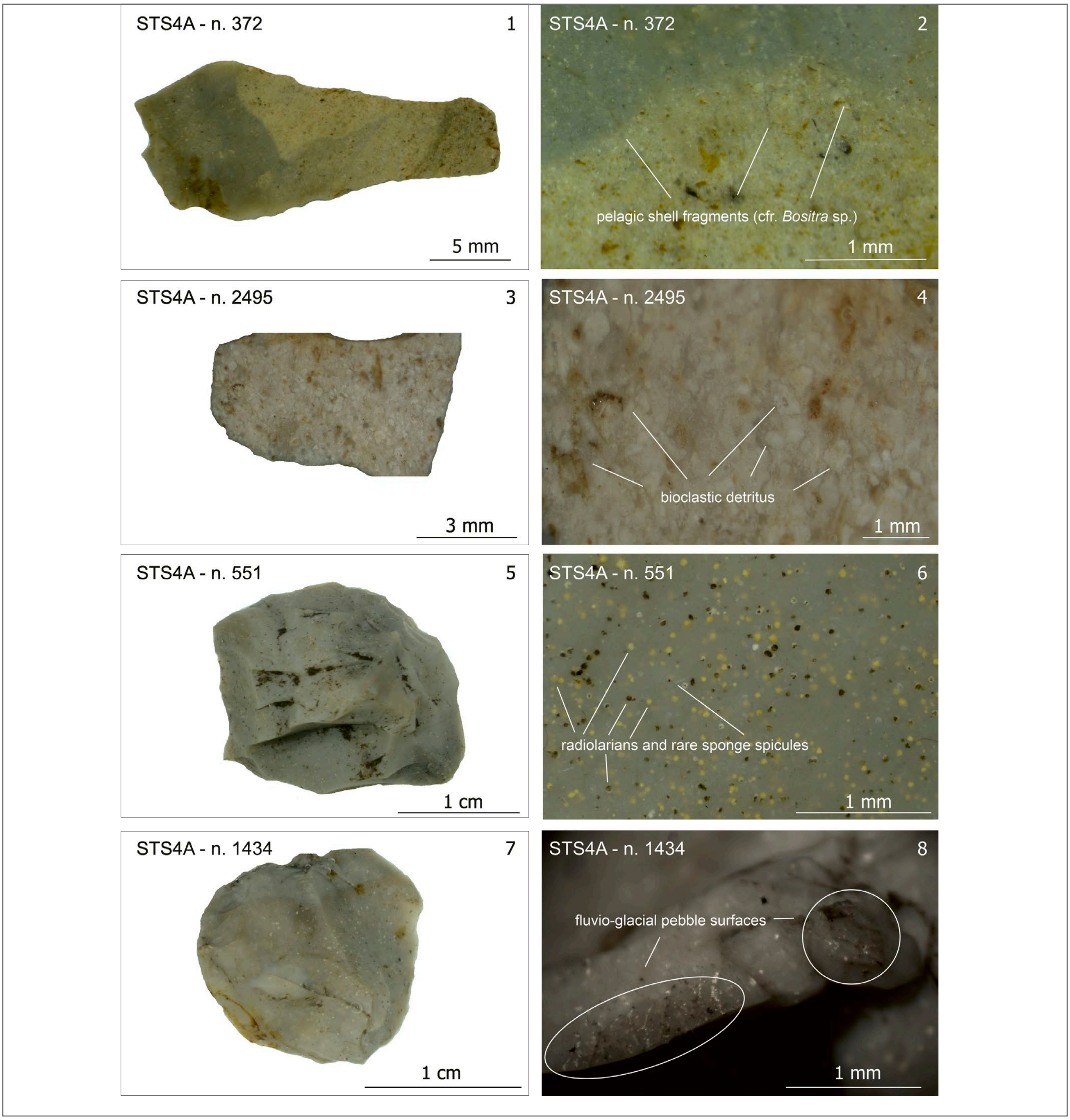

Plate 3 – *Cherts from the Belluno-Friulian Prealps - Fonzaso, Soccher and Maiolica. 1. Vitreous grey-green chert bladelet from Fonzaso (Dogger, Belluno-Friulan Prealps) with large cortical portions rich in "filaments"; 2. Detail showing a microcrystalline matrix embedding radiolarians, sponge spicules and pelagic lamellibranchs; 3. Backed fragment made of chert from Soccher/Fadalto Limestone (Upper Jurassic-Lower Cretaceous), deposited in areas closer to the feeding Friulian Platform; 4. The detail highlights the coarse and hetereogeneous bioclastic debris (rudists, corals, algae, crinoids, resedimented benthic foraminifers); 5. Endscraper from Maiolica grey chert, with broad faded bands; 6. Detail of fine cryptocrystalline texture embedding minute re-sedimented radiolarians and rare sponge spicules, often with calcite fillings; 7. Endscraper from Maiolica chert, similar to the previous sample; 8. In this case the presence of a strongly rounded surface, the impregnation by oxides and the significant decarbonization suggests the collection of the pebble from ancient alluvial deposits in the high Friulian Plain, close to the Tagliamento morainic amphitheater. /* ***Tav. 3 –*** *Selci delle Prealpi Bellunesi-Friulane – Fonzaso, Soccher e Maiolica. 1. Lamella in selce grigio-verde vetrosa del Fonzaso (Dogger, Belluno-Friulan Prealps) con ampie porzioni corticali ricche di "filaments"; 2. Dettaglio della stessa che mostra una matrice microcristallina inglobante radiolari, spicole di spugna e lamellibranchi pelagici; 3. Frammento di dorso in selce del Soccher/Calcare di Fadalto (Giurassico Superiore-Cretaceo Inferiore), deposta in aree più prossimali rispetto alla piattaforma friulana alimentatrice; 4. Il dettaglio evidenzia il detrito bioclastico grossolano ed eterogeneo (rudiste, coralli, alghe, crinoidi, foraminiferi bentonici risedimentati); 5. Grattatoio in selce grigia della Maiolica con larghe bande sfumate; 6. Dettaglio della tessitura finissima criptocristallina inglobante minuti radiolari ri-sedimentati e rare spicole di spugna, spesso con riempimenti di calcite; 7. Grattatoio in selce della Maiolica, analogo al campione precedente; 8. In questo caso la presenza di caratteristiche superfici fortemente arrotondate, l'impregnazione di ossidi e la forte decarbonatazione suggeriscono la raccolta del ciottolo da alluvioni antiche nel contesto dell'alta pianura friulana, vicino all'anfiteatro morenico del Tagliamento.*

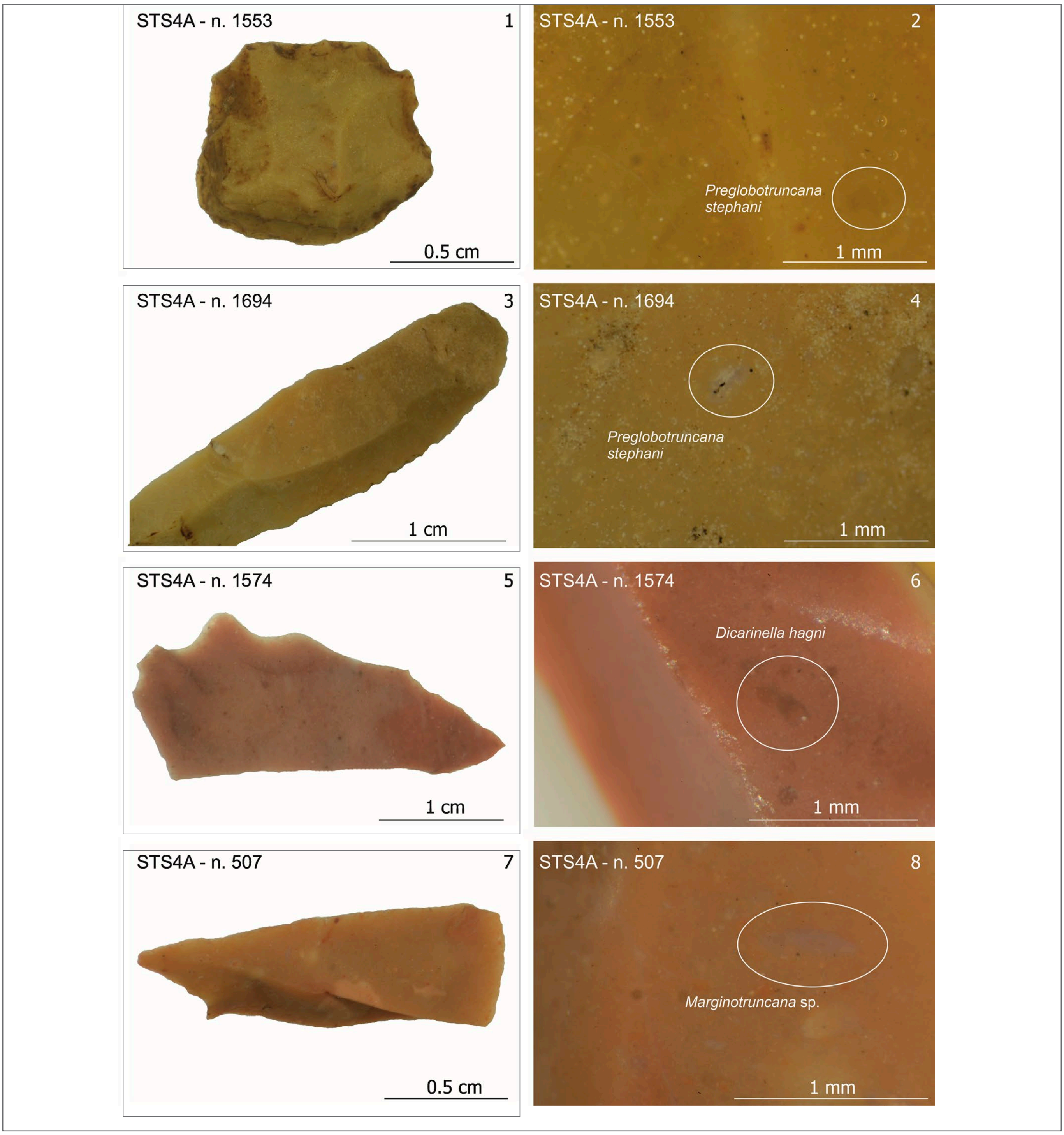

Plate 4 – *Cherts from the Belluno-Friulian Prealps - Scaglia Variegata Alpina summit and Scaglia Rossa basal. 1. Endscraper made of opaque yellow-greenish chert from Scaglia Variegata Alpina; 2. Microfacies composed of radiolarians and planktonic foraminifers (Preglobotruncana stephani) of Cenomanian/Turonian age; 3. Bladelet of yellow chert from Scaglia Variegata Alpina, with fine debris and part of the radiolarians filled with bright calcite resulting in tiny spotted inclusions; 4. Microfacies characterized by dispersed minute calcite crystals and rare milky planktonic foraminifers, including Rotalipora cushmani and Preglobotruncana stephani of Cenomanian age; 5. Bladelet fragment of reddish-brown chert with greyish patches from the Scaglia Rossa basal; 6. Well-preserved microfossils composed of radiolarians and planktonic foraminifers (Dicarinella hagni) indicating Turonian age; 7. Flake fragment of chert from Scaglia Rossa with a reddish-brown and yellowish-brown mottled matrix, and rare brown-pink calcareous inclusions; 8. The very fine siliceous matrix embeds radiolarians and planctonic foraminifers (Marginotruncana sp.) of Turonian-Coniacian age. /* ***Tav. 4 –*** *Selci delle Prealpi Bellunesi-Friulane - Scaglia Variegata Alpina sommitale e Scaglia Rossa basale. 1. Grattatoio in selce selce giallo-verde opaca della Scaglia Variegata Alpina; 2. Microfacies a radiolari e foraminiferi planctonici (Preglobotruncan astephani) di età Cenomaniana/Turoniana; 3. Lamella in selce gialla della Scaglia Variegata Alpina, con detrito fine, e parte dei radiolari riempiti da calcite brillante, con effetto di piccole inclusioni a chiazze; 4. Microfacies caratterizzata da minuti cristalli di calcite dispersi e da rari foraminiferi planctonici lattei, tra cui Rotalipora cushmani e Preglobotruncana stephani di età Cenomaniana; 5. Frammento di lamella in selce di colore bruno rossastro con plaghe grigiastre della Scaglia Rossa basale; 6. Microfossili ben conservati formati da radiolari a foraminiferi planctonici (Dicarinella hagni) che indicano età Turoniana; 7. Frammento di scheggia in selce della Scaglia Rossa a matrice bruno rossastra e bruno giallastra a chiazze, con rari inclusi calcarei bruno rosati; 8. La finissima matrice silicea ingloba radiolari e foraminiferi planctonici (Marginotruncana sp.) di età Turoniana-Coniaciana.*

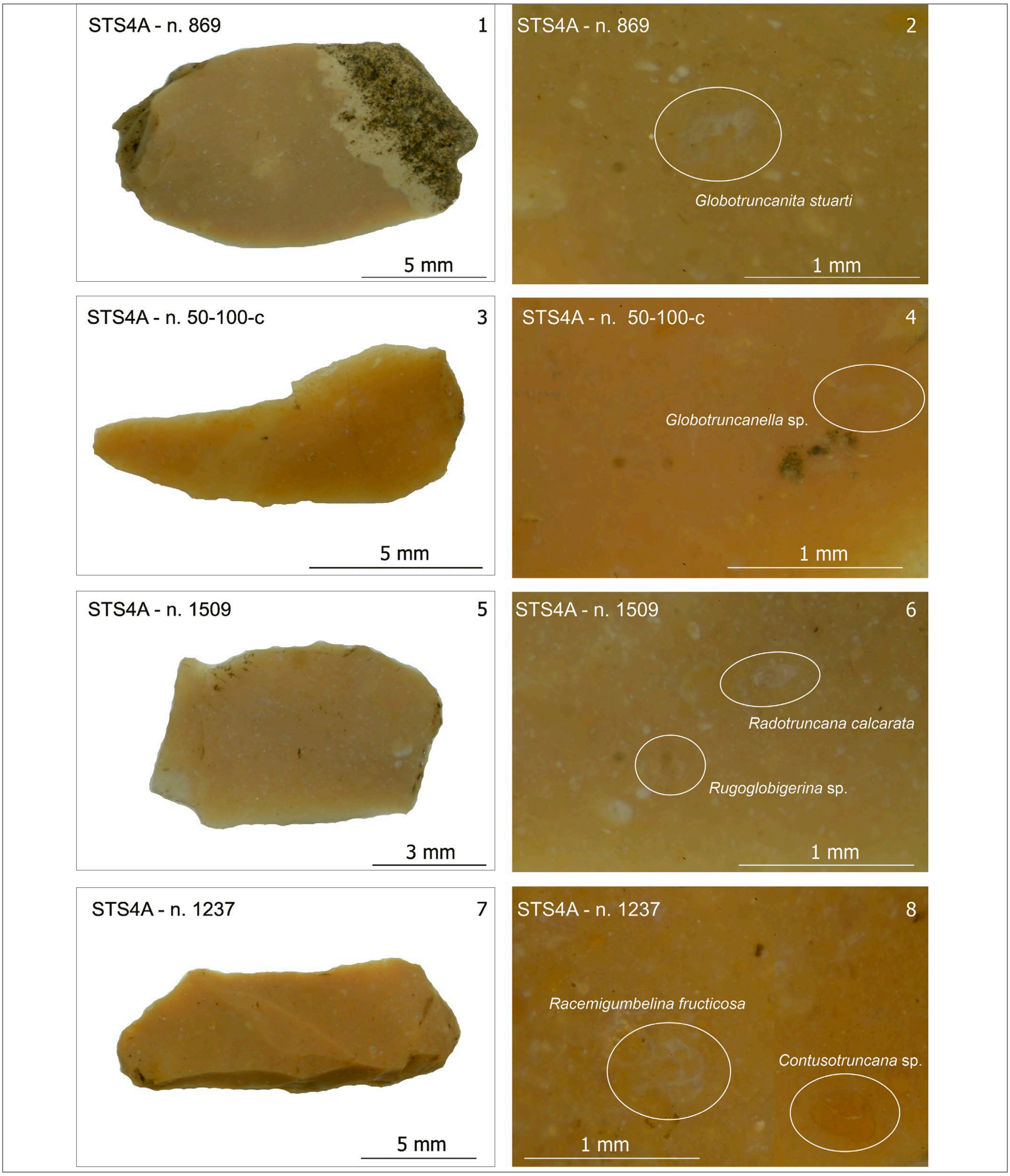

***Plate 5 –** Cherts from the Belluno-Friulian Prealps - Scaglia Rossa summit. 1. Flake made of light brown chert, partially cortical, from Scaglia Rossa; 2. Detail of the microfacies with planktonic foraminifers of Campanian/Maastrichtian age (Globotruncanita stuarti); 3. Bladelet of yellowish brown chert, opaque and homogeneous; 4. Planktonic foraminifers, including Globotruncanella referable to the Maastrichtian; 5. Small flake fragment of light brown chert; 6. The micropalaeontological association includes, among others, Rugoglobigerina sp. and Radotruncana calcarata of Campanian age; 7. Bladelet in opaque yellowish brown chert; 8. Detail of the microfacies showing a micropalaeontological association with Contusotruncana sp. and Racemigumbelina fructicosa of Maastrichtian age. / **Tav. 5 –** Selci delle Prealpi Bellunesi-Friulane – Scaglia Rossa sommitale. 1. Scheggia in selce della Scaglia Rossa colore bruno chiaro, parzialmente corticata; 2. Dettaglio della microfacies con foraminiferi plactonici di età Campaniana/Maastrichtiana (Globotruncana Stuarti); 3. Lamella in selce di colore bruno giallastro, opaca e omogenea; 4. Foraminiferi planctonici, tra cui Globotruncanella sp. riferibile al Maastrichtiano; 5. Piccola scheggia in selce di colore bruno chiaro, 6. L'associazione micropaleontologica comprende tra gli altri Rugoglobigerina sp. e Radotruncana calcarata di età Campaniana; 7. Lamella in selce bruno giallastra opaca; 8. Dettaglio della microfacies che mostra un'associazione micropaleontologica a Contusotruncana sp. e Racemigumbelina fructicosa di età Maastrichtiana.*

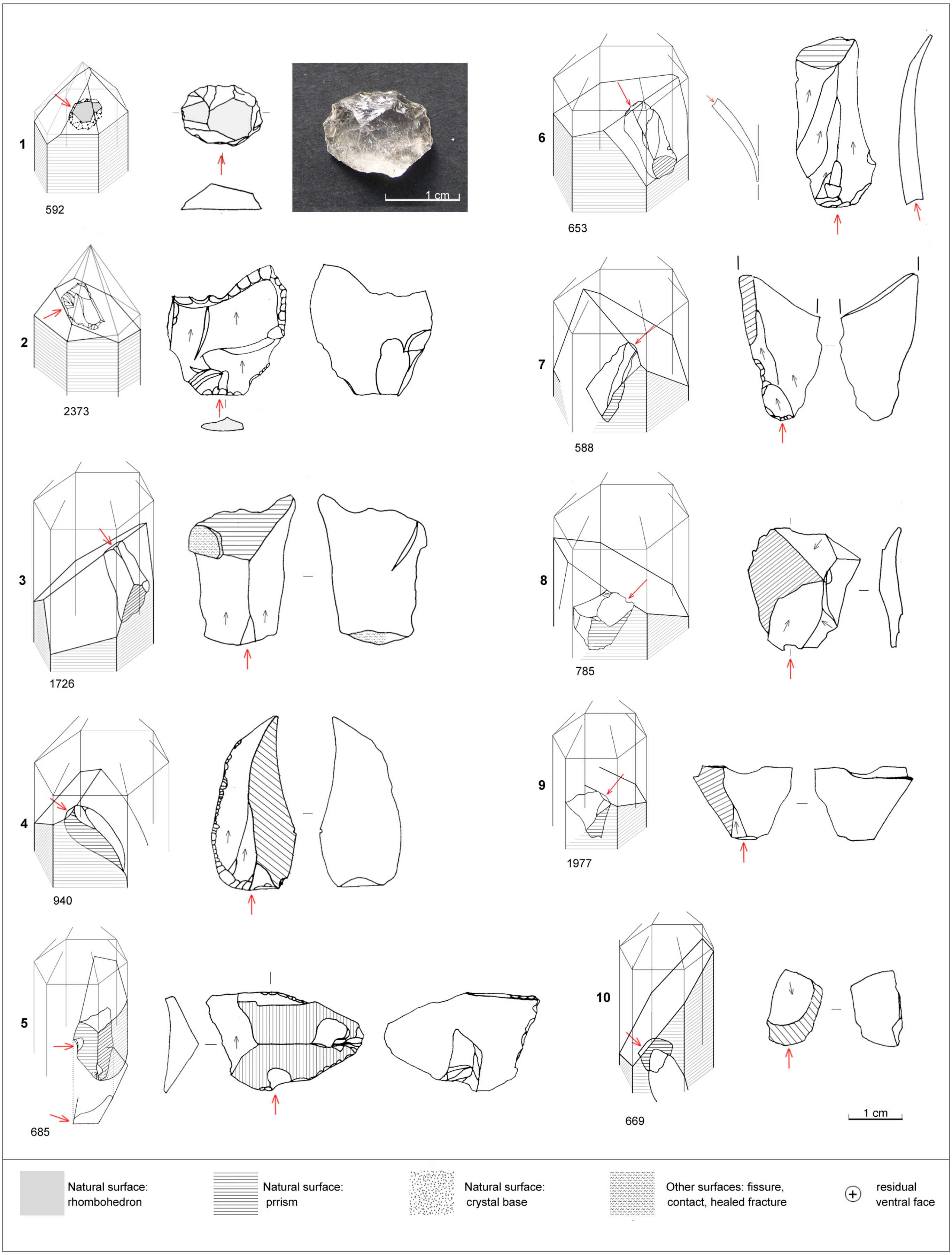

Plate 6 – *Rock crystal artefacts from STS4A showing the reduction of crystals and the production of different types of blanks. Retouched artefacts: 1. Endscraper; 2, 7. Denticulates; 4. Long sidescraper; 5. Truncation. With use-wear: nn. 4, 6-8, see plate 19. /* ***Tav. 6 –*** *Reperti in cristallo di rocca da STS 4A mostrando la riduzione dei cristalli e la produzione di diversi tipi di supporti. Ritoccati: 1. Grattatoio, 2, 7. Denticolati, 4. Raschiatoio lungo; 5. Troncatura. Con tracce d'uso: nn. 4, 6-8, vedi tavola 19.*

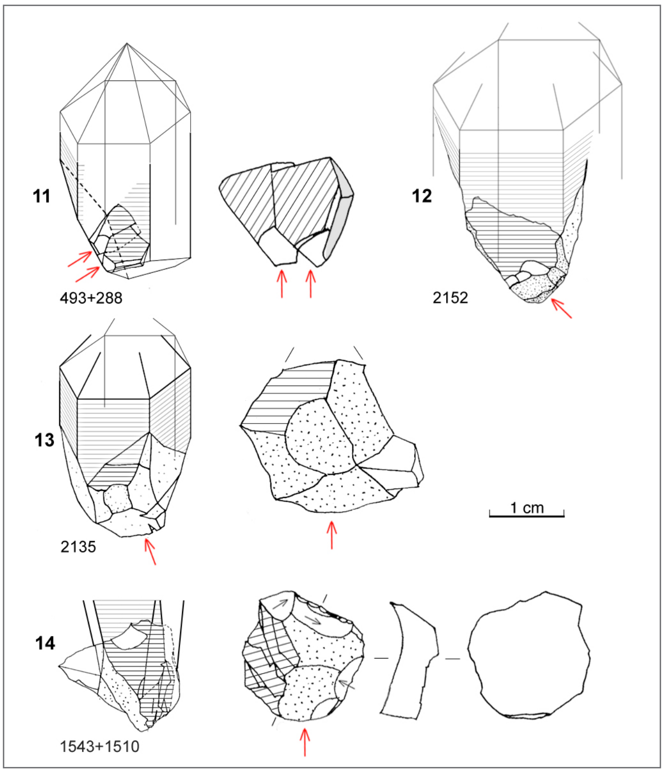

Plate 7 – *Rock crystal artefacts from STS 4A showing the reduction of crystals from the base, and the production of different types of blanks. Retouched artefacts: 14. Denticulate. With use-wear: n. 11 (flake on the left), see plate 19. /* ***Tav. 7 –*** *Reperti in cristallo di rocca da STS 4A mostrando la riduzione dei cristalli dalla base e la produzione di diversi tipi di supporti. Ritoccati: 14. Denticolato. Con tracce d'uso: n. 11 (scheggia sulla sinistra), vedi tavola 19.*

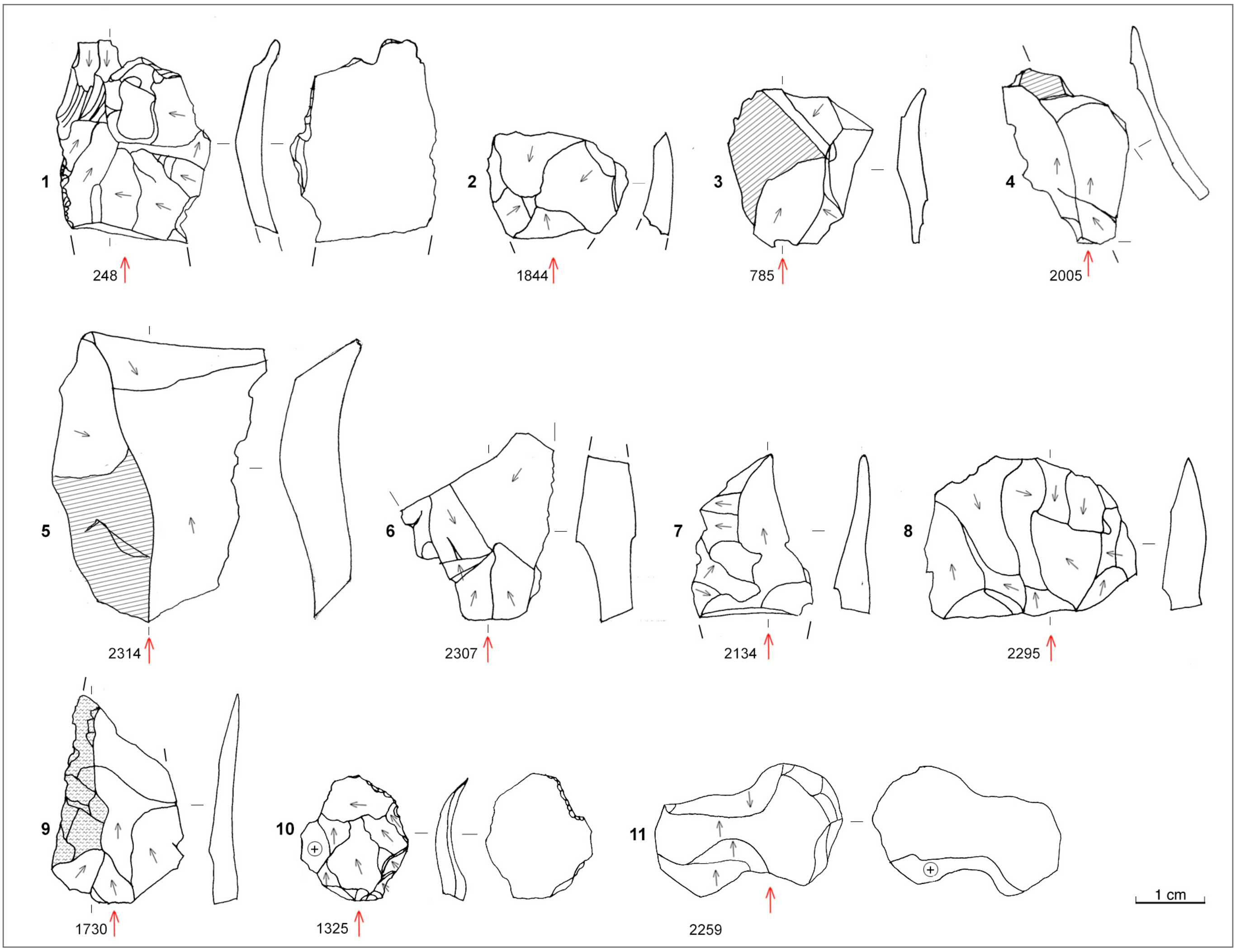

Plate 9 – *Rock crystal flakes from STS 4A. Retouched tools: 10. Denticulate. With use-wear: nn. 1 and 3, see plate 19.. /* ***Tav. 9 –*** *Schegge in cristallo di rocca da STS 4A. Ritoccati: 10. Denticolato. Con tracce d'uso: nn. 1 e 3, vedi tavola 19.*

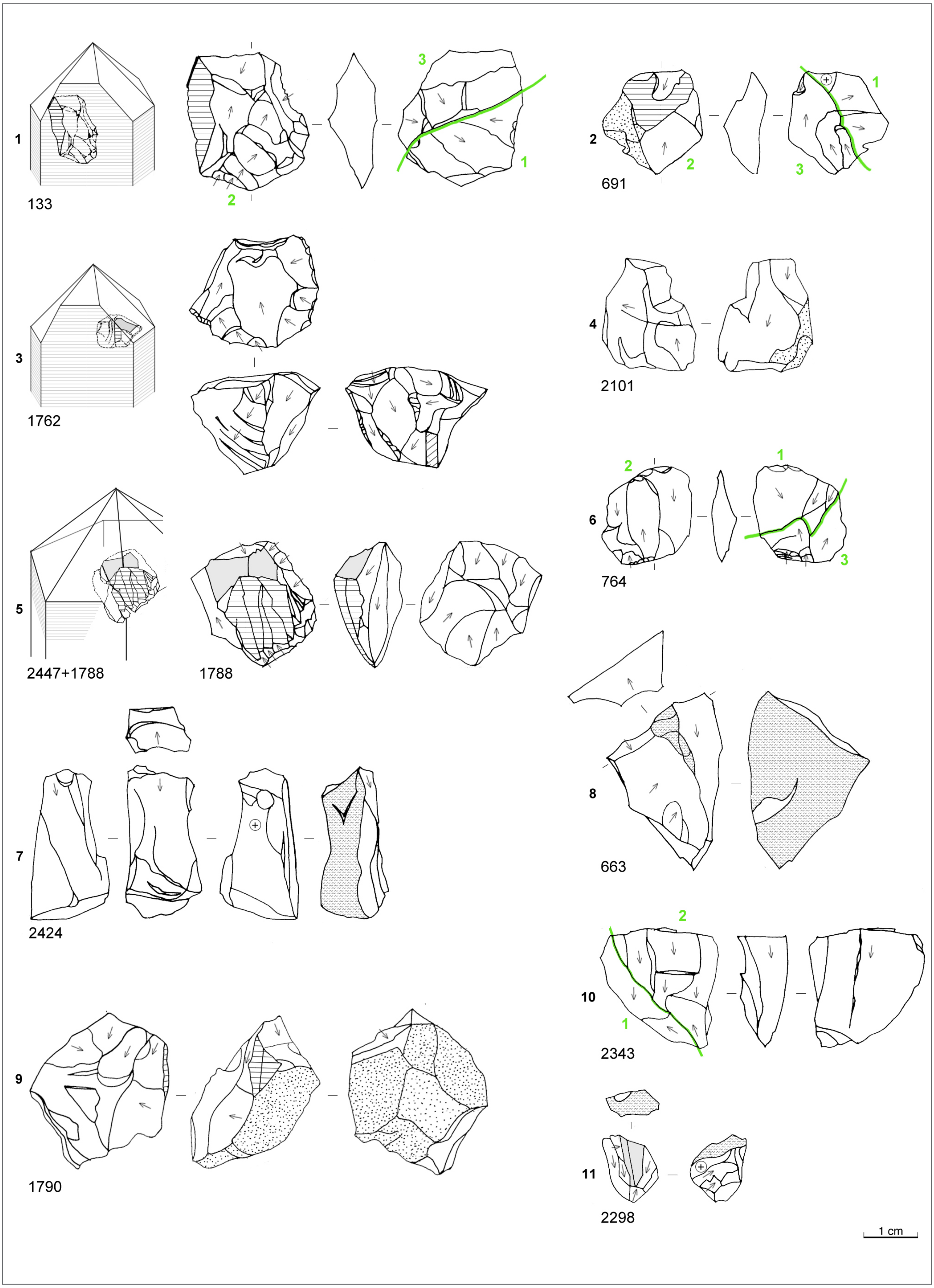

Plate 8 – *Intact rock crystal cores from STS 4A. /* ***Tav. 8 –*** *I nuclei intatti da STS 4A.*

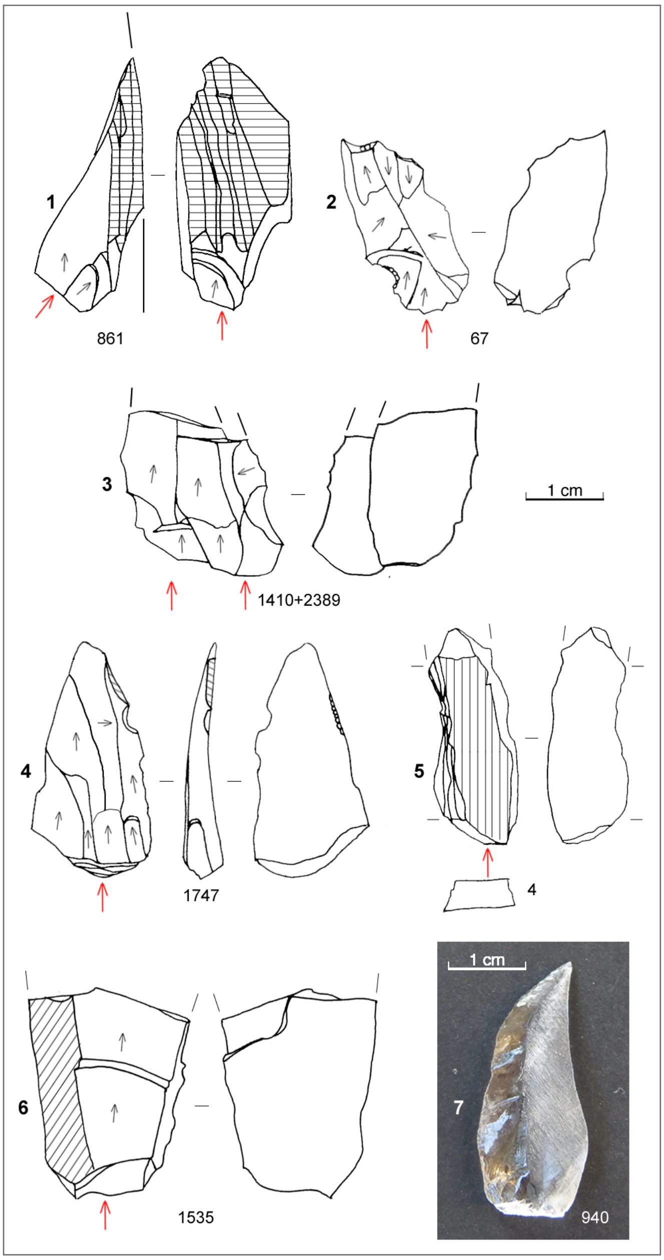

Plate 10 – Rock crystal blades from STS 4A. Retouched tools: 2. Denticulate; 4 and 7. Long sidescraper. With use-wear: nn. 2, 5, 7, see figures 18-19 and plate 19. / ***Tav. 10 –*** *Lame in cristallo di rocca da STS 4A. Ritoccati: 2. Denticolato; 4 e 7. Raschiatoi lunghi. Con tracce d'uso: nn. 2, 5, 7, vedi figure 18-19 e tavola 19.*

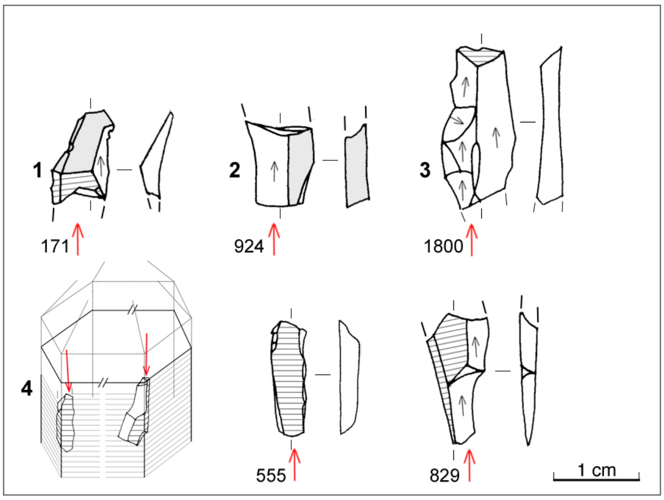

Plate 11 – *Rock crystal bladelets from STS 4A.* / ***Tav. 11 –*** *Lamelle in cristallo di rocca da STS 4A.*

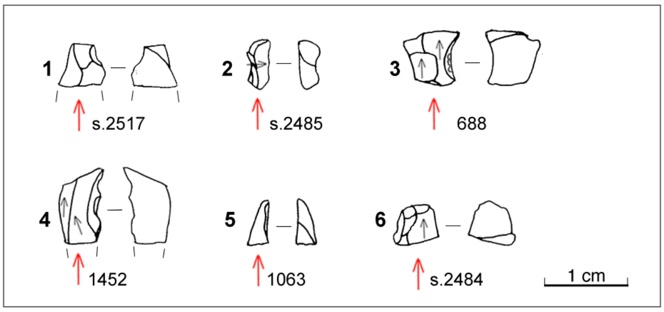

Plate 13 – *Waste from armature manufacturing on rock crystal. 1-2. Microburins; 3-4. Notch adiacent to fracture; 5-6. Krukowski microburins.* / ***Tav. 13 –*** *Scarti del confezionamento delle armature su cristallo di rocca. 1-2. Microbulini ordinari; 3-4. "Incavo adiacente a frattura"; 5-6. Microbulini Krukowski.*

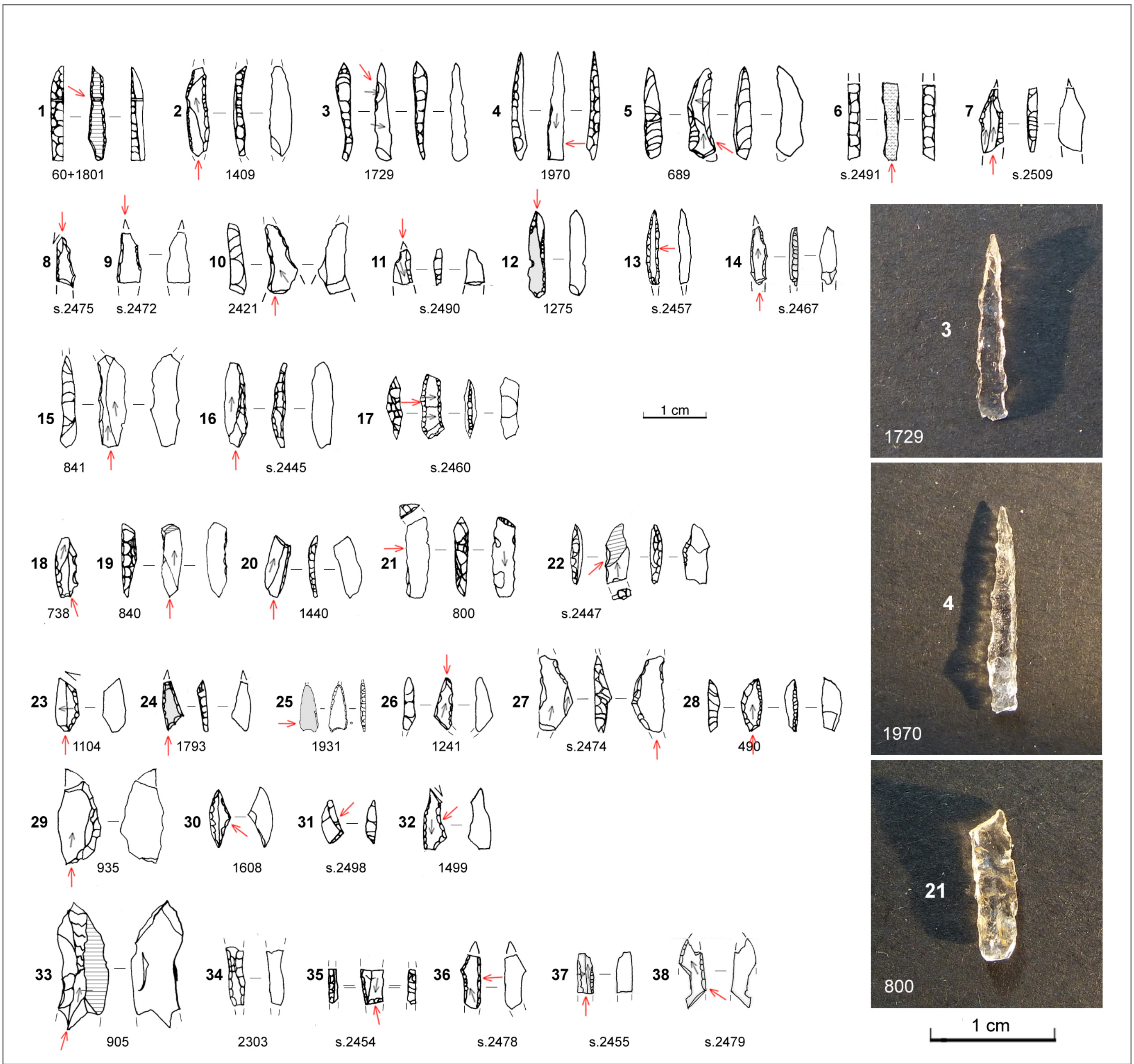

Plate 12 – *Rock crystal armatures (backed tools) from STS 4A. 1-14. Backed points; 15-17. Backed bladelets; 18-22. Backed bladelets with truncation; 23-32. Geometric pieces; 33-38. Backed fragments. /* ***Tav. 12 –*** *Armature (strumenti a dorso) in cristallo di rocca da STS 4A. 1-14. Punte a dorso; 15-17. Lame a dorso; 18-22. Lame a dorso e troncatura; 23-32. Geometrici; 33-38: Frammenti di dorso.*

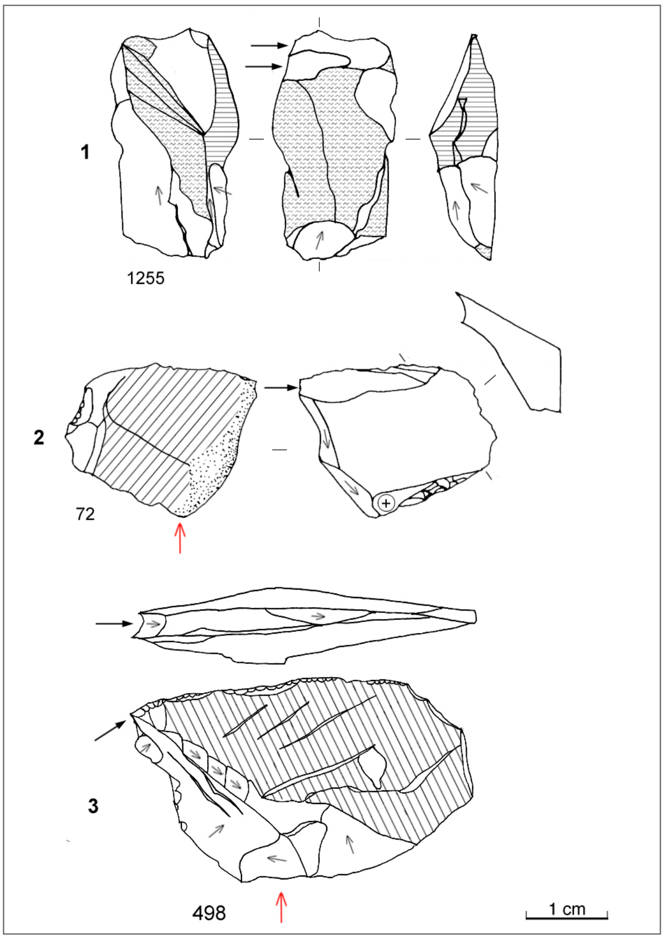

***Plate 14 –** Burins from rock crystal. With use-wear: nn. 2-3, see figure 18 and plate 19. / **Tav. 14 –** Bulini su cristallo di rocca. Con tracce d'uso: nn. 2-3, vedi figura 18 e tavola 19.*

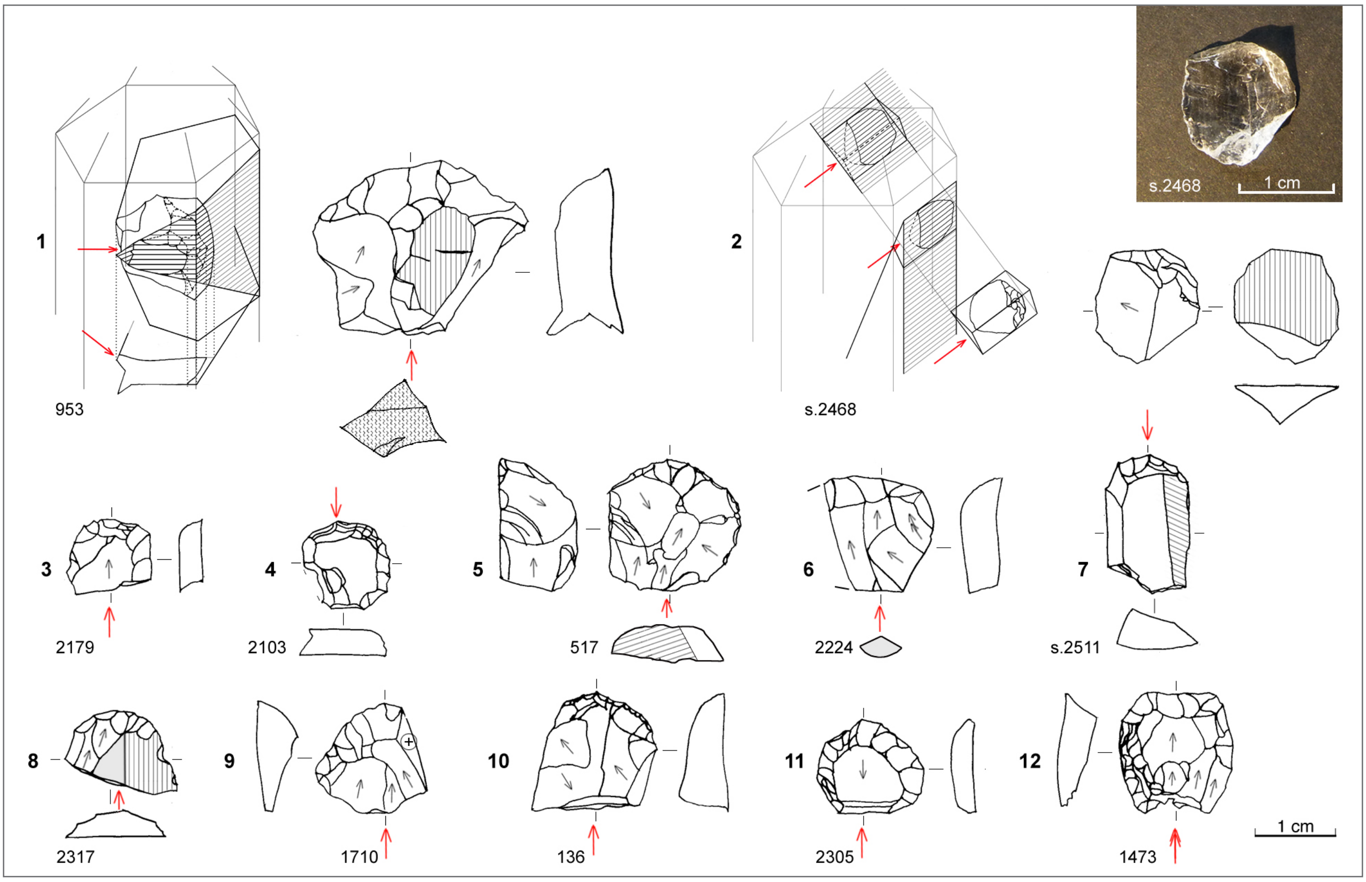

***Plate 15 –** Endscrapers from rock crystal. With use-wear: nn. 1-2, 5, 10, see figure 18 and plate 19. / **Tav. 15 –** Grattatoi su cristallo di rocca. Con tracce d'uso: nn. 1-2, 5, 10, vedi figura 18 e tavola 19.*

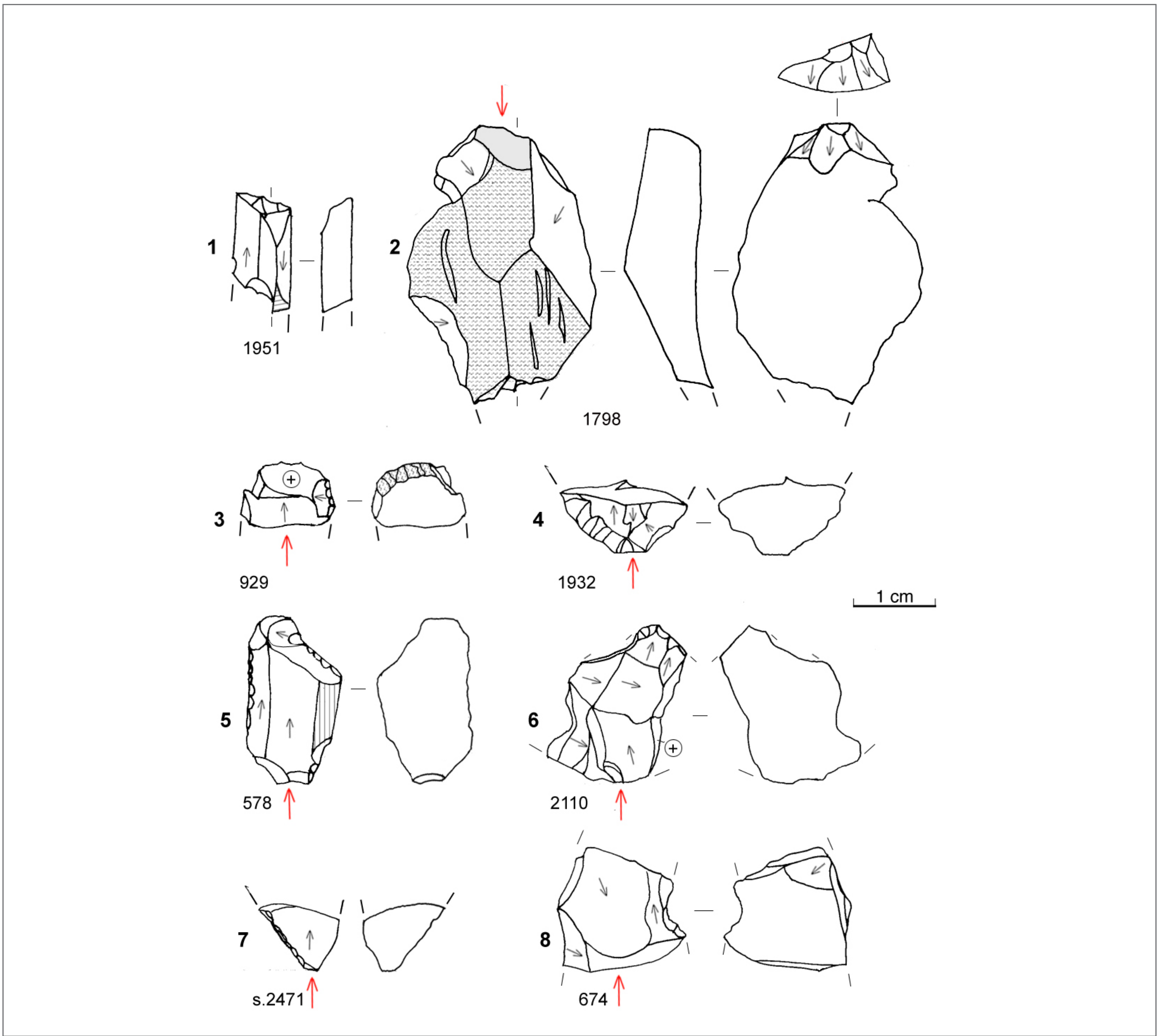

Plate 16 – *1-2. Truncations; 3-6. Scrapers; 7. Undifferentiated abrupt pieces; 8. Denticulates. All made of rock crystal. With use-wear: n. 5, see plate 19. /* ***Tav. 16 –*** *1-2. Troncature; 3-6. Raschiatoi, 7. Erti indifferenziati; 8. Denticolato. Tutti su cristallo di rocca. Con tracce d'uso: n. 5, vedi tavola 19.*

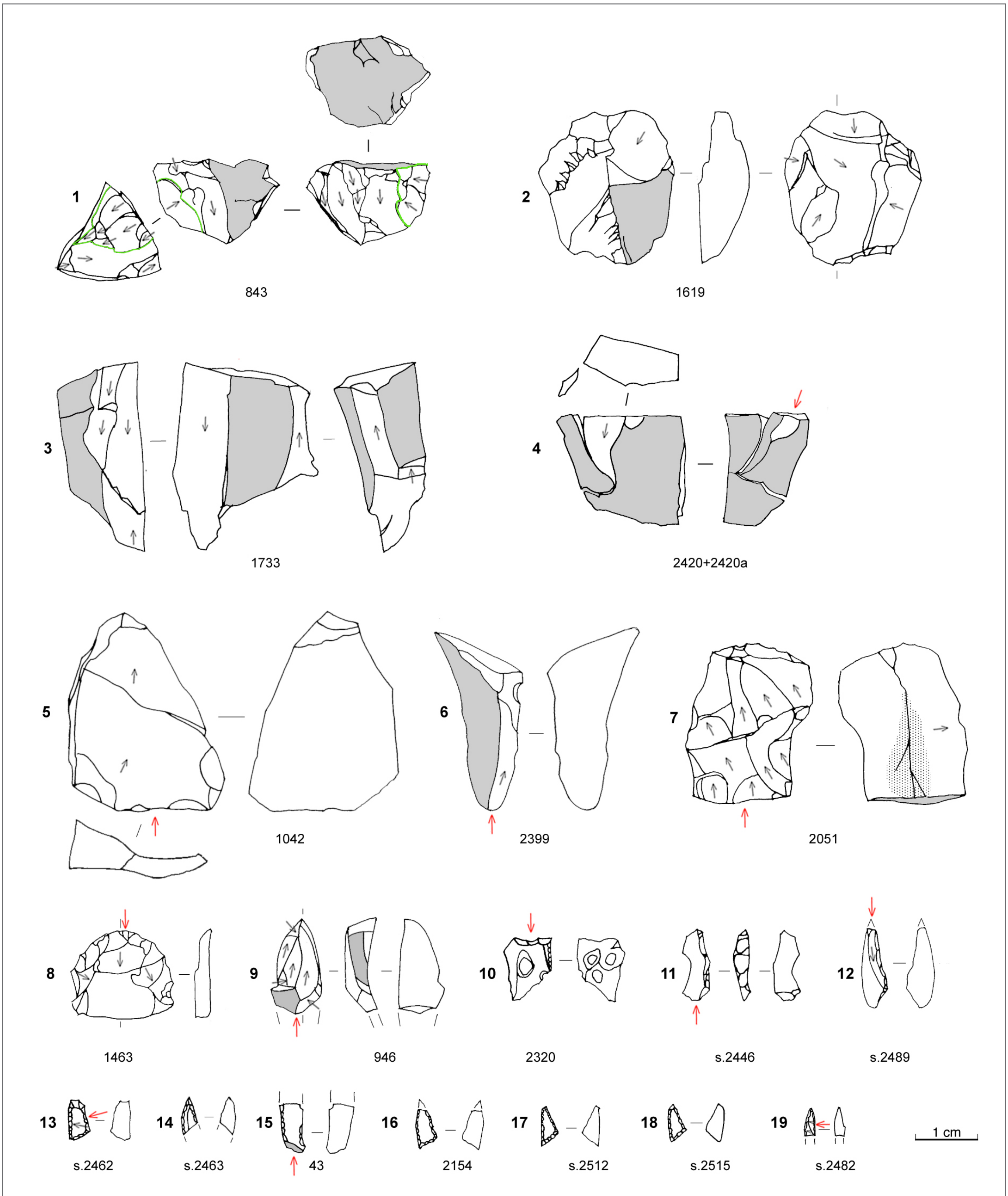

Plate 17 – *Artefacts made of Buchenstein chert. 1-4. Cores; 5-7, 9. Unretouched artefacts; 8. Endscraper; 10. Truncation; 11. Backed blade; 12, 16-18. Geometrics; 13. Backed piece with truncation; 14 and 19. Backed point fragments; 15. Backed fragment. /* ***Tav. 17 –*** *Industria litica ricavata da selce del Buchenstein. 1-4. Nuclei; 5-7, 9. Non ritoccati; 8. Grattatoio; 10. Troncatura; 11. Lama a dorso; 12, 16-18. Geometrici; 13. Strumento a dorso e troncatura; 14 e 19. Frammenti di punte a dorso; 15. Frammento di dorso.*

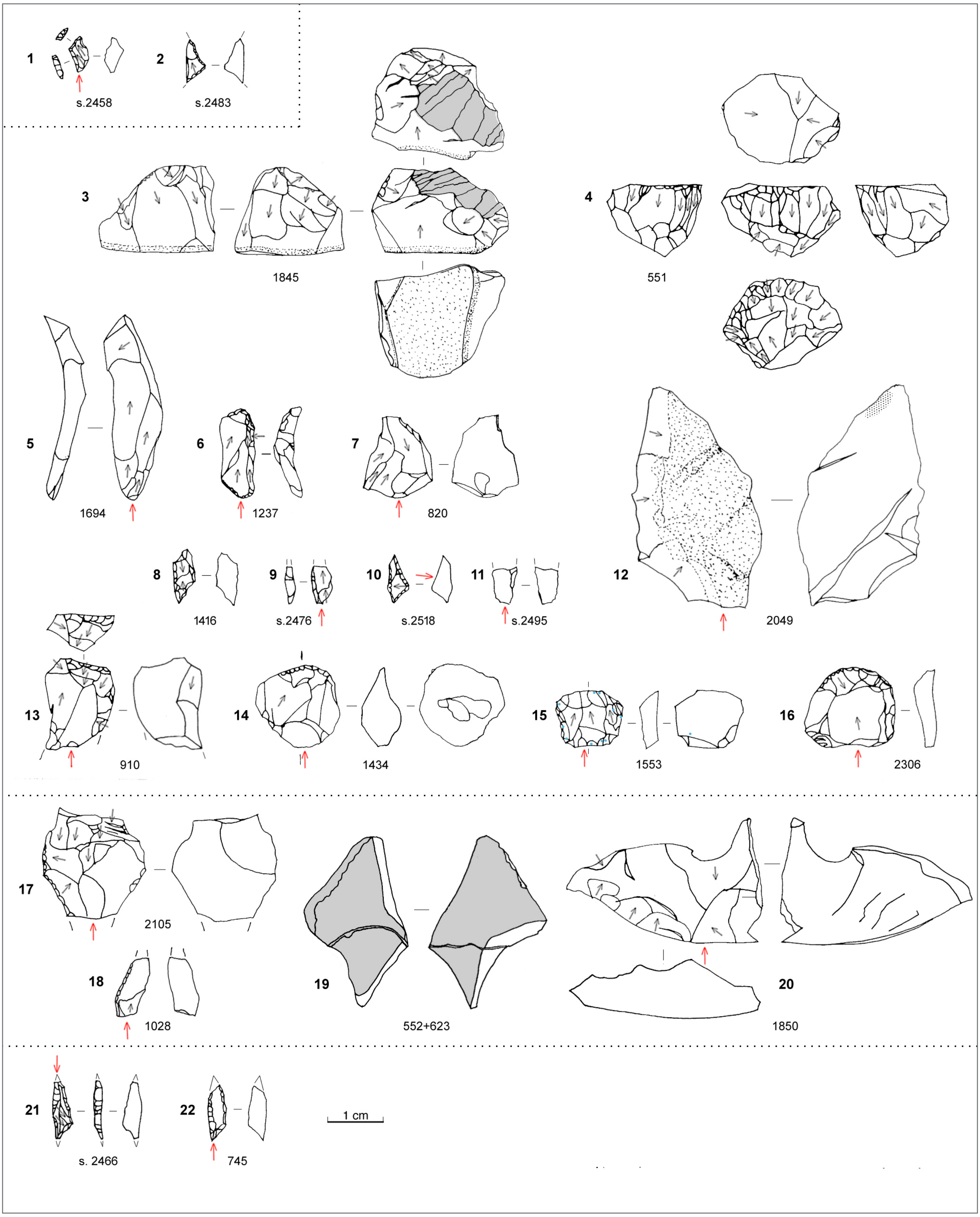

Plate 18 *– Armatures made of Rosso Ammonitico chert: 1. Backed piece with truncation; 2. Geometric piece. Artefacts made of prealpine cherts: 3. Core; 4. Endscraper on former core; 5-6. Unretouched artefacts; 7. Abrupt undifferentiated piece; 8 and 10. Geometrics; 9 and 11. Backed fragments; 13-16 Endscrapers. Artefacts made of filonian („pegmatitic") quartz: 17. Scraper; 18. Backed fragment; 19-20 Unretouched artefacts. Armatures made of northern Alpine radiolarite: 21-22. Geometrics. With use-wear: n. 4, see figure 18. /* ***Tav. 18*** *– Armature realizzate su selce del Rosso Ammonitico: 1. Strumento a dorso e troncatura; 2. Geometrico. Industria ricavata su selce prealpina: 3. Nucleo; 4. Grattatoio su ex nucleo; 5-6. Non ritoccati; 7. Erto indifferenziato; 8 e 10. Geometrici; 9 e 11. Strumenti a dorso; 13-16. Grattatoi. Manufatti ricavati su quarzo filoniano ("pegmatitico"):17. Rasciatoio; 18. Frammento di dorso; 19-20. Non ritoccati. Armature fatte su radiolarite nordalpina: 21-22. Geometrici. Con tracce d'uso: n. 4, vedi figura 18.*

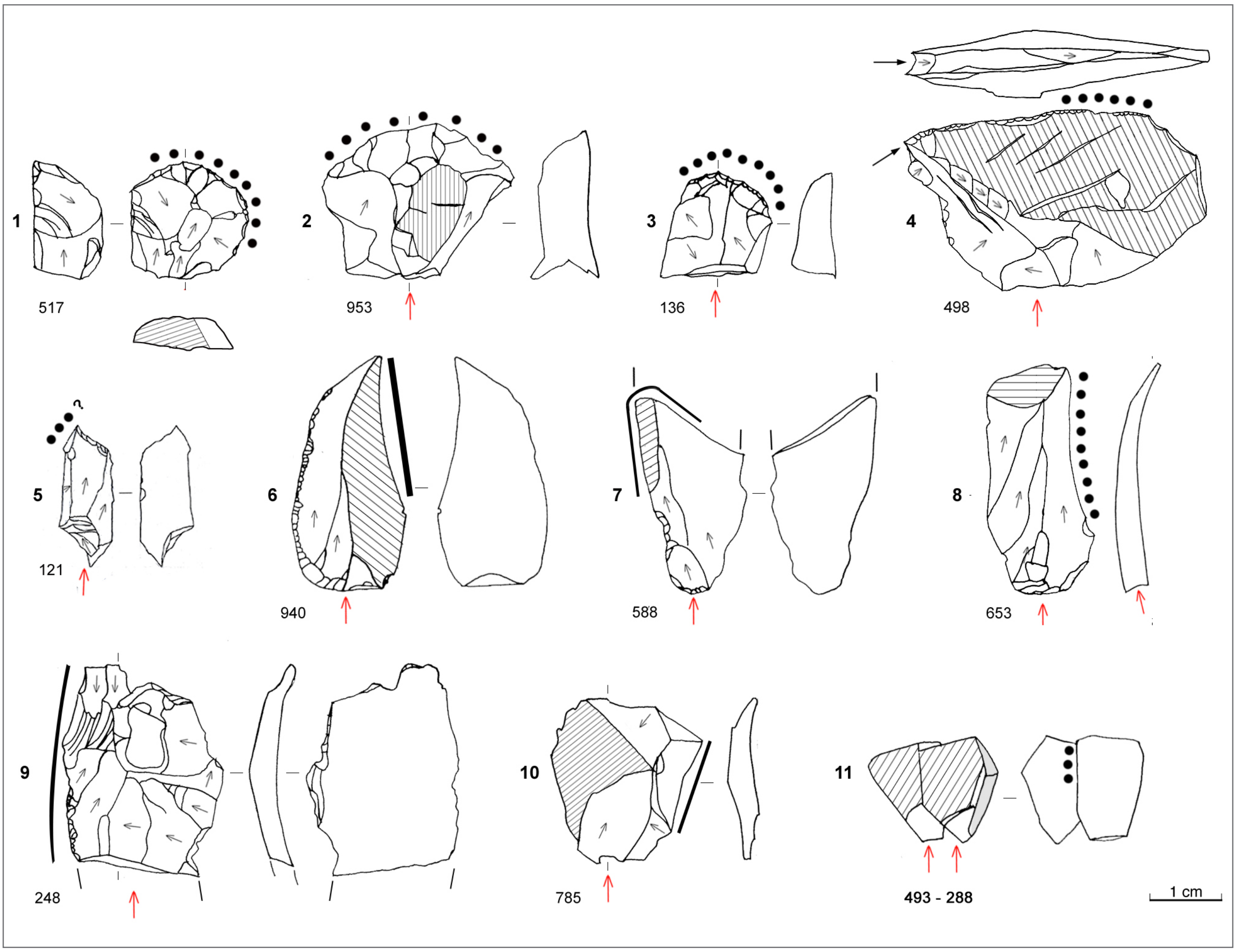

Plate 19 – *Archaeological sample from Staller Sattel STS 4A on rock crystal. Wear traces from scraping (dots) and cutting (straight line): 1-3. Endscrapers; 4. Burin; 5. Truncation; 6. Long sidescraper; 7. Denticulated piece; 8-11. Unretouched blade, laminar flake and flake. /*
Tav. 19 – *Campione archeologico da Staller Sattel STS 4A su cristallo di rocca. Tracce d'uso compatibili con raschiare (punti) e tagliare (linea): 1-3. Grattatoi; 4. Bulino 5. Troncatura; 6. Raschiatoio lungo; 7. Denticolato; 8-11. Lama, scheggia laminare e scheggia, non ritoccati.*