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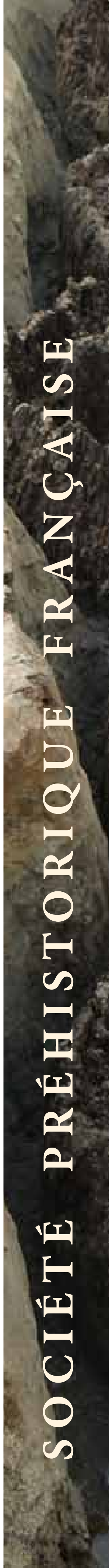

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RESSOURCES LITHIQUES, PRODUCTIONS ET TRANSFERTS ENTRE ALPES ET MÉDITERRANÉE

ACTES DE LA SÉANCE
DE LA SOCIÉTÉ PRÉHISTORIQUE FRANÇAISE
NICE
28-29 MARS 2013

Textes publiés sous la direction de
Antonin Tomasso, Didier Binder, Gabriele Martino,
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5

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The Gargano Promontory Flint

Mining Practices and Archaeometric Characterisation

Massimo Tarantini, Giacomo Eramo, Alessandro Monno and Italo Maria Muntoni

Abstract: An archaeological project on prehistoric mining has been carried out in the Gargano promontory, in south-eastern Italy, since 1986, leading to the discovery of a large network of at least twenty mining sites, which was active from the Early Neolithic to the Early Bronze Age. The large area in which the mines are located, the considerable size of some mines and the skills required, together with the long duration of mining activities (four millennia), enable us to regard the Gargano as one of the main areas of flint supply in the central-northern Mediterranean.

Three geological Gargano formations were mined: the Maiolica, Scaglia and Peschici formations. They appear to differ significantly with regard to the morphology of the flint. In the mines opened in the Nummulite limestone formation, flint seems to occur only as generally rather large lenticular nodules (often more than one metre in diameter). The Maiolica and Scaglia formations are different: the exploited flints primarily occur in the form of spherical and irregular nodules, only in some cases associated with lenticular lists.

During the sixth millennium BC on the Gargano promontory we exclusively find flint mines with entrances opened into the slope of a hill and developing sub-horizontally. This type of mining generated large amounts of mining debris that were accumulated outside the mine and that are sometimes still preserved in their entirety.

Neolithic mining techniques in the Gargano underwent a radical transformation from the fifth millennium BC on and especially during the fourth millennium BC: rather small mines can be identified that are characterised by vertical access to the flint-bearing formations, with or without horizontal digging at the base of the shafts.

Systematic characterisation studies of the flint from primary and secondary Gargano sources are still lacking and the paper presents the plan and the preliminary results of a new project, applying multi-parametric characterisation obtained by non-destructive approaches that are rapid and economic (during this initial stage of the project macroscopic/petrographic description, colour and reflectance/gloss measurements). A total of 151 flint samples, representative of the three flint-bearing limestone formations, the ancient exploitation of which is demonstrated by mining indicators, and of a fourth formation (Fucoid Marls), which has not provided evidence of flint mining yet, was collected. The flint samples were taken from Neolithic mines and from accessible flint outcrops throughout the Gargano promontory.

The macroscopic description of the flint samples provided a matrix of categorical and numerical data which helps to identify the distinctive features of the four formations investigated. Spectro-colorimetry provided coordinates in CIE L*a*b* colour space and reflectance in the visible spectrum of the flint matrix. The two main mining districts hitherto identified by archaeologists, namely those of Vieste and Peschici, cut into specific formations (Peschici limestone and Maiolica respectively), with mines that exploited flint with various characteristics even within the same formation. However, we observed some chromatic homogeneity at site level. This classification of chromatic and reflectance data confirms the similarities visible to the naked eye between most of the samples from the Maiolica and the Peschici limestone formations, which also turned out to be more homogeneous than the Scaglia and the Fucoid Marls formations. No mines were found in the Fucoid Marls formation, though the quality of flint was similar to that of most of the mining sites in the other formations.

Although our interpretations have to be tested with chemical and mineralogical data, the statistical approach using quantitative macroscopic data seems to be a promising way of classifying and correlating geological and archaeological flints from the Gargano. Following the steps of the multi-analytical protocol, flints will be analysed with Raman spectroscopy to determine their mineralogical composition, whereas the chemical composition will be obtained by LA-ICP-MS. A detailed micro-structural and palaeontological study will be carried out using a scanning electron microscopy in order to distinguish flint sources of different ages.

Keywords: Gargano, Neolithic, mining sites, flint, macroscopic analysis.

Résumé : Le Gargano est un grand promontoire situé dans le Sud-Est de l'Italie. À ce jour, vingt sites d'extraction y ont été identifiés, concentrés surtout dans la partie nord-est du Gargano et couvrant la période du début du VI^e^ au début du II^e^ millénaire av. J.-C.

(Néolithique ancien-âge du Bronze ancien). Ces études nous permettent d’aborder la question de la gestion des ressources lithiques du côté spécifique des pratiques d’extraction.
Au VIe millénaire av. J.-C., les mines sont creusées à l’horizontale à partir de la pente des collines, avec des accès verticaux occasionnels (type A). Elles donnent lieu à l’extérieur à des accumulations de déchets miniers de dimensions remarquables. Les modalités de gestion de ce type de mines sont bien connues grâce aux conditions de conservation exceptionnelles de la mine de la Defensola. On observe : a) une standardisation des techniques ; b) un haut niveau des savoir-faire mis en place ; c) une grande dimension souterraine des mines, qui implique aussi des difficultés à se déplacer à l’intérieur et une certain dangerosité. Tous ces éléments nous conduisent à supposer que l’exploitation néolithique a été le fait d’un groupe restreint de spécialistes, qui contrôlaient également la transmission des compétences et, de ce fait, l’accès aux sources de silex.
Cette tradition technique minière est l’objet d’un bouleversement au Ve et surtout au IVe millénaire, quand apparaissent des mines à accès presque exclusivement vertical, avec ou sans creusement horizontal à la base des puits qui ne dépassent pas les trois mètres de profondeur (types B et C). Le creusement horizontal présente une extension limitée et se déroule le long de formations crayeuses ou présentant des dislocations tectoniques importantes. On peut supposer que dans des structures où l’équilibre est incertain, le creusement ait été mené rapidement et que chaque puits représente un seul épisode d’extraction. La stratégie d’exploitation ne prévoyait-elle donc pas une structure complexe à gérer, mais une aire sur laquelle on revenait chaque fois pour ouvrir une nouvelle petite structure. Cette stratégie d’exploitation différente requiert un investissement technique bien plus limité que celui observé au Néolithique et une transformation de la nature du travail minier. Au cours du IVe millénaire, l’activité d’extraction du silex, moins spécialisée, va vraisemblablement perdre en prestige social.
Les formations géologiques concernées par l’exploitation minière sont au nombre de trois. Leur exploitation diffère de façon significative au fil du temps. La formation exploitée au VIe millénaire est, géologiquement, la plus récente des trois formations concernées. Il s’agit de la formation de Peschici, qui est une plate-forme à nummulites de l’Éocène moyen (Lutétien-Bartonien). Le silex y est présent uniquement à l’intérieur d’une série des calcaires micritiques pélagique de très faible épaisseur. Ce silex, d’excellente qualité, est surtout présente en nodules lenticulaires, souvent de grandes dimensions. Les deux formations concernées à partir du Ve millénaire, au contraire, présentent principalement du silex sous la forme de nodules sphériques ou irréguliers ; plus rares sont les nodules lenticulaires. La principale de ces deux formations est la formation Maiolica, qui est un dépôt de bassin formé au cours du Jurassique supérieur-Crétacé inferieur (Tithonien-Aptien). L’autre formation est la Scaglia, une unité de bassin du Crétacé supérieur (Cénomanien-Paléocène) qui n’a été que peu exploitée.
À en juger par plusieurs observations préliminaires, le silex du Gargano ou les objets produits à partir de celui-ci, ont circulé – à des moments différents– dans toute l’Italie centre-méridionale, et également de l’autre côté de la mer Adriatique. Des études systématiques de caractérisation du silex du Gargano font cependant encore défaut : les silex des mines du Gargano ont bénéficié seulement d’une simple caractérisation macroscopique visuelle et d’analyses géochimiques préliminaires.
La deuxième partie de cette communication est donc consacrée à la présentation d’un projet de caractérisation multiparamétrique, qui vient tout juste d’être lancé. Ce projet de caractérisation vise à l’application de plusieurs méthodes d’analyse afin d’identifier des marqueurs discriminants du silex du Gargano à reconnaitre par le biais d’une approche qui serait la moins destructive possible et à la fois relativement rapide, économique et fiable.
L’analyse macroscopique a été formalisée en tenant compte des propriétés du silex et du cortex. Elle prend en compte sept paramètres pour la portion de silex (notamment subcortex, texture, structure, fracture, couleur, réflectance et lustré) et cinq paramètres pour le cortex, lorsqu’il est présent (épaisseur, nature, induration, surface et délimitation).
Lors de cette première étape du projet, nous nous sommes d’abord concentrés sur l’analyse macroscopique des 151 échantillons géologiques de silex du Gargano pour comprendre la variabilité des caractéristiques intrinsèques et les utiliser comme des facteurs discriminants potentiels pour la provenance. La description macroscopique-pétrographique a été suivie de l’analyse colorimétrique (Cie L*a*b*) de la réflectance dans le domaine du visible et de celle du lustré.
Cette première tentative de fournir une approche non destructive et non biaisée de la classification du silex du Gargano a atteint son objectif qui était d’établir une base pour approfondir les analyses de laboratoire.
Les deux principaux districts miniers connus à ce jour des archéologues, à savoir celui de Vieste et celui de Peschici, impliquent plusieurs phases de formation successives. Les mines présentent souvent des silex avec des caractéristiques différentes, même au sein d’une même formation. Notre stratégie d’échantillonnage vise à accroître les connaissances sur les caractéristiques et l’homogénéité du silex provenant des vingt mines néolithiques et des sources de silex du Gargano.
D’après nos premiers résultats, coexistent dans chaque formation des silex possédant des caractéristiques et qualités différentes. Cependant, au niveau de certaines mines, nous avons observé une homogénéité chromatique (p. ex. Defensola, Arciprete, Tagliacantoni en ce qui concerne le calcaire de Peschici, et Martinetti, Valle Sbernia/Guariglia, Bosco della Risega en ce qui concerne la formation de Maiolica).
Nos interprétations doivent encore être confrontées à des données chimiques et minéralogiques, mais il nous semble déjà possible d’affirmer qu’une approche statistique sur des données quantitatives macroscopiques paraît une voie prometteuse pour classer et mettre en corrélation les silex géologiques et archéologiques.

Mots clés : Gargano, Néolithique, exploitation minière, silex, analyse macroscopique.

Editor’s note: the tables 1, 2 and 3 can be downloaded on the web site (**here**) in the form of Excel files.

This paper is dedicated to the memory of Giuseppe Ruggieri from Vieste (FG), who discovered the Defensola mine in 1981

This paper deals with a specific regional context in South-Eastern Italy, the Gargano promontory, which covers an area of about 2,000 km². A mining archaeology project has been going on in the Gargano since 1986, leading to the discovery of a large network of at least twenty mining sites, concentrated especially in the north-eastern part of the promontory (Tarantini et al., 2011; Tarantini and Galiberti, 2011). This mining network was active from the Early Neolithic to the Early Bronze Age, or from the beginning of the sixth millennium BC until the beginning of the second millennium BC (calibrated age; for a complete review of the radiocarbon dates see Muntoni and Tarantini, 2011). The large area in which the mines are found, the considerable size of some mines and the skills required, together with the long duration of mining activities (four millennia), enable us to consider that the Gargano promontory was one of the main areas of flint supply in the Central-Northern Mediterranean.

Judging from several preliminary observations, Gargano flint, or objects produced from Gargano flint, circulated throughout Southern and Central Italy (e.g. Guilbeau, 2010), and on the opposite side of the Adriatic, i.e. on the Croatian islands and coast (Forenbaher and Miracle, 2006; Forenbaher and Kaiser, 2011). Nevertheless, systematic characterisation studies of the flints from primary and secondary Gargano sources are still lacking. An initial attempt to carry out geochemical characterisation was made at the end of the 1990s, but, despite encouraging results (D'Ottavio, 2001), it was not further developed.

To optimise the description and classification procedure for flint and to support the correlation of materials from different regions, a new project, this time using multiparametric characterisation, has recently been launched: the plan and preliminary results of which are presented here.

This paper is therefore subdivided into two parts:

– a short overview of the Gargano mines and the geological context to help explain the exploitation strategy for flint sources from the specific point of view of extraction practices;

– the plan and the preliminary results of the multiparametric characterisation project.

This paper then focuses on the following issues:

To what extent is the flint stemming from a single formation petrographically and/or colorimetrically homogeneous?

Are there any characteristic petrographic and/or colorimetric features that may enable us to distinguish flints stemming from different formations?

THE GEOLOGICAL CONTEXT OF THE GARGANO FLINT SOURCES AND MINES (M. T.)

The Gargano promontory is geographically isolated from the Apennine ridge. Its geological supporting structure is an Upper Jurassic-Lower Cretaceous carbonate platform (the so-called Apulia Carbonate Platform), which acted as a reef complex (fig. 1). To the north-east of the platform we observe all the depositional environments of a typical carbonate platform (Bosellini et al., 1999; Morsilli et al., 2004; Morsilli, 2011).

Since the Early Cretaceous the clinostratified surface of the platform has been covered by a basin unit of white micritic limestone—the Maiolica formation (Tithonien-Aptien). The Maiolica formation is one of the most extensive formations in the Gargano. The micritic limestone is arranged in thin layers, often affected by tectonic alteration and synsedimentary sliding (slumpings). The Maiolica formation contains abundant tabular and nodular flint. A lot of mines were opened here in the Peschici and Mattinata districts.

An interruption of the sedimentation process linked to the carbonate platform is represented by the marly limestone formation (Marne a Fucoidi; Aptian–Albian). Platform sedimentation resumed at the beginning of the Upper Cretaceous and continued for almost all of the Palaeocene. This period saw the Scaglia formation, a Cenomanian-Palaeocene formation of white and powdery micritic limestone with an abundance of flint arranged mainly in fine layers, which was hardly exploited by prehistoric miners. Only two mines opened into the Scaglia formation in the Gargano (Finizia and Valle Guariglia I, II).

Finally, during the Middle Eocene, the platform margin collapsed and subsequently a Nummulite platform formed (Lutetian-Bartonian). The Nummulite limestone is limited to the north-eastern part of the Gargano promontory, between Vieste and Peschici. This succession (about 350 m thick, known as the Calcare di Peschici formation) is represented by graded breccias and nummulitic turbidites, alternating with hemipelagic marly mudstones, and underwent only minor tectonic deformations. At the bottom of this formation is a relatively thin series of compact pelagic micritic limestone with high quality flint, generally in the shape of large-size nodules. These were the object of intense mining activities, particularly during the Neolithic.

Three Gargano formations were mined: the Maiolica, Scaglia and Peschici formations, notably concentrated north of the Varano-Mattinata line. In the case of the Peschici formation, the exploited flint-bearing levels are located at the bottom of the series, just above the stratigraphic gap with the Scaglia formation (and therefore belong to the Lutetian). In the case of the Maiolica and Scaglia formations the exact location of flint levels within the sequence, and thus their geological age, are not yet precisely defined.

The flint mines are clustered in the north-eastern part of the Gargano promontory. A series of isolated mining complexes and two major mining districts have been identified. First, the Vieste district, which covers an area of about 5 km², with mines cut into the Nummulite limestone formation. These mines consist of a series of features found on hill slopes (often fairly steep, as at Defensola A and B). Second, the Peschici district, which

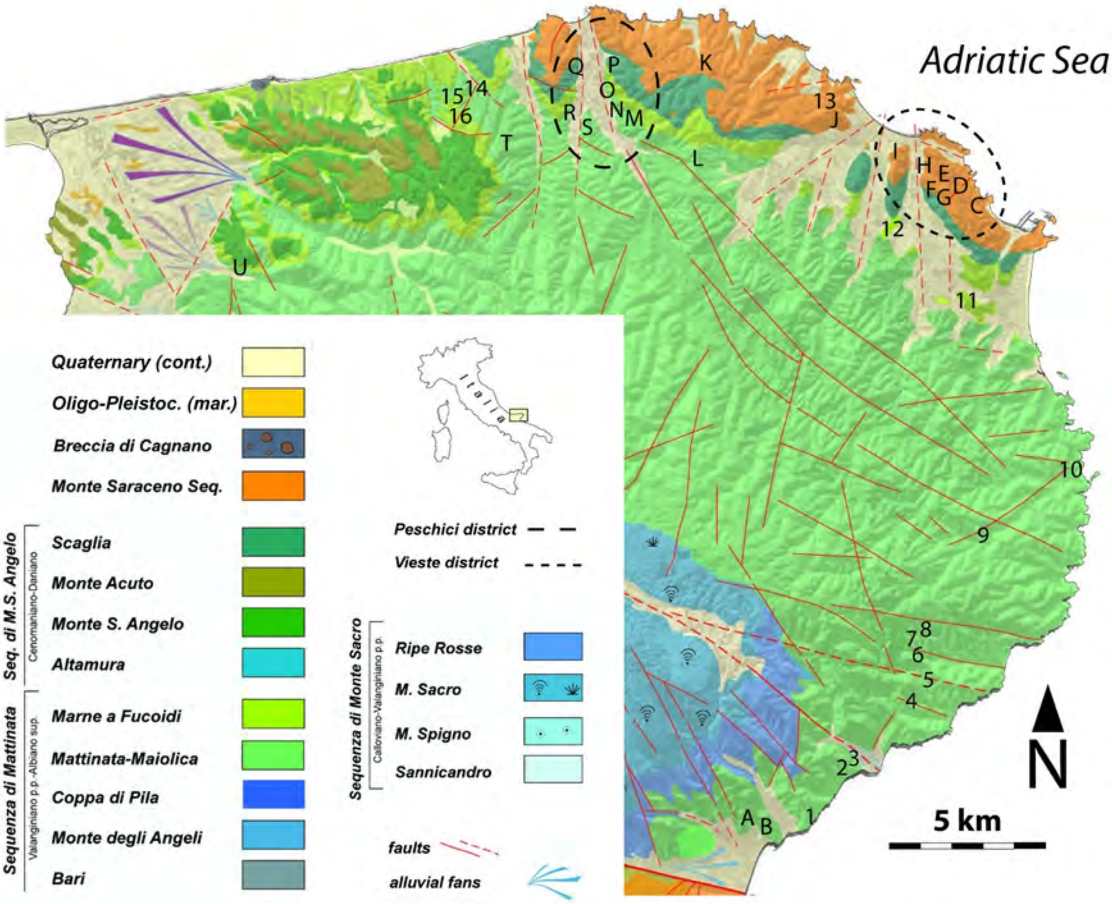

Fig. 1 – Schematic geological map of the Gargano promontory (from Morsilli, 2011, modified) and sample positions (see table 1 for the key).
Fig. 1 – Carte géologique schématique du promontoire du Gargano (d'après Morsilli, 2011, modifié) et localisation des échantillons (voir le tabl. 1 pour la légende).

covers an area of 4 km^2, with mines cut into the Scaglia and Maiolica formations. Here a series of mining complexes were found in the Ulso valley.

It is important to point out that the three exploited formations appear to differ significantly with regard to the morphology of the flint, though more detailed observations have yet to be made. In the mines that opened into the Nummulite limestone formation, flint generally seems to occur only in rather large lenticular nodules (often more than one metre in diameter). The situation of the Maiolica and Scaglia is different: the exploited flint primarily occurs as spherical and irregular nodules, only in some cases associated with lenticular lists (Martinetti structure 1, Cruci and Carmine).

Finally, a strong connection between the geology and the mining system should be stressed. During the sixth millennium BC the sub-horizontal mines were opened exclusively into compact formations (i.e. into the Middle Eocene limestone), which from a static point of view makes it possible to underpin the large cavities created by this type of mining technique. From the fifth millennium BC, vertical mining techniques were used in tectonised formations belonging to both the Scaglia and Maiolica formation. Therefore, a classic geological factor —i.e. the hardness of the host rock—is clear. In any case evidence that different extraction systems were preferred at different times enables us to rule out an interpretation in terms of rigid geological determinism.

FLINT SOURCES EXPLOITATION STRATEGY: MINING PRACTICES (M. T.)

In the sixth millennium BC on the Gargano promontory we exclusively find flint mines with entrances opening into the slope of a hill and developing sub-horizontally; only in a few cases do we also find occasional vertical accesses (fig. 2c: type A; fig. 3a-f). This type of mining gives rise, outside the mine, to large accumulations of mining debris, sometimes still preserved in their entirety.

The management strategies of this type of mining are well known thanks to the exceptional state of preservation of the Defensola mine (Galiberti, 2005), which is also the earliest mine in Neolithic Europe. It is still partially accessible, without the need for archaeological excavation, for an area of about 3,000 square metres (fig. 2b), though conditions are far from being optimal (the floor-

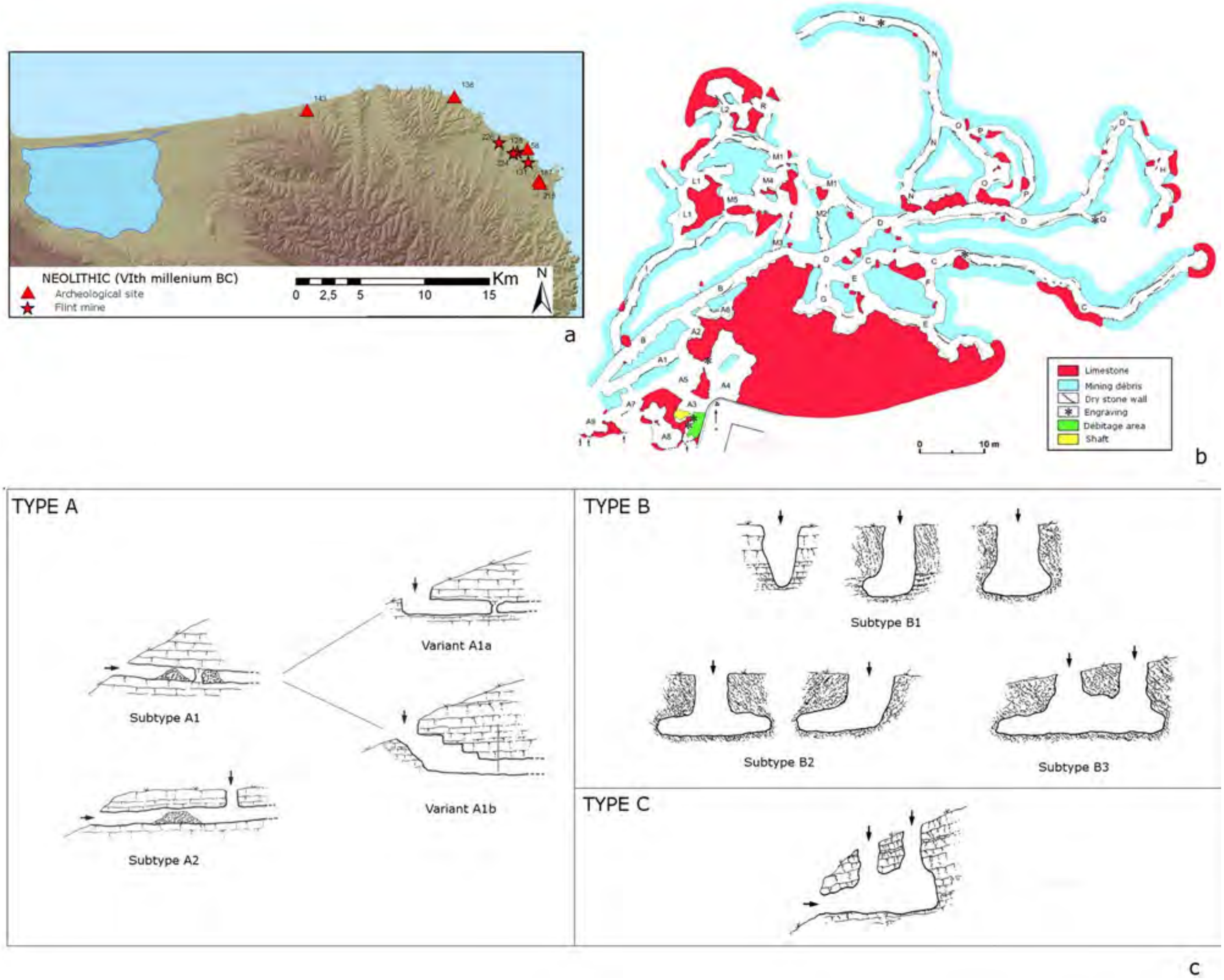

Fig. 2 – a: location of sixth millennium BC mines and sites; b: plan of Defensola A, mine no. 1; c: different mining systems in the Gargano (drawings A. Galiberti).
Fig. 2 – a : localisation des mines et sites datés du VI[e] millénaire BC ; b : plan de Defensola A, mine n[o] 1 ; c : différents systèmes d'exploitation minière dans le Gargano (dessins A. Galiberti).

to-ceiling height is always under 60 cm, requiring major logistical skills and a specific familiarity with this very special working environment). Neolithic materials were found inside in their functional positions (e.g. fig. 3a).

Overall, the mine is a large empty underground space filled with excavation debris. Among this debris there is an extensive network of corridors, often bounded by dry stone walls (fig. 3b), that lead to the mining faces (fig. 3d). The main corridor is 110 m long and was cut through previously accumulated debris heaped up to the ceiling, as indicated by the obstruction of previous corridors. This corridor reveals a reorganisation of the exploitation strategy for the mine and proves the long-term planning of activities.

The technique used to extract the nodules in the Defensola mine almost invariably entailed the use of a single model, i.e. the mining of individual seams starting from the top, resulting in an 'extraction step' indicating the removal of a flint nodule (fig. 3d).

The same techniques and morphological characteristics were observed in the other three mines of the sixth millennium BC (Arciprete, Defensola C, San Marco), which have the same floor-to-ceiling height, the same 'stepped' extraction (e.g. fig. 3c), the same plan of 'room-and-pillar' type and, at least in one case (Arciprete), comparable underground dimensions, known from geophysical surveys (Tarantini et al., 2010).

Thus, the Neolithic mines of the Gargano have at least three shared characteristics: first, the standardisation of techniques and the high level of skills required; second, the large size of individual mines; and third, the difficulty of moving around inside and hazardousness. All these facts lead us to suppose that the Neolithic mines were the domain of a small group of specialists, who also controlled the transmission of skills and, as a consequence, the access to the flint sources.

It is important to stress that the earliest Defensola dates were obtained from charcoals collected among the accumulated debris in deep parts of the mine; this shows that in the early sixth millennium mining was already advanced. These dates are among the earliest Neolithic dates for South-Eastern Italy, thus supporting

Fig. 3 – Some examples of sub-horizontal mining systems (type A). a, b, d: Defensola A, mine no. 1; c: S. Marco; e: Tagliacantoni; f: Martinetti, mine no. 1.

Fig. 3 – Exemples de systèmes d'exploitation minière subhorizontaux (type A). a, b, d : Defensola A, mine no 1 ; c : S. Marco ; e : Tagliacantoni) ; f : Martinetti, mine nº 1.

the hypothesis that the exploration and mining of lithic resources were part of the process of neolithisation itself.

In addition, the Gargano was unsettled during the Mesolithic and it was located along one of the supposed routes along which the Neolithic spread across Southern Italy, the 'bridge' formed by the Adriatic islands connecting Southern Croatia to Northern Apulia. In the current state of research the geography of the Early Neolithic landscape of the promontory shows that only the area exploited for flint was inhabited. Early Neolithic sites and mines are distributed along the coast in a well-defined area, and not a single site is present within a radius of about 25 km (site no. 143 in fig. 2a is very doubtful: see Pizziolo et al., 2011). This suggests an interpretation of the Neolithic mining area as an 'island' area and thus the establishment of maritime routes for the supply of Gargano flint, as is the case for the Mediterranean islands rich in obsidian (e.g. Perlès, 2001).

Neolithic mining techniques in the Gargano saw a radical transformation from the fifth and especially during the fourth millennium BC, when less specialised mining techniques are used almost exclusively. During this period we observe rather small mines compared to the Neolithic; they are characterised by vertical access to the flint-bearing formations, with or without horizontal digging at the base of the shafts (fig. 2c: type B and C; fig. 4a-d). Unlike other European mining contexts, in which the depth of the shafts implies difficulties of access, the shafts in the Gargano are not very deep; i.e. at most three and a half metres.

The horizontal excavation at the base of the shafts was of variable height, but, in any case, of very limited extent. These mines opened mainly into heavily tecton-

Fig. 4 – Some mines of type B. a: Carmine; b: Valle Guariglia I; c: Defensola B/P9; d: Finizia, shaft no. 3.
Fig. 4 – Exploitations minières de type B. a : Carmine ; b : Valle Guariglia I ; c : Defensola B/P9 ; d : Finizia, puits nº 3.

ised or crumbly formations, which make it impossible to carry out deep sub-horizontal mining safely. However, this technique is also documented in compact formations (e.g. Defensola B/7: fig. 4c), showing that we are dealing not only with a new technique adapted to rock formations with a different consistency but also with a more general and radical transformation of the nature of mining work.

At that time mining sites consisted of a set of different independent extraction units of small size. It can also be assumed that the digging was carried out quickly in structures with precarious stability. The know-how and the technical investment required were obviously much more limited than in the Neolithic and extraction potentially become accessible to everyone.

This significant transformation of mining techniques is associated with:

– a radical change in the settlement of the Gargano, as shown by the numerous sites distributed throughout the northern coast; this change is evident at the beginning of the fourth millennium BC, in association with the spread of the Macchia a Mare pottery (Pizziolo et al., 2011);

– important changes that are also related to the lithic production of the Gargano (with the emergence of a major production of ogival preforms, with bifacial retouch and a bi-convex cross-section) and to the exchange network in Southern Italy (for example with the end of large-scale circulation of obsidian) (see discussion in Tarantini, 2012).

In short, it is the whole technical lithic system that seems to have been reorganised, but it must be emphasised that in-depth studies on the technical systems of lithic production and on exchange networks are still lacking for the Gargano. In any case, the Gargano mines suggest a shift of the investment in energy and skills from one phase of the lithic chaîne opératoire to the other (using *chaîne opératoire* in a broad sense, from sourcing to consumption). This shift also invites us to consider the change in social status not only of the lithic production but also of the producers themselves: as a consequence of the lesser know-how required we can assume that during the fourth millennium mining activity lost social prestige. The question that remains is whether this loss of prestige of mining activities also implies a decline in prestige for lithic raw materials in favour of lithic or metal products.

THE ARCHAEOMETRIC CHARACTERISATION OF THE GARGANO PROMONTORY FLINT: THE STATE OF THE ART

An initial attempt to characterise the geological flint and to distinguish different flint mine groups through chemical analyses was carried out by a team from the Italian CNR led by Alberto M. Palmieri (D'Ottavio et al., 2000; D'Ottavio, 2001; Volterra et al., 2002). This study aimed to identify the chemical fingerprint of each flint type and then to identify the exchange network of tools supposedly made of flint stemming from the Gargano promontory. In order to try to identify each mine chemically ICP-AES chemical analyses were carried out on flint nodules recovered from seven of the Neolithic flint mines identified in the Gargano promontory which were dug into two different geological formations. Cluster and discriminant analyses carried out on nine trace elements (Al, Ba, Ca, Cr, Fe, Mg, K, Li and Ti) made it possible to divide the mines into two groups corresponding to these two geological formations. Moreover, it was also possible to identify the mines located within a same formation. Analysis was then carried out on some artefacts which had been sampled from two Early Neolithic sites in the Tavoliere area (Monte Aquilone and Ripa Tetta), located at a distance of about 50-80 km from the Gargano mines. In some cases flint samples were attributed to mines, in which flint nodules were exploited.

In the end, more than a decade after the previous study, we opted for a multiparametric approach when carrying out this new programme of Gargano flint characterisation. Such an approach was developed by Luedtke (1992) and applied to flint stemming from South-Western Germany (Bressy and Floss, 2006). This approach seems suitable, especially as an initial step, for the identification of the typical markers of Gargano flint.

SAMPLING STRATEGY (G. E., A. M., I. M. M.)

The new project carried out on the multi-analytical characterisation of Gargano flint adopted a variety of analytical methods in order to identify discriminant parameters obtainable with approaches that were as non-destructive, rapid and economical as possible.

The flint samples were taken from prehistoric mines and from accessible flint outcrops throughout the Gargano promontory. This approach made it possible to identify differences between the flints that were definitely mined and those that were potentially exploited in the past, in order to highlight the material parameters preferred by ancient craftsmen. As well as mine waste (i.e. archaeological samples), further outcropping flint (i.e. geological samples) from the mines was collected, to check lateral and vertical homogeneity. Some samples from Martinetti and Cruci mines and km 31A of the SP53 were collected from the same flint layer to assess lateral variability.

A total of one hundred fifty-one flint samples, representative of the three flint-bearing limestone formations (i.e. Maiolica, Scaglia and Peschici limestone), the ancient exploitation of which is demonstrated by mining indicators (Tarantini and Galiberti, 2011), and of a fourth formation (i.e. Fucoid Marls), which has hitherto not shown evidence of flint mining, were collected throughout the Gargano promontory. The following samples were analysed in more detail:

– a) eighty-five samples from Neolithic mines and production areas related to mines. Representative specimens of all the twenty known ancient mining districts were collected;

– b) nineteen geological samples from road sections to complement the sampling of flints from areas of an extensive formation such as the Maiolica, and from the Fucoid Marls formation, where no mining was identified;

– c) a further seventeen samples from the Maiolica formation were taken from the road section at km 31 of the SP 53 'Mattinata-Vieste' road (fig. 5): nine specimens from the same layer, one metre from one another, and eight specimens from eight layers arranged in a vertical sequence.

In total, eighty-nine samples (table 1) were collected from the Maiolica formation; forty-nine samples from the Peschici limestone formation; eight samples from the Scaglia formation; and five samples from the Fucoid Marls.

ANALYTICAL METHODS (G. E., A. M., I. M. M.)

Generally speaking, our analytical approach focused on the correlation between qualitative and quantitative data on petrography, colourimetry, reflectance/gloss, chemistry and mineralogy obtained from geological and archaeological flints from Northern Apulia.

The samples were analysed under a Leica MZ16 stereoscope (up to × 60). The macroscopic analysis was

Fig. 5 – The road section at km 31 of the SP 53 'Mattinata-Vieste' road: nine specimens from the same horizontal layer (a), at a distance of 1 m, and eight specimens from eight layers arranged in a vertical sequence, were recovered from the area highlighted here by the white rectangle and illustrated by two details (b-c) of the upper and the lower part.

Fig. 5 – La section de route à 31 km de SP 53 route de « Mattinata-Vieste » : neuf éléments ont été prélevés dans la même couche horizontale à 1 m de distance (a), et huit éléments proviennent de huit couches d'une séquence verticale, prélevés dans la zone indiquée ici par l'encadrement rectangulaire en blanc et illustré par deux détails (b-c) de la partie supérieure et inférieure.

formalised by describing the properties of the flint and cortex with pre-defined terms. We considered seven features for the flint portion, namely subcortex, texture, structure, fracture, colour, reflectance and gloss. A further five features for cortex, when present, were described (thickness, nature, induration, surface and boundary).

Flint texture was classified according to the Dunham (1962) scheme for limestone, as also proposed by other authors (Bressy, 2003; Bressy and Floss, 2006; Fernandes and Raynal, 2010). To provide an objective classification of structure we defined seven basic categories, which could be combined in the presence of complex structures. The figures 6 to 8 show the typical appearance of each basic structure category: homogeneous (inclusions < 10%), spotted, mottled, shaded, streaked, laminated (stripe thickness < 1 cm), banded (stripe thickness > 1 cm). We also attempted to categorise the fracture, distinguishing between conchoidal (curved breakage surface), subconchoidal (less curved breakage surface, no ripples) and uneven (faceted) fractures. For the samples which presented a cortex, we also reported the presence/absence of subcortex. The description of the cortex recorded the maximum thickness in mm, the nature (i.e. calcareous or siliceous) determined with an acid test (HCl 2%), the induration (i.e. hard or friable) tested with a steel knife, the feel of the surface (i.e. harsh, rough or smooth) and the boundary with the flint (i.e. sharp, clear or diffuse).

A series of colour and reflectance measurements were taken using a portable spectrophotometer (Konica-Minolta CM-2600d), which is both versatile and accurate. The CIE L*a*b* colour system was used instead of the traditional Munsell colour system because it has continuous numerical coordinates that can be easily processed with statistical techniques. Colour coordinates were taken using the standard illuminant D65 (Xe flash light source, UV included) on a measurement area of ∅ = 6 mm (observer angle = 10°). Each measurement was made considering the specular component included (SCI) and was replicated three times in the same position. The surface was cleaned with a 2% HCl water solution before the colour measurements. Three measurements were taken on the matrix portion of the flint to obtain the mean value reported in the table. When two or more colours could be distinguished with the naked eye, two or more series of colour measurements were carried out. It was not always possible to take colour measurements given the uneven geometry of the flint surface.

Measurements of gloss values were obtained with a Horiba IG-331 gloss checker (incident/reception angle = 60°; measuring area = 3 × 4 mm oval; light source = LED; wave length = 890 nm). Three measurements were taken on the surface of each measurable sample.

RESULTS (G. E., A. M., I. M. M.)

The macroscopic description of the flint samples provided a matrix of categorical and numerical data that were of help in understanding the distinctive features of the four formations investigated. Table 2 presents all the data collected, displayed in frequency diagrams in figure 9.

Cortex is present in all the samples from the Fucoid Marls and is fairly common in the flints from other formations. In the samples from the Peschici limestone its thickness exceeds 10 mm. The cortex/flint boundary is sharp in all the samples, except for those stemming from the Peschici limestone formation, where it is sharp only in 74% of samples, clear in 21% and diffuse in 5%. The cortex is prevalently siliceous in flints from the Maiolica (80%), Peschici limestone (92%) and Fucoid Marls (60%) formations, whereas all the cortexes in the samples from the Scaglia formation are siliceous. Some differences were also observed in cortex induration. 5% of the cortexes from the Peschici Limestone are friable and 95% are hard. In the case of the Maiolica formation 56% of the samples have a hard cortex and 44% a friable one. The outer surface of the cortex is mostly smooth for the Peschici limestone (84%) and Fucoid Marls (60%) formations, and fairly variable in the Maiolica samples (37% smooth, 34% rough and 23% harsh). The cortex/flint boundary is exclusively sharp for the Fucoid Marls, Scaglia and Maiolica (99%) samples and somewhat varied in the flints from the Peschici limestone (74% sharp, 21% clear and 5% diffuse).

Sub-cortex was only observed in some samples from the Fucoid Marls (20%), Peschici limestone (39%) and Maiolica (16%) formations, and never in samples from the Scaglia formation.

The texture of the flint is mudstone for 33% of the samples from Peschici limestone and the remainder are wackestone. 75% of Maiolica flints are wackestone. 80% of Fucoid Marls and 88% of Scaglia flints are also wackestone. Very few flints have a packstone texture. Some porosity was observed (table 2) only in a few flints from Martinetti and Cruci (Maiolica) .

Peschici limestone and Scaglia flints present prevalently conchoidal fractures, whilst those from the Maiolica and Fucoid Marls formations have almost evenly distributed conchoidal, subconchoidal and uneven fractures.

The structure of the flint differs markedly in the various samples. Only some Maiolica and Peschici limestone flints have a homogeneous structure (fig. 8, no. 11), with most being spotted and mottled.

The inclusions observed in the flints are mainly siliceous spheroids (up to 5 mm), typical of the spotted structure (fig. 7, nos. 5 and 7). In the mottled samples we observe silicified intraclasts of complex geometry (fig. 8, no. 6). These inclusions combine to form the mottled-spotted structure, quite common among the Maiolica samples (16%). The shaded structure (fig. 7, no. 8) is frequent, mainly in combination with the spotted structure in the Scaglia, Maiolica and Peschici limestone formations. Lamine and bars occur frequently in mottled-laminated and in spotted-laminated or spotted-banded structures, whereas only Maiolica presents a purely laminated structure (fig. 8, no. 2). Two of the forty-nine samples from

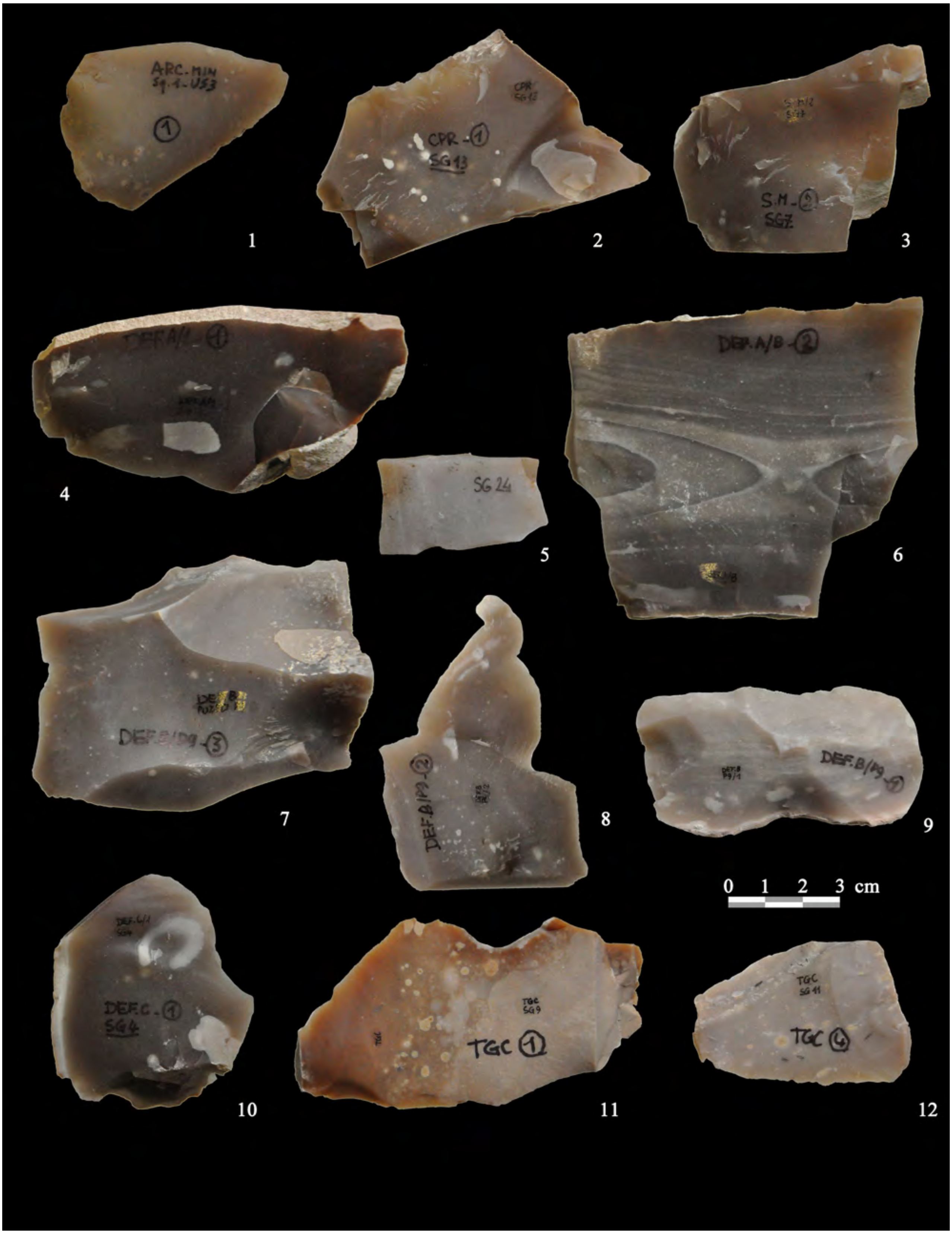

Fig. 6 – Representative flint samples from the flint-bearing Peschici limestone formation (Calcare di Peschici). 1: Arciprete mine; 2: Caprarezza mine; 3: San Marco mine; 4-6: Defensola A mine; 7-9: Defensola B mine; 10: Defensola C mine; 11-12: Tagliacantoni mine.

Fig. 6 – Échantillons de silex représentatifs des formations calcaires à silex des « calcaires de Peschici ». 1 : mine d'Arciprete ; 2 : mine de Caprarezza ; 3 : mine de San Marco ; 4-6 : mine de Defensola A ; 7-9 : mine de Defensola B ; 10 : mine de Defensola C ; 11-12 : mine de Tagliacantoni.

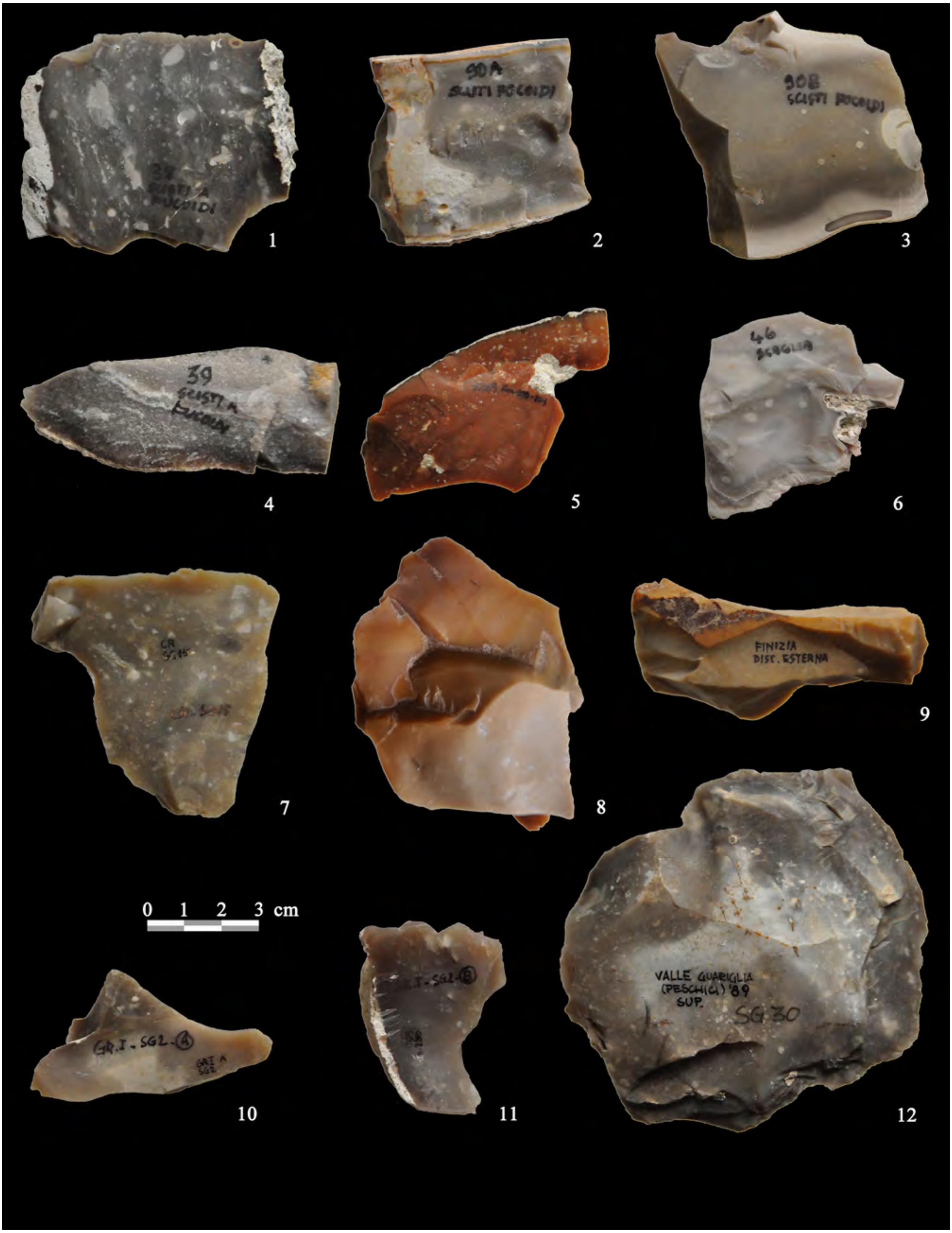

Fig. 7 – Representative flint samples from the flint-bearing limestone formations of the Fucoid Marls (1-5) and the Scaglia (6-12) formations. 1-5: geological samples taken from road sections; 6: geological samples taken at Fioravanti; 7-9: Finizia mine; 10-11: Guariglia I mine; 12: Valle Guariglia I mine.

Fig. 7 – Échantillons représentatifs de silex provenant des calcaires à silex de la formation des schistes à fucoïdes (1-5) et de la formation « Scaglia » (6-12). 1-5 : échantillons géologiques prélevés dans des profils des sections de route ; 6 : échantillons géologiques prélevés à Fioravanti ; 7-9 : mine de Finizia ; 10-11 : mine de Guariglia I ; 12 : mine de Valle Guariglia I.

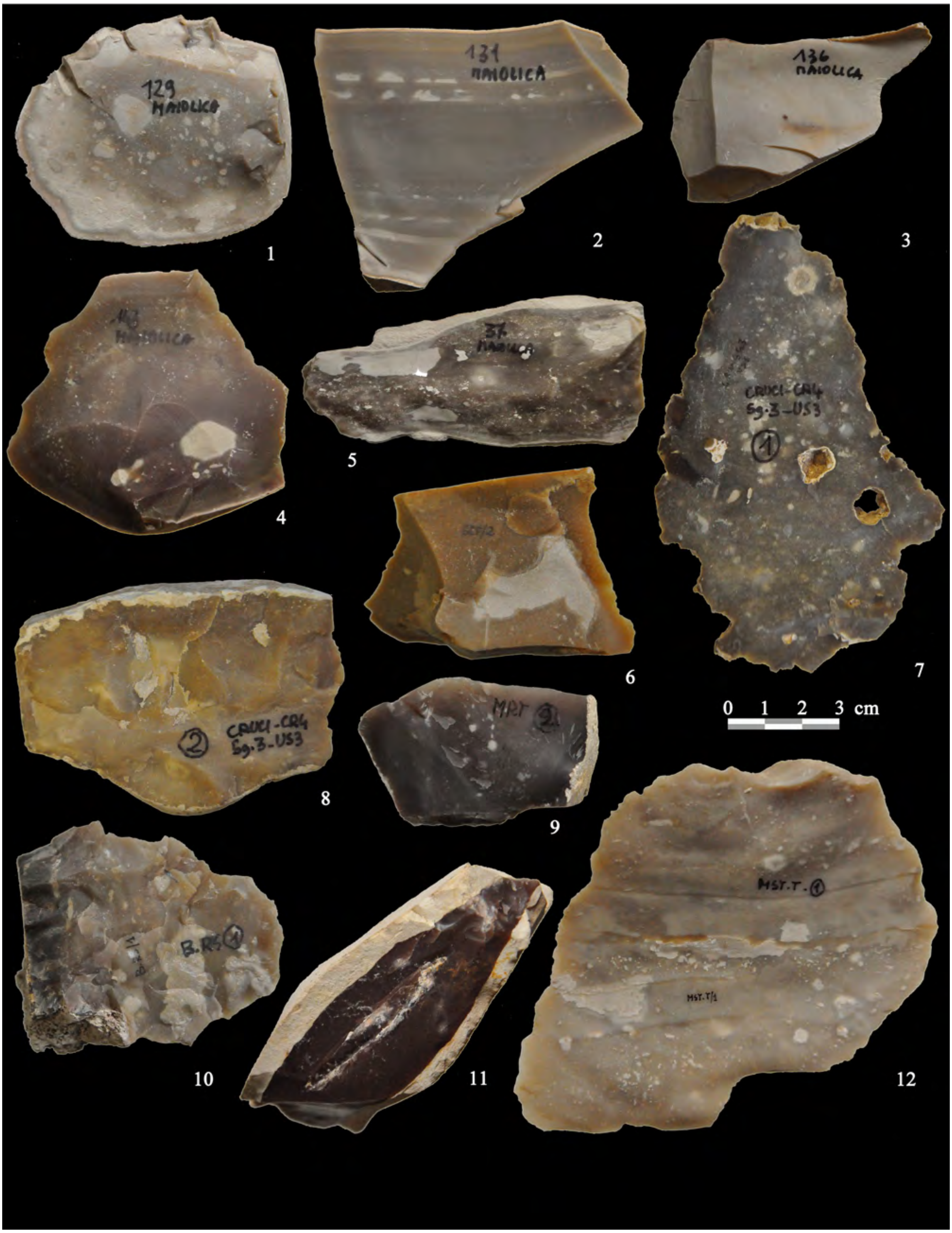

Fig. 8 – Representative flint samples from the flint-bearing Maiolica limestone formation. 1-5: geological samples taken from road sections; 6: geological samples taken at Scarcafarina; 7-8: Cruci mine; 9: Martinetti mine; 10: geological samples taken at Bosco della Risega; 11: Carmine mine; 12: Mastrotonno mine.

Fig. 8 – Échantillons représentatifs de silex provenant de la formation calcaire à silex de la Maiolica. 1-5 : échantillons géologiques prélevés dans des profils de section de route ; 6 : échantillons géologiques prélevés à Scarcafarina ; 7-8 : mine de Cruci ; 9 : mine de Martinetti ; 10 : échantillons géologiques prelevés à Bosco della Risega ; 11 : mine de Carmine ; 12 : Mastrotonno mine.

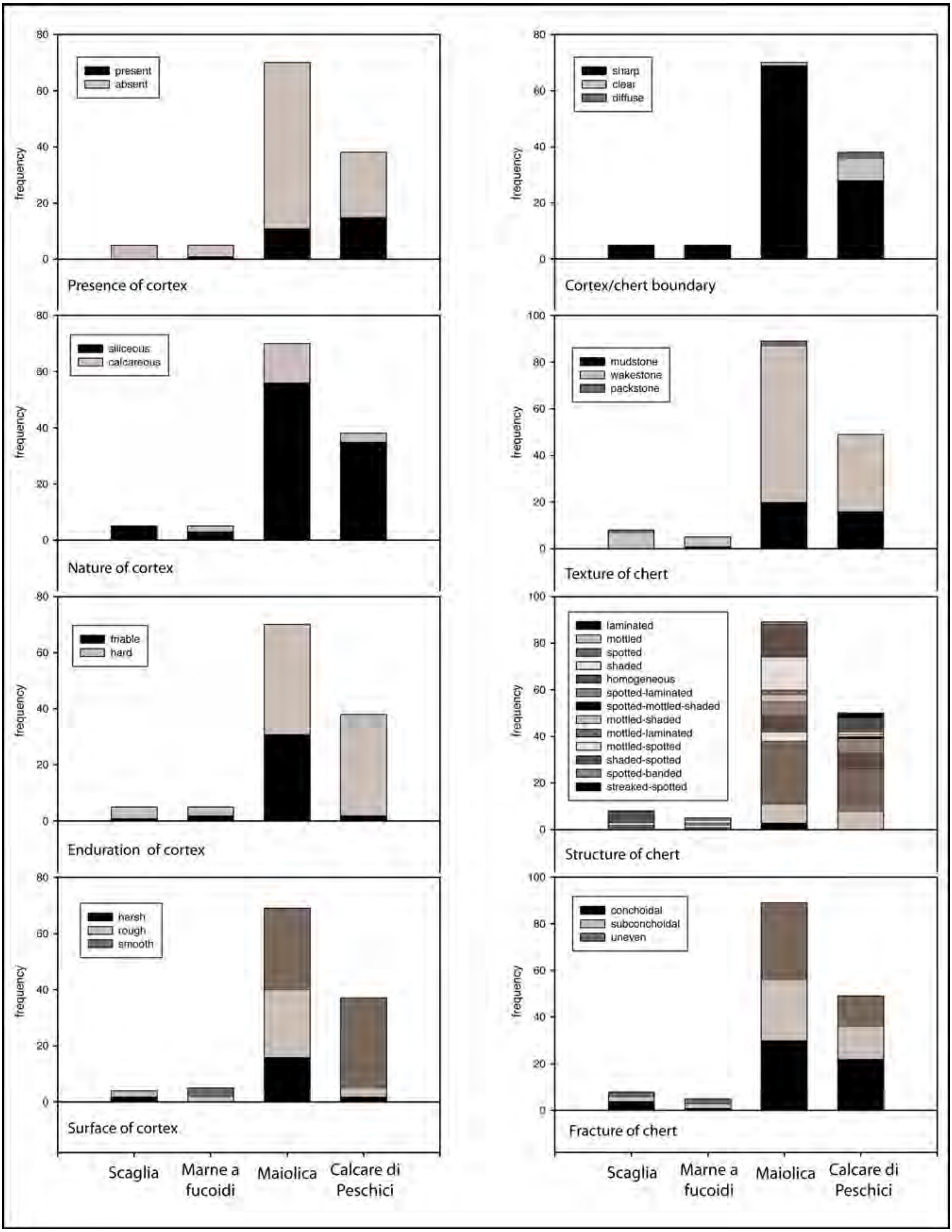

Fig. 9 – Frequency histograms of the macroscopic/petrographic data obtained from the geological and archaeological flints from the Gargano reported in table 3.

Fig. 9 – Histogramme des fréquences des données macroscopiques-pétrographiques des échantillons de silex géologiques et archéologiques de la région du Gargano mentionnés dans le tableau 3.

the Peschici limestone formation have the striped-spotted structure (fig. 6, no. 6).

Gloss measures on fresh fractures revealed very low values between 1 and 5 out of 100. The highest gloss values were recorded for some flints from the mines of Cruci, Defensola A and C, Martinetti, Arciprete, Tagliacantoni, Guariglia, Finizia and San Marco (table 2).

Spearman's rank correlation coefficient (ρ) applied to ordinal variables, such as gloss, fracture and texture (table 2), gives a nonparametric measure of statistical dependence between two variables. In figure 10, it can be observed that the positive correlation among these three variables is quite high, with a maximum between gloss and fracture ($\rho = 0.89$).

Spectrophotometry provided coordinates in CIE L*a*b* colour space (table 2) and reflectance in the visible spectrum (table 3) of the flint matrix. A representation of the colour coordinate of all the samples analysed, as a function of geological formation and output of cluster analysis run on colour coordinates and reflectance (see below), is provided in figure 11. Most of the samples present medium grey tones (around the origin of L*a*b* diagram, fig. 11) or yellowish hues. Two samples from the Maiolica (MRT 10 str, CR2/9) and one from the Peschici limestone formation (SG24) have a bluish colour.

Although the sample sizes from the Maiolica and Peschici limestone formations are larger, these samples present less chromatic dispersion than samples from the Scaglia and the Fucoid Marls formations (fig. 11). Extreme colours are those of SS89 (Fucoid Marls), Finizia (Scaglia) and Tagliacantoni (Peschici limestone).

In order to attempt correlation of the flints from the Gargano we processed the whole colorimetric and reflectance data set by running a cluster analysis. The three colorimetric coordinates (L*, a*, b*) and the thirty-one percentages of reflectance calculated for each wavelength in the visible range with a step of 10 nm (e.g. R%400, R%410, R%420, up to R%700) were used as untransformed variables. Ward's method as the clustering procedure with squared Euclidean distances as the measure of similarity was used. The output of cluster analysis shows two main groups (A and B) which are composed of very similar subgroups (A1 and A2, B1 and B2). Further hierarchisation was observed in subgroups B1 (i.e. B1a and B1b) and B2 (B2a and B2b). The cluster to which each sample belongs is indicated in table 3. Overall, cluster B is much more heterogeneous than cluster A. While the samples from the Scaglia and the Fucoid Marls formations are mainly dispersed in B subclusters, those from the Maiolica and the Peschici limestone formations are distributed throughout the dendrogram (table 3 and fig. 11). Even though the cluster analysis made it not possible to identify flints from different formations according to colorimetric and reflectance data, it highlighted some characteristic features of given outcrops or mines. As an example, the nine samples from the same layer of km 31 (SP 53, Maiolica) are in cluster A, those from the vertical sequence are dispersed in four clusters (table 3). Again for the Maiolica samples, ten of eighteen samples from Martinetti and those from Carmine (Mattinata) are in subcluster A1, whereas the twenty-five samples from Cruci are divided between clusters A and B. Equally, three of four samples from Valle Guariglia/Sbernia (Maiolica) are in subcluster A2.

Regarding the samples from the Peschici limestone formation, eleven of thirty samples from Defensola (mostly A and C), and the samples from San Marco and Caprarezza are in subcluster A1 (table 3). Another eleven samples from Defensola (mostly B) are in subcluster A2.

The main features of cluster B are the presence of the samples from Tagliacantoni (three in B1b, two in B2b), as regards the Peschici limestone, and the two samples from Finiza in B1b (Scaglia). In the case of Maiolica, five of twenty-six samples collected along the SP 53 road are in subcluster B1a, and another six in B1b as are four and eight samples from Cruci, respectively.

DISCUSSION AND CONCLUSIONS (G. E., A. M., I. M. M., M. T.)

This initial attempt to provide a non-destructive and unbiased approach to the classification of flint from the Gargano has achieved its aim of laying a foundation for further laboratory analyses. The macroscopic/petrographic characterisation of the Gargano flint also involved spectrometric, colorimetric and gloss analyses, able to supply a parametrical and numerical database useful for accurate classification. These preliminary data do not claim to offer an exhaustive picture of flint availability in the Gargano promontory, but attempt to provide a preview of the potential of our multi-parametrical approach. Our protocol considers a detailed description of the cortex, though this may not always be present in archaeological flints.

The two main mining districts hitherto identified by archaeologists, namely those of Vieste and Peschici, are cut into specific formations, with mines that sometimes exploit flint with different characteristics even within the same formation. Our sampling strategy aimed to increase knowledge of the features and homogeneity of the flints from the twenty Neolithic and Copper Age mines and the flint sources of the Gargano.

In the district of Vieste, which was active especially in the sixth millennium BC, only Calcare di Peschici flint was exploited (e.g. Defensola, Arciprete, San Marco). Mining techniques required particular skills such as only specialists have. The flint exploited seems to be only in large lenticular nodules. Cluster analysis of colour coordinates and VIS reflectance revealed strong affinities among the flints from Defensola A and C and the samples from San Marco and Caprarezza, and differences from those of Defensola B. These data seem to be confirmed by some petrographic features, such as the presence of cortex and sub-cortex alongside complex structures for Defensola B compared to those of flints from Defensola A and C and from San Marco and Caprarezza (table 3).

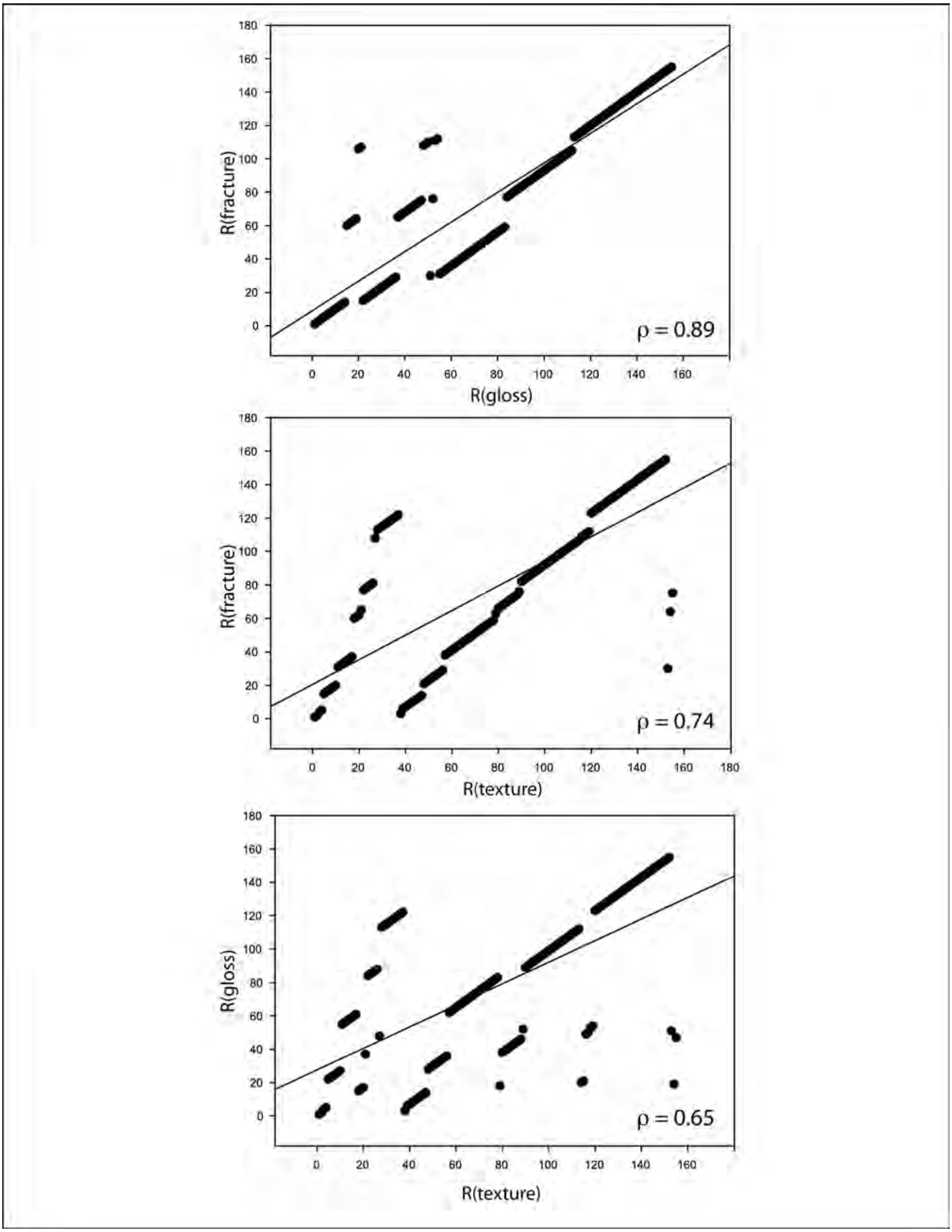

Fig. 10 – Scatter plots and Spearman's rank correlation coefficients (ρ) of the ranked fracture, texture and gloss variables.
Fig. 10 – Nuages de points et coefficients des rangs de corrélation de Spearman (ρ) des variables hiérarchisés fracture, texture et lustré.

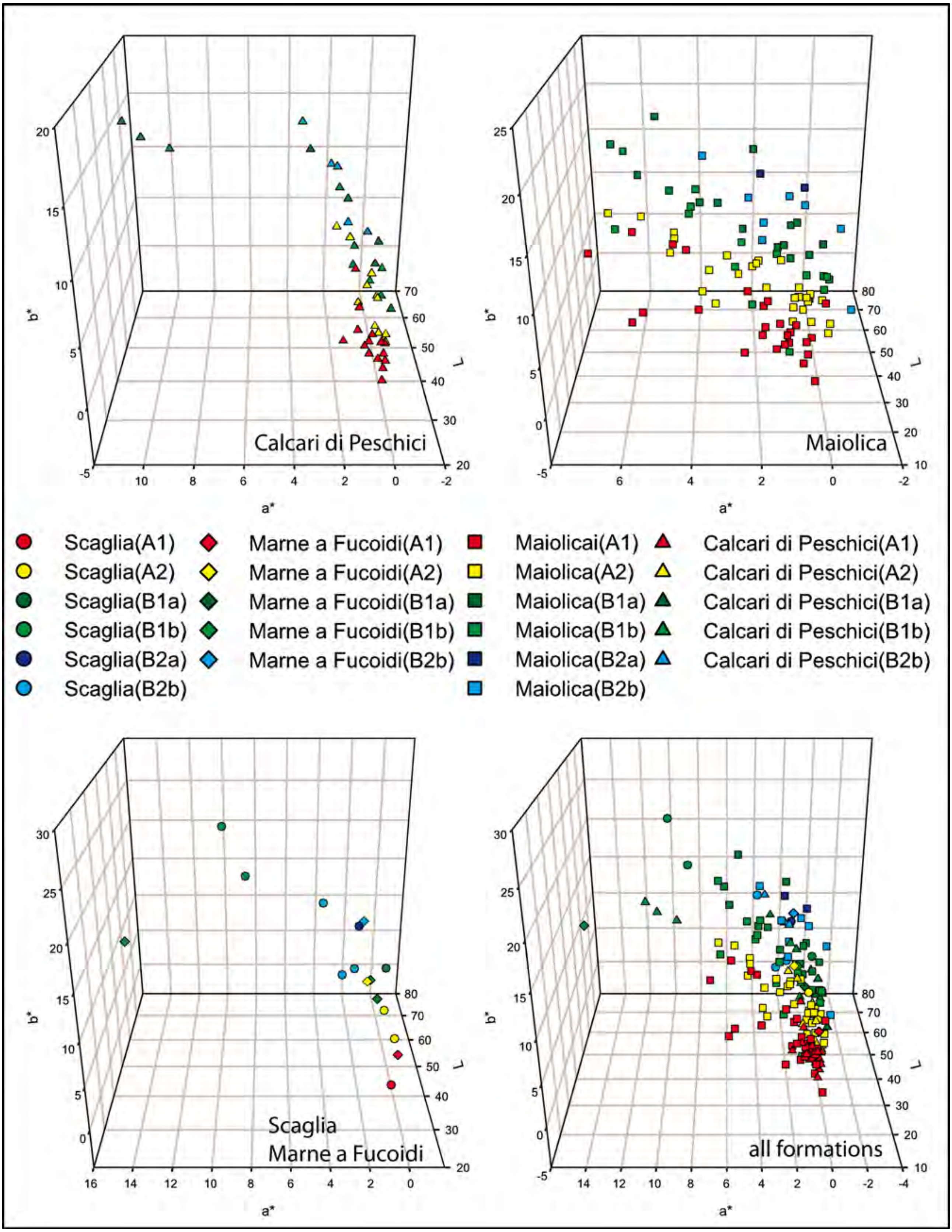

Fig. 11 – 3D scatter plots of Cie L*a*b* coordinates displayed according to their geological origin (glyph form) and colour/reflectance cluster (glyph colour).

Fig. 11 – Nuages de points en 3D des coordonnées Cie L*a*b* arrangées selon leur origine géologique (forme de la pierre) et distribution couleur/réflectance (couleur de la pierre).

The flint from Arciprete mostly falls into cluster B, but is macroscopically similar to that of Defensola A and C (cluster A).

As for the district of Peschici, it was active above all in the fourth millennium BCE with a lower technical investment than in the Neolithic mines. The flint exploited is that of the Maiolica and Scaglia formations and occurs primarily in spherical and irregular nodules, rarely associated with lenticular lists (Martinetti structure 1, Cruci and Carmine). The Cruci and Martinetti mines (Maiolica) present mainly spotted structures with some porous flint. Cortex is very thin or absent. Despite these petrographical similarities, the colour/reflectance classification for the Martinetti (cluster A) and Cruci (cluster B) samples is different. In the same area the samples from Valle Sbernia/Guariglia (Maiolica) present the same classification as Martinetti (cluster A), but have a characteristic calcareous and friable cortex (table 3). In the samples from Mastrotonno (Maiolica) a spotted-laminate structure is common. The Finizia and Valle Guariglia mines are in the Scaglia formation and are located north of the Peschici district. Although their flints have a spotted-shaded structure, those from Finizia (cluster B) are of a distinctive variable yellowish colour (fig. 7, no. 9).

Almost all the outcrops/mines located outside the two mining districts belong to the Maiolica formation (fig. 1). The flints of Bosco della Risega and Coppa di Rischio share similar macroscopic features and colour (cluster A). The Scarcafarina mine is located on the north-western side of the Gargano promontory. The samples present a variable structure and those with cortex are in colour/reflectance cluster A.

In the opposite south-eastern part of the Gargano we find the two mines of Carmine (fig. 4a), which yielded samples belonging to subcluster A1. The series of geological flints sampled along the SP 53/km 31 road (Maiolica) all have a thin cortex and variable texture, structure and colour. The km 31 samples present lateral homogeneity and vertical heterogeneity.

In the same area we sampled SS89 (Fucoid Marls) with a characteristic reddish colour (fig. 1, 5). Finally, the samples from Tagliacantoni (Peschici limestone), a mine located between the districts of Peschici and Vieste, are mainly spotted, with a characteristic orange hue.

No mines were found in the Fucoid Marls formation, though the quality of flint was similar to that in most of the mining sites in the other formations.

To sum up, flints with different features and quality coexist in each formation. However, we observed some chromatic homogeneity at site level (e.g. Defensola, Arciprete, Tagliacantoni for Calcare di Peschici, and Martinetti, Valle Sbernia/Guariglia, Bosco della Risega for Maiolica). This classification of chromatic and reflectance data confirms the similarities visible to the naked eye between most of the samples from the Maiolica and the Peschici limestone formations, which also turned out to be more homogeneous than the Scaglia and Fucoid Marls formations. However, the combination of petrographic and spectro-colorimetric data may be a helpful tool for identifying the provenance of flint artefacts. Though our interpretations must be tested using chemical and mineralogical data, we can state that our statistical approach using quantitative macroscopic data seems to be a promising way of classifying and correlating geological and archaeological flints from the Gargano.

FURTHER WORKS

The analytical strategy of adopting the same methodological approach to both geological and archaeological flints aims to create an internally consistent database for better correlation. As such, we planned to use non-destructive, or micro-destructive, methods, applicable to both flint categories without restrictions. Following the steps of the multi-analytical protocol, flints will be analysed with Raman spectroscopy to determine their mineralogical content, whereas the chemical composition will be obtained by LA-ICP-MS. A detailed micro-structural and palaeontological investigation will be undertaken using scanning electron microscopy, in order to distinguish among flint sources of different ages (as already proposed by Bertola, 2012 for the formations in Central-Northern Italy). Further, though the Gargano promontory is well known as regards the primary sources of flint, we believe that the characterisation of local secondary sources is of paramount importance for our understanding of exploitation trends in time and space.

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