Proceedings of the 2nd International Conference of the UISPP Commission on Flint Mining in Pre- and Protohistoric Times (Madrid, 14-17 October 2009)

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Cover figure: Last mining event at Casa Montero, Madrid (c. 5200 cal BC). Illustration by Juan Álvarez-Cebrián

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The impact of geological factors on flint minig and large blade production in the Betic Cordillera (Spain) in the 4th–3rd mill. BC

Antonio MORGADO and José A. LOZANO

Abstract

Siliceous rocks are abundant in the Betic Cordillera (Andalusia, Spain). These resources were used by human groups in the Late Neolithic and the Copper Age for manufacturing large flint blades (4th-3rd mil. BC), but their exploitation has not been studied systematically. The present work describes the geological background to flint exploitation in this region. The geological features of the areas with flint outcrops determined how readily raw materials could be found, which in turn influenced the mining techniques used. One group of exploitations (those of the Campo de Gibraltar Complex), set against a background of conglomerates and tectonic *mélanges*, involved the use of open air quarrying techniques. A second group, characterized by the continuity of the flint levels of the Milanos Formation (Middle Subbetic), required pit mining often be practised for the sought-after flint to be extracted.

Keywords

Flint mining. Large blade production. Copper Age. Betic Cordillera. Spain.

1. Introduction

Archaeological evidence indicates that a technical change in mid-sized and large flint blade production took place in southern Spain in the Late Neolithic (*c*. 3700 BC). The knapping methods and techniques used in this period are very different to those of the Early Neolithic (Martínez and Morgado 2005; Pelegrin and Morgado 2007) (Figure 1). Large blade craftsmanship remained a major human activity until well into the Copper Age, when such blades disappeared from the archaeological record alongside the dissemination of Beaker culture pottery (*c*. 2400/2300 BC).

The technical features of the blades from this period underline the need for highly selected raw materials, both in terms of quality and block size. The best flint outcrops in southern Spain were exploited intensely throughout the Neolithic, and a series of innovations in the blade production process made this region stand out from the rest of Europe (Morgado *et al.* 2008; Morgado *et al.* 2009). A number of flint mining sites associated with blade production have been located throughout the Betic Cordillera (Fernández Ruiz and Márquez Romero 1985; Vallespí *et al.* 1988; Ramos Muñoz 1997; Morgado 2002). However, there has been a dearth of petrological analyses of the raw materials they contain, and no archaeological survey has been conducted to document the mining activities associated with these sites.

The aim of the present study was to establish the geological characteristics of the flint outcrops known to date in southern Spain. This should help in the conceptualisation of the geological factors involved in the flint mining processes followed in the Betic Cordillera. This study is part of a wider research line on flint technology in southern Spain.

2. Geological context

The mining sites included in this analysis are located in the Betic Cordillera, in the south and southeast of the Iberian Peninsula. Three major geological units exist in the Betic Cordillera, established on the basis of lithological,

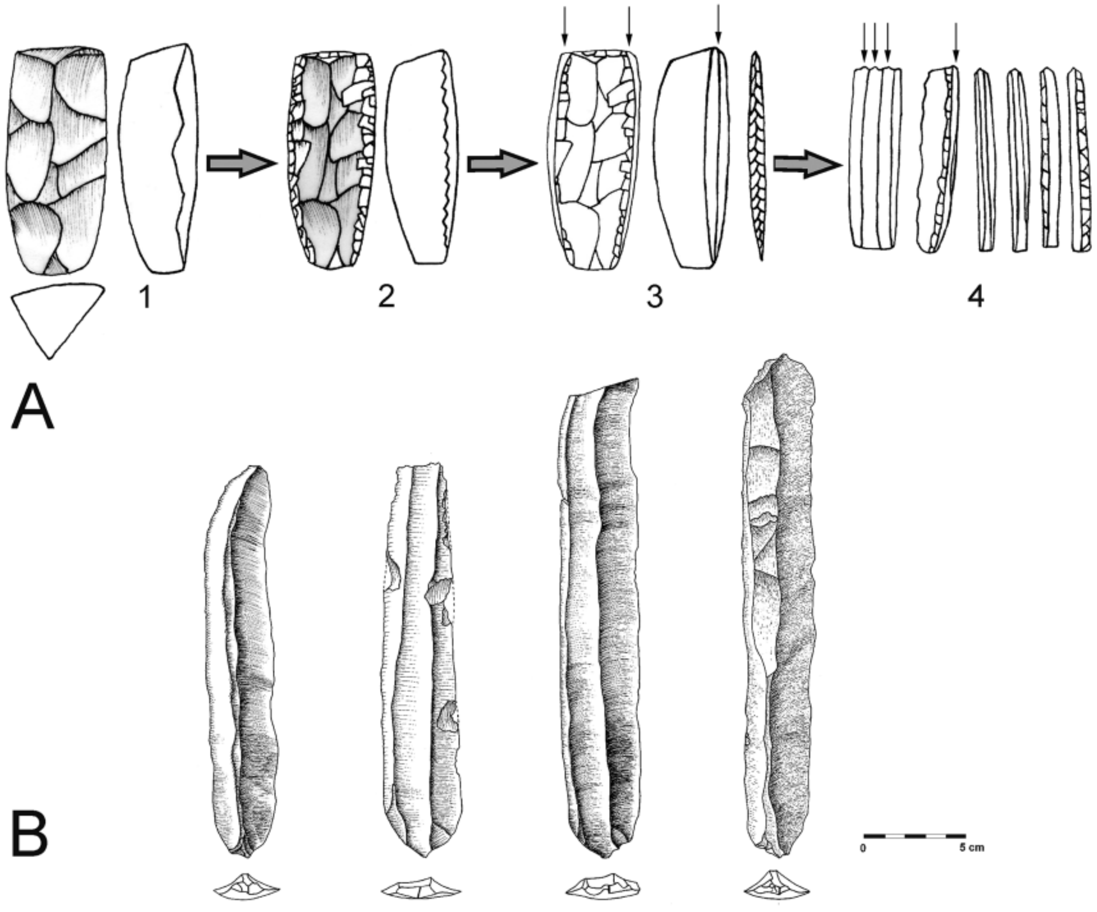

Figure 1. A. Method of blade making (Late Neolithic-Copper Age, southern Spain). 1 and 2: Preparation of core. 3: First extractions of crested blades. 4: Debitage. B. Large Blades from Cueva de Los Molinos (Granada Museum, Spain).

stratigraphic, petrological and structural factors (see Vera 2004 for a review): the External Betic Zone, the Campo de Gibraltar Complex, and the Internal Betic Zone. Each unit has its own subdivisions (Figure 2).

Two major tectono-stratigraphic settings make up the External Betic Zone: the Prebetic and Subbetic. The Prebetic area is located towards the north of the Betic Cordillera and consists mainly of quasi-autochthonous units with locally allochthonous subdivisions. The Subbetic area is composed of intensively deformed allochthonous units. The materials of the External Betic Zone were deposited at the southern Iberian palaeomargin during the Mesozoic and Cenozoic as a result of episodes of intracontinental fracturing, convergence and collision (García Hernández *et al.* 1980, 1989; Vera 1988, 2004). The Prebetic unit is composed of Triassic to Miocenic sedimentary rocks deposited at the southeastern edge of the southern Iberian palaeomargin. Sediments from shallow marine waters with short intervals of continental episodes prevail in the Prebetic area. Consequently, a profusion of detritic materials is found in this area. No flint mining sites associated with blade technology have to date been found in the Prebetic area.

The Subbetic unit covers the southernmost External Betic Zone and is composed of a sequence of sedimentary materials ranging from the Triassic to the Middle Miocene. In addition, pelagic facies are abundant starting in the Upper Lias. Volcanic and subvolcanic rocks have been also documented. The Subbetic unit has been divided into three paleogeographic subdomains: the External, Middle and Internal Subbetic subdomains. The External Subbetic domain expands throughout the northernmost section of the Subbetic area and is composed of Jurassic limestones and condensed facies depositions in boundary environments. Most of the Middle Subbetic subdomain is part of a subsiding sedimentary environment. Jurassic and Cretaceous marly facies are abundant. There are also interspersed volcanic rocks from the Middle and Upper Jurassic. The Internal Subbetic subdomain is located in the southernmost sector of the Subbetic unit, and possesses calcareous facies that were deposited in ocean-boundary environments during the Middle and Upper Jurassic, a period during which this subdivision was not actively subsiding. An additional subdomain with specific stratigraphic, paleogeographic and tectonic features - the Penibetic unit - emerges in the western sectors of the Betic Cordillera.

The Campo de Gibraltar Complex is located over the remaining units of the Betic Cordillera. It has a variable tectonic setting and is composed of a set of allochthonous units detached from their original substrate. It is unaffected by Alpine metamorphism. These units make up the Meso-Cenozoic cover that expands from the Middle-Upper Jurassic to the Lower Miocene. This cover is composed of deep marine facies made from clay and, to a lesser extent, marls. Siliciclastic turbidites (flysch facies) are abundant in the Campo de Gibraltar Complex, especially for the Lower Cretaceous and the period between the Upper Oligocene and Lower Miocene.

The Internal Betic Zone has traditionally been divided into three tectonically superimposed complexes: the Malaguide, Nevado-Filabride, and Alpujarride complexes (from top to bottom). They also incorporate a frontal unit (frontal units of the Internal Betic Zone) in contact with the Campo de Gibraltar Complex and the External Betic Zone. These frontal units are at the front of the Internal Betic Zone in the Central and Western sectors of the Betic Cordillera (between the Malaguide Complex and the External Betic Zone). External and internal frontal units can be distinguished according to their tectonic setting, stratigraphic features and facies (Martín-Algarra *et al.* 2004). The Malaguide Complex at the top is composed of a slightly metamorphosed or unmetamorphosed Palaeozoic basement of detritic material (Sanz de Galdeano 1997). Red Permic-Triasic detritic sediments, and a thin marine sedimentary layer of Liasic dolomites and limestones overlay the Palaeozoic basement. The remaining Jurassic and Cretaceous materials are mostly limestones or marly limestones with pelagic influences. According to Sanz de Galdeano (1997) three superimposed groups of units exist in the Alpujarride Complex: phyllites and quartzites, gypsum and basic igneous intrusions, and thick sections of dolomite or dolomitic marbles and limestones with metapelitic intercalations (from bottom to top). Bodies of peridotites are located at the base of some of the units. Most of the shale results from the Palaeozoic sediments under the influence of the Alpine orogeny, while the phyllites result from Lower Triassic sediments. Finally, the carbonates composing the cover have been dated to the Middle and Upper Triassic. The Nevado-Filabride Complex is the deepest tectonic unit and is composed exclusively of metamorphic rocks. Its stratigraphic sequences are similar to those of the Alpujarride Complex, although with a more ancient Palaeozoic basement (Precambrian) and a partly carbonated Triassic/post-Triassic cover.

3. Mining sites associated with the production of large flint blades

Flint mining sites from the Late Neolithic and Copper Age have been documented in the central and western sections of the Betic Cordillera between the Provinces of Granada and Malaga (Figure 2). Taking the geological units described above as a reference, these mining sites can be grouped into three distinct areas: the Middle Subbetic area, the

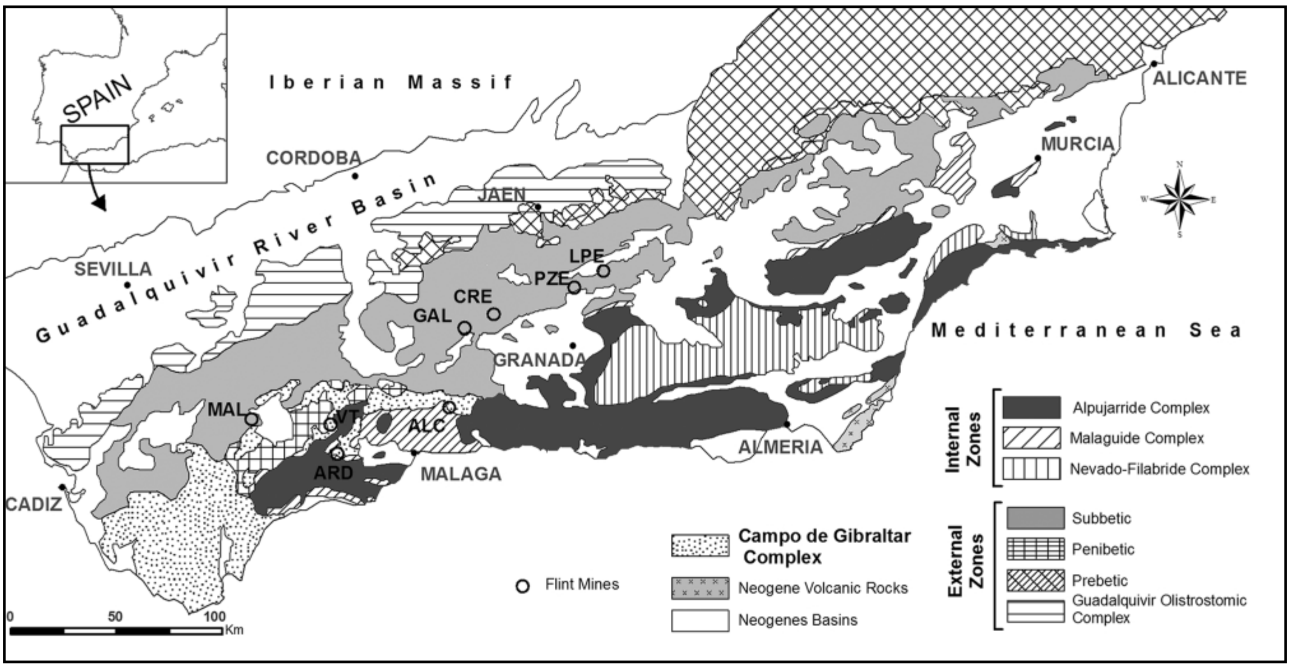

Figure 2. Geological map of the studied flint mines, southern Iberian Peninsula.

Campo de Gibraltar Complex, and the Malaver unit. The Middle Subbetic unit and Campo de Gibraltar Complex are part of the Neonumidian flysch.

a. Mining sites in the Middle Subbetic Zone

Scattered references since the early 20th century mention the existence of flint quarries dated to late prehistoric times in the Middle Subbetic Zone. Early findings were made in the vicinity of the towns of Piñar and Iznalloz (Obermaier 1934). However, no thorough analysis of these sites has ever been conducted.

The best known site is located in the Gallumbares valley (GAL-Loja, Granada). Since the 16th century, military engineers referred to this valley as Spain's largest quarry for gun-flint production (Morgado and Roncal 2009). The site has been studied by the Prehistory Department at the University of Granada (Morgado *et al.* 2001). Additional sites have been documented at Cerro del Reloj (CRE, Montefrio, Granada), Cortijo del Zegrí/Onitar (CZE-Iznalloz) and Loma de Los Pedernales/El Cuarterón (LPE-Iznalloz, Granada).

The flint found at these sites (GAL, CRE, CZE and LPE) comes from the calcicastites level (calcarenites and calcilimolites), which belongs to the Milanos Formation (Middle Subbetic; Molina and Vera 1996a, 1996b) dated to the late Jurassic (Kimmeridgian-Berriasian) (Molina *et al.* 2008). Levels with calcilimolites and calcarenites present structures of internal order including parallel lamination, hummocky cross-stratification and ripples. These structures are associated with storms affecting the bottom of a shallow ocean located away from the continent (Molina and Vera 1996a, 1996b).

The flint found at the Milanos Formation is of variable colour, with tones ranging from grey-white to grey-blue or even very dark grey. Microfacies show wakestone-packstones of peletoidal type with rounded quartz grains, iron oxide, sponge spicules and other bioclasts. Oolitic flint (grainstone) is also present.

b. Mining sites of the Neonumidian Formation in the Campo de Gibraltar Complex

These flint mining sites were first discovered in the 1980s as a result of several archaeological surveys. The nucleus of the mining resources is located in the Valle del Turón (Málaga). Additional mining sites are located at Ardite/El Garrotal (ARD) and Cerro Alcolea (ALC) (Ramos Muñoz *et al.* 1986; Espejo and Cantalejo 1989-90).

Our team has recently conducted a petrological analysis of the mining sites at the Valle del Turón (Lozano *et al.* i.p.). Eight sites have been identified in this area: La Galeota (GAL), Castillo del Turón (CTR), Canchal Herriza the Ram (CHC), Reconco (REC), Puerto de los Martínez (PLM), Espíldora (ESP), Cortijo el Pilar (PIL) and El Chorrito (ECH). Macroscopically, the flint from these sites is of a grey-black tone, semi-translucent, fine-grained and of homogeneous texture. According to the microfacies of the samples studied, this flint originated diagenetically from hemipelagites derived from limestone, mudstones and wackestones. Radiolarians, abundant sponge spicules, and, to a lesser extent, filaments and foraminifera dated to the Early and Middle Jurassic are present. Local dolomitization is observed frequently in the presence of idiomorphic and rhombohedral dolomite microcrystals ($<10\mu$). Phycosiphon and chondrite ichnotaxa have been identified by ichnological analysis, a new means of analysing archaeological flint that allows the non-destructive characterisation of samples (Rodríguez-Tovar *et al.* i.p.). Other mining sites of the Campo de Gibraltar Complex can be found throughout the Province of Malaga, such as Ardite/El Garrotal (Alozaina, Málaga) (Fernandez and Marquez 1985; Marquez *et al.* 2004) and Cerro Alcolea (ALC) in the upper Velez river valley (Ramos Muñoz 1997).

Together, all the above sites are part of the Neonumidian Formation (Martín-Algarra 1987; Martín Algarra *et al.* 2004), which is made up predominantly of clays and sandstones with some *mélange*-like features from the Miocene (Aquitanian-Burdigalian). Mesozoic and Tertiary materials are incorporated in varying proportions. In addition, flint blocks are found among the Mesozoic materials identified above. The Neonumidian lies primarily along the front of the internal areas. Therefore, the flint embraced by the *mélange* comes from the edge of the Internal Betic Zone (i.e., frontal units) (Lozano *et al.* i.p.). Thus, all mining sites in the Valle del Turón (LGA, CTR, CHC, REC, PLM, ESP, PIL and ECH), in addition to those of Ardite/El Garrotal site (ARD), are located near the outcrops in the External Frontal sections of the Internal Betic Zone (i.e., the Pereila type unit; Martín Algarra 1987). The Pereila unit has limestones and marly layers with Lower Jurassic flint, which provided the raw material exploited by Man.

The Cerro Alcolea site (LAC, Periana) is composed of thick conglomerate strata. The microfacies of these flints provide evidence of its connection with the External Frontal units of the Internal Betic Zone.

c. Malaver Formation mining site (Campo de Gibraltar Complex)

The mining site at the Malaver Formation (Ronda, Málaga) was among the first to be subjected to archaeological analysis (Vallespí and Cabrero 1980-81; Espin Canovas 1989-90; Aguayo and Moreno Jimenez 1998). Some scholars have regarded this site as 'the most important flint workshop in Andalusia' (Aguayo and Moreno Jimenez 1998, 111). However, the nature of its raw materials and their geological genesis have not yet been extensively studied.

The Malaver Formation emerges in the northwest section of the city of Ronda, between the municipalities of Montecorto (Málaga) and El Gastor (Cádiz) and is part of the

Campo de Gibraltar Complex. The unit is located near the Subbetic-Penibetic boundary overlying the Montecorto Unit, which in turn backthrusts over the Campo de Gibraltar Complex. The Malaver Formation is a chaotic clay unit also composed of clay blocks (Gutiérrez-Mas *et al.* 1991). The diversity of flint types found in this source provides an indication of the geological complexity of the Malaver Formation. This formation originated in the Lower Miocene and is composed of megabreccias packages, massive conglomerates hundreds of meters thick, giant blocks (e.g., Malaver mountain) from the Middle Subbetic (e.g., Sierra del Pinar), and scaly clays from the Campo de Gibraltar Complex. All these materials rest on top of the Permo-Triassic layer of the Montecorto unit (Gutiérrez-Mas *et al.* 1991).

The flint exploited by Man came from the conglomerates of the Malaver Formation. These conglomerates originated due to the dismantling of the sedimentary series of the Middle Subbetic. The Middle Subbetic series (e.g., Sierra del Pinar type) possesses marly silts and oolitic limestones along with flint from the Middle and Upper Lias. Martín-Algarra (1987) has also documented marls and radiolaritic marls intercalated with micritic limestones with flint, and filaments from the Dogger-Malm boundary. It should be noted that the raw materials for large blade production was primarily large oolitic flint nodules.

4. Mining types

The geological features of flint-rich areas determined how readily raw materials could be found, which in turn affected the mining technique of choice. In this respect, the tectosedimentary features of the different areas required mining systems different to those used at flint sources in the Middle Subbetic area and the Campo de Gibraltar Complex.

a. Mining sites in the Middle Subbetic (External Betic areas and Central Betic Cordillera).

The flint extracted at the four mining sites currently known in this area belongs to the Milanos Formation and has been dated to the Upper Jurassic (Malm: Kimmeridgian-Tithonian) (Vera and Molina 1996) (sites: Los Gallumbares, Cortijo del Zegrí/Onitar, Cerro del Reloj, and Loma de Los Pedernales/El Cuarterón). The Milanos Formation has marl and limestone levels that originated in a pelagic platform. The extension of the Milanos Formation strata, the integrity of the flint levels, and the abundance of flint nodules in this area made this geological unit highly attractive to human communities of recent prehistory. Flint sources were readily located and exploited by shafts (Figure 3).

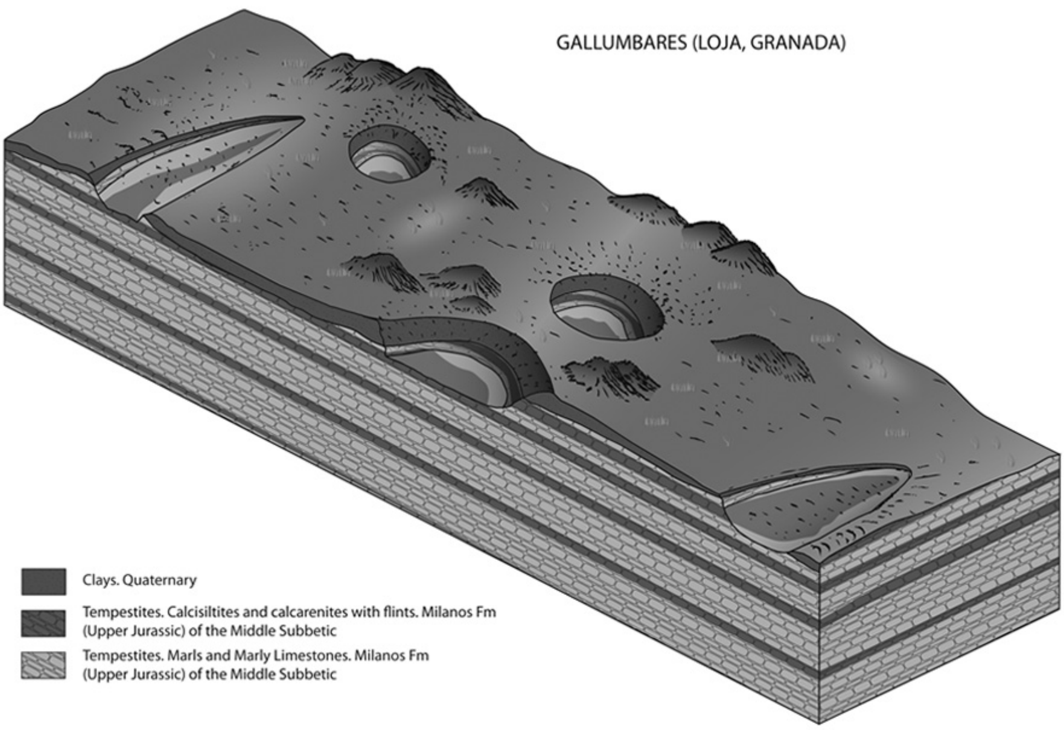

Figure 3. Model of flint exploitation, Milanos Formation (Middle Subbetic).

b. Mining in the Malaver Formation (Campo de Gibraltar Complex, western Betic Cordillera)

The mining activities here focused on extracting large flint blocks from the conglomerates and megabreccias. Conglomerates were taken directly from the Malaver mountain's cliffs via quarrying activities.

c. Mining sites of the Campo de Gibraltar Complex (Figure 4 and 5)

The Campo de Gibraltar Complex is paleogeographically composed of sedimentary Cenozoic materials deposited over the ancient oceanic crust. Large flint nodules have been extracted from conglomerates and *mélanges* in the mining sites in this area (Cerro Alcolea, Ardite/El Garrotal and the Valle del Turón: La Galeota, Castillo del Turón, Espíldora, Cachal H. Carnero, Chorrito, Los Reconcos and El Pilar). The flint found in the conglomerates (primarily *mélanges*) resulted from the erosion or dismantling of the frontal units of the Internal Betic Zone. The absence of continuous flint levels determined the need for quarrying activities and trenching for exploitation to be possible.

5. Conclusions

The geological characteristics of the flint outcrops in the south of the Iberian Peninsula influenced the strategies required for their exploitation. From the record of the fifteen mentioned exploitations linked to flint blade production, it can be concluded that the background to one group of exploitations involved conglomerates and tectonic *mélanges*. The impossibility of predicting the size and quality of their flint nodules predetermined the use of open air quarrying techniques. This behaviour was based on opening large areas to locate and select the best nodules for the production of large blades. This extensive quarrying was also favoured by the steep geomorphology of the Malaver and the Campo de Gibraltar exploitations. The background of a second group is characterized by the continuity of flint levels based on the alternation of the marl and limestone of the Milanos Formation (Middle Subbetic). In addition,

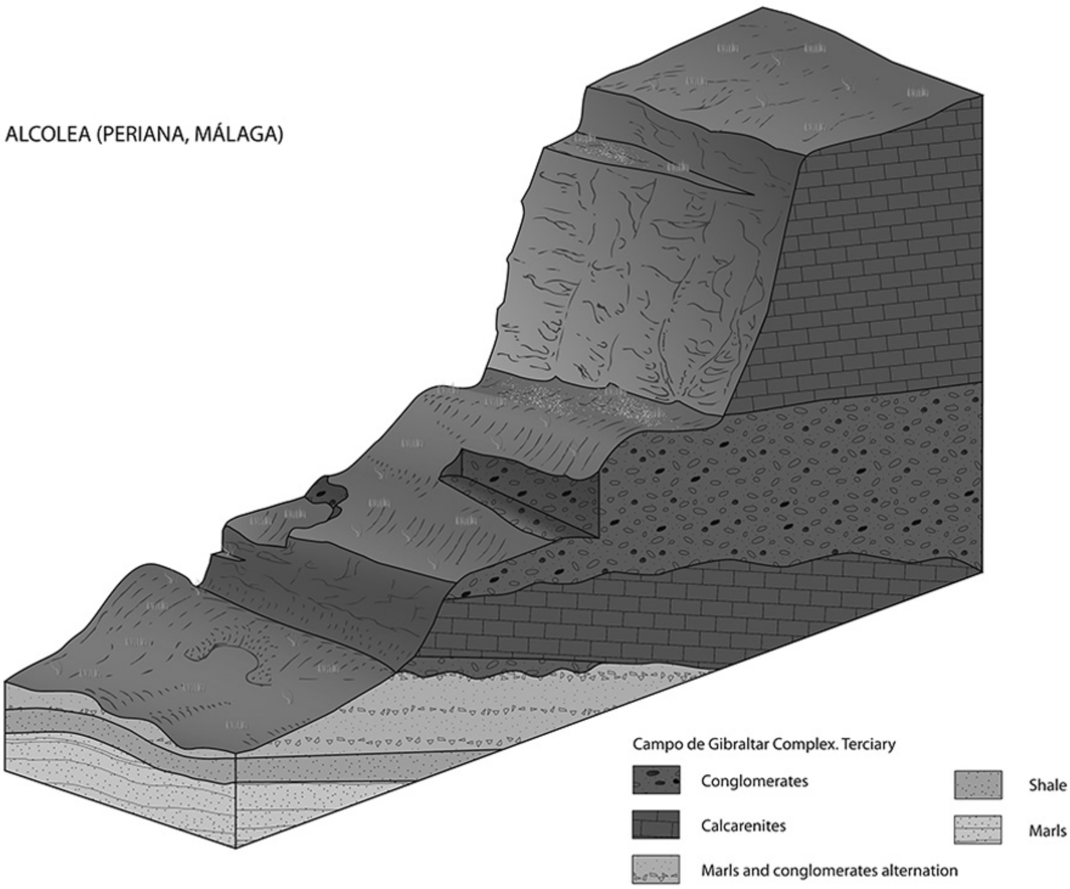

Figure 4. Model of flint exploitation, Campo de Gibraltar Complex (Alcolea conglomerate).

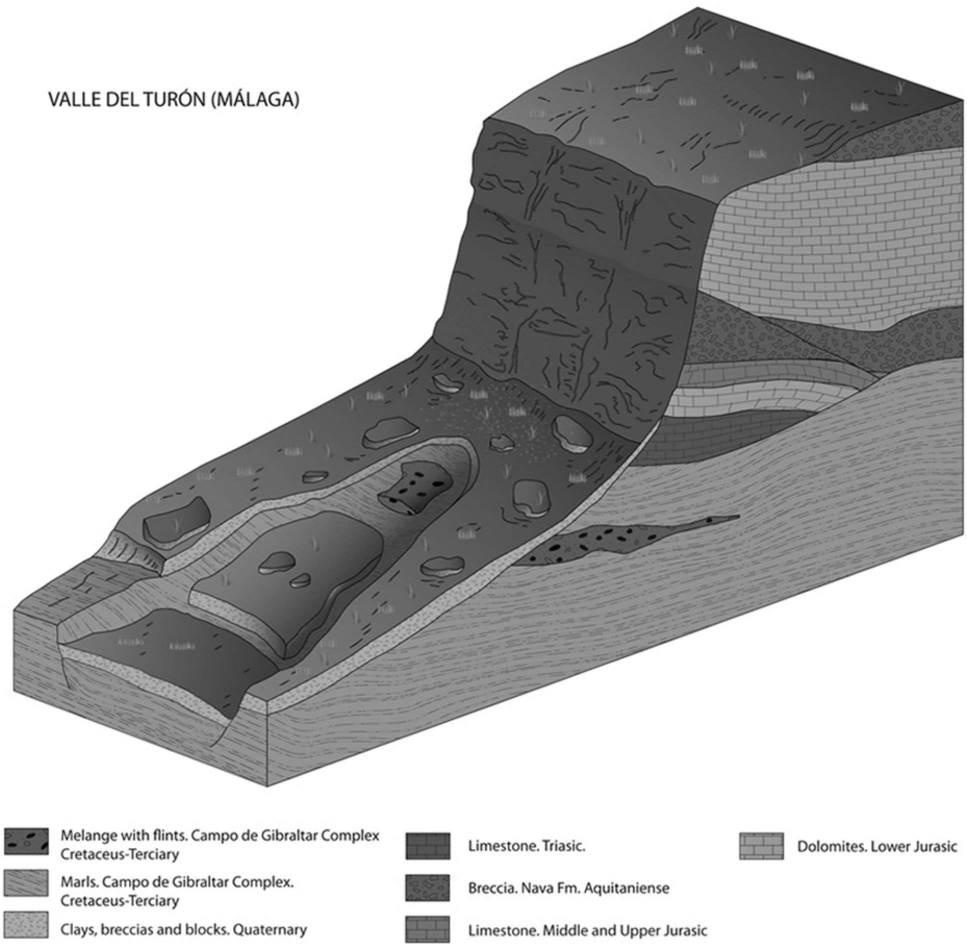

Figure 5. Model of flint exploitation, Campo de Gibraltar Complex (Valle del Turón mélanges).

the Milanos Formation has a smoother geomorphology. This facilitated the location of large nodules of flint by pit mining.

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