

Raw material and provenance identification of Late Neolithic and Chalcolithic chert artefacts from Drakaina Cave, Kephallonia, through petrographic and geochemical analysis

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Abstract

Although visual morphological characteristics (colour, lustre, fracture, patina or inclusions) are often similar among chert raw materials, petrographic and geochemical studies of outcrops can help in the identification of the original source used for artefacts found in prehistoric sites. This chapter focuses on the detailed mineralogical, petrographic and geochemical study of ten pieces of chert from the Neolithic layers at Drakaina Cave on Kephallonia. The chert assemblage was compared with 16 natural chert samples collected from six outcrops across the island. This analysis has allowed us to document a number of chert types on Kephallonia, some of which are likely to have been the sources used by the Neolithic inhabitants of the cave. In addition to identifying the sources of chert in use across the island, this study also investigates raw material collection and quarrying activities, as well as the distances over which they were transported. Thin and polished sections of artefacts and natural outcrop samples were mineralogically studied using optical and scanning electron microscopy, as well as X-ray diffractometry. For trace and rare earth element identification, 26 chemical analyses were undertaken using inductively coupled plasma and inductively coupled plasma-mass spectrometry. Microscopic examination and X-ray diffractometry of the four naturally occurring chert types (grey, black, brown and red) as well as the archaeological samples identified microcrystalline quartz as the main mineral type. Other minerals observed, although only locally and in small concentrations, included calcite, pyrite and iron hydroxides (goethite), along with microfossils in all cases. Variation amongst the natural and archaeological samples could not be defined visually. Determination of the sources was primarily made on the basis of the geochemical study and in particular the rare earth element analysis. We conclude that the raw materials used to make all ten of the pieces from Drakaina were derived from four specific geological outcrops on Kephallonia, including Megali Rachi hill, Anninata, Skala and Sami.

Introduction

Chert is a tough and usually dense or compact, dull to semi-vitreous natural material which breaks with a splintery or conchoidal fracture and is suitable for transforming into tools (see Nockolds *et al.* 1978: 291; Moorhouse 1985: 383; Andrefsky 1998: 17). In structure it is homogeneous and comprised of microcrystalline or cryptocrystalline quartz (SiO₂). It occurs in a wide variety of forms and is commonly found in limestone and dolomite, as well as in other sedimentary rocks such as argillites, shales and sandstones, where it forms layers and nodules. Chert also appears as pockets and interbeds within pillow lavas and tuffs, or as the latest alteration product of volcanogenic epithermal systems covering extensive zones. Flint is a variety of a dark coloured chert which occurs commonly as nodules and bands in chalk (Sieveking *et al.* 1972: 153, 155; Moorhouse 1985: 385). The term flint was originally applied to the high quality black cherts found in Upper Cretaceous chalk formations in England.

Chert artefacts, like all chipped stones, comprise the most long-lived cultural materials (Runnels 1994: 163; Della Casa 2005: 221). Therefore, their study is significant in our understanding of aspects of prehistoric life and behaviour. The identification of raw materials used for the manufacture of lithic artefacts, particularly the recognition of their sources, contributes significantly to our knowledge about the patterns of environmental exploitation and material acquisition in prehistory. Moreover, they provide evidence for the existence of exchange networks and interaction between prehistoric communities. Although visual morphological characteristics such as colour, lustre, fracture, patina and inclusions are often similar amongst chert (Crandell 2005: 140), detailed petrographic and geochemical study of outcrops can often allow the geological sources of material used

in the manufacture of artefacts to be identified (see Craddock *et al.* 1983; Hess 1996; Malyk-Selivanova *et al.* 1998; Dimitriadis & Skourtopoulou 2003; Lyons *et al.* 2003; Crandell 2005; Bressy *et al.* 2006).

Lithics and other stone artefacts from Drakaina Cave

Numerous chipped stone artefacts of chert were recovered from the Middle and mostly the Late Neolithic (ca 5,600–4,800 cal BC), as well as the Chalcolithic (ca 4,800/4,500–3,700 cal BC) deposits at Drakaina Cave on the island of Kefhalonia (Fig. 1). The cave is located within a steep gorge, close to the small coastal village of Poros in southeastern Kefhalonia (Fig. 2). Drakaina was systematically investigated by the Ephorate of Palaeoanthropology-Speleology in 1992–1996, 1999–2002 and 2004–2005 (see Chatziotou *et al.* 1995; Chatziotou 2007; Stratouli 2007) (Figs 3–4). The cave is situated at an altitude of approximately

70masl and has an internal area of less than 100 square meters. Based on the radiocarbon dating (see Stratouli *et al.* 1999; Stratouli 2005), Neolithic activity began during the 6th millennium and continued until the beginning of the 4th millennium cal BC (Fig. 5). The cave continued to be used sporadically into the mid-3rd millennium cal BC (Early Bronze Age II), followed by a long hiatus. From the late 7th century BC to the beginning of the 2nd, the cave was used as a votive site dedicated to the Nymphs (Chatziotou 2007). It was again abandoned until recently when it was used as a sheepfold.

The Neolithic layers have produced large numbers of lithic artefacts, including over 550 chert tools and 12,000 pieces of debitage, indicative of on-site knapping (Figs 6–7). There were also approximately 90 artefacts made from Melian obsidian (Stratouli 2005; Andreassen forthcoming). Likewise, there were significant numbers of ground stone implements, with almost 440 pieces used for a variety of tasks including the working of chert, food preparation and pigment processing (Fig. 8) (Bekiaris forthcoming). In addition, there were a number of stone ornaments and other



Figure 1. Satellite image of Kefhalonia Island and its environs (© NASA) showing the location of Poros



Figure 2. Satellite image of Poros and surrounding area (© Google earth) showing the location of Drakaina Cave on the cliffs of the Vochynas Gorge, from the northeast (Drakaina Cave archive)



Figure 3. Drakaina Cave: state of the excavations in its western part since 2005, from the east (Drakaina Cave archive)



Figure 4. The eastern part of Drakaina Cave during the excavations of 2004, from the northwest (Drakaina Cave archive)

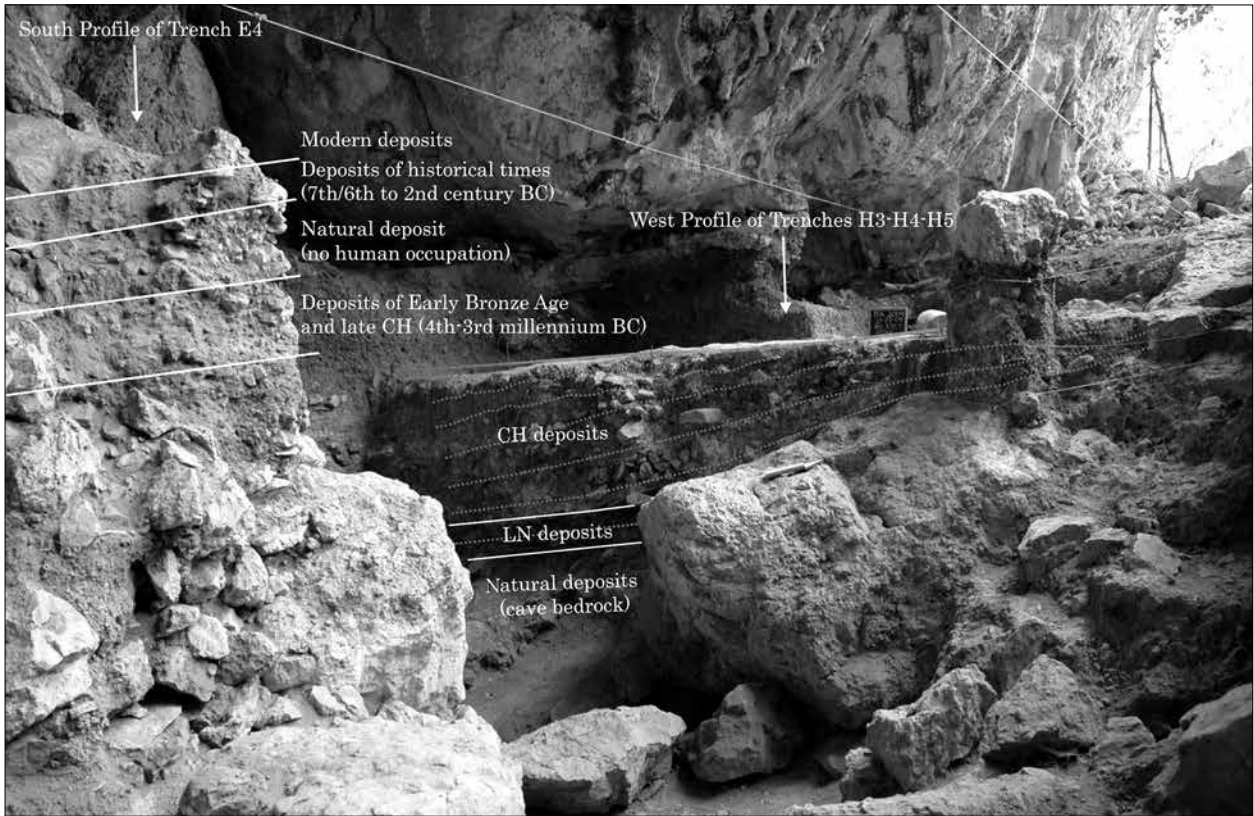


Figure 5. The stratigraphic sequence in the western part of Drakaina Cave, from the east (LN Late Neolithic, CH Chalcolithic)

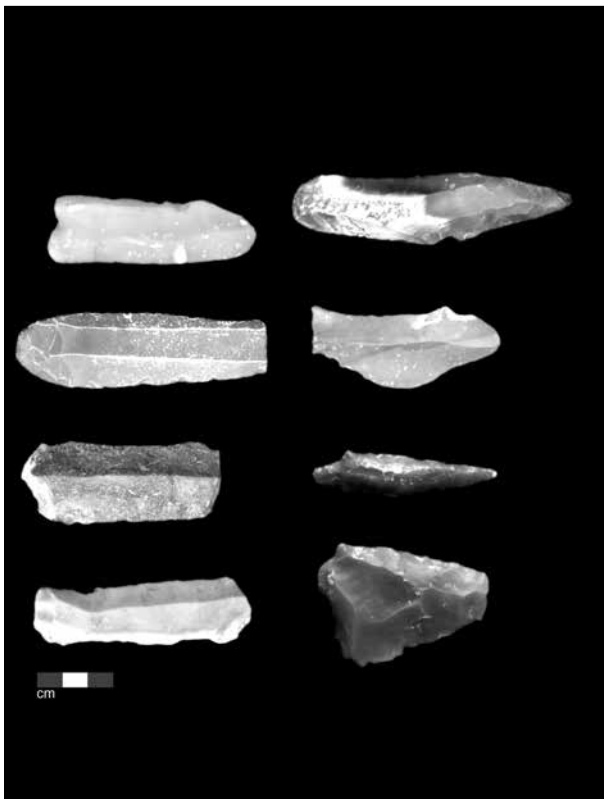


Figure 6. Various chert artefacts from Late Neolithic and Chalcolithic layers of Drakaina Cave

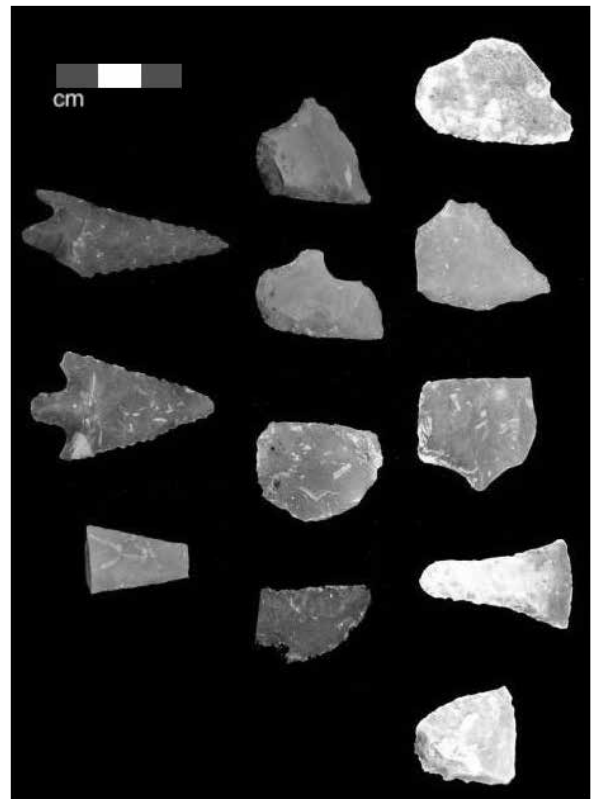


Figure 7. Several types of Late Neolithic and Chalcolithic chert projectile tips from the tool-kit of Drakaina Cave

small special purpose or high value stone objects. There were also several medium to small stone celts made of gabbro (Fig. 9), cylindrical and discoid beads (Fig. 10), as well as button-like ornaments made of talc (Fig. 11). All of these were transported onto the island from the Greek mainland, probably through inter-regional exchange networks (Stratouli & Melfos 2008: 385).

The chipped stone assemblage from Drakaina consisted of complete or fragmentary pieces, including projectile points, scrapers, blades and bladelets, as well as the by-products of on-site knapping, cores, chips,



Figure 8. A variety of ground stone implements from Late Neolithic and Chalcolithic deposits at Drakaina Cave



Figure 9. A cutting edged tool from Drakaina Cave made out of gabbro, a rock type transported onto the island of Kefhalonia

chunks and flakes (Stratouli 2005; Stratouli & Metaxas 2008; Andreasen forthcoming). The numerous flakes found in the cave indicate that raw materials were mostly being introduced as nodules or pebbles. Sourcing of these raw materials provides important information about the degree of exploitation of particular chert resources by the Neolithic occupants of the cave, both in terms of raw material acquisition as well as tool use.

Chert is very common on Kefhalonia and occurs either as layers and nodules within Mesozoic to Tertiary limestone or as reworked pebbles in Pliocene to Holocene sediments. However, the actual sources of these raw materials have so far only been hypothetically discussed and tentative suggestions made as to their origin (Marinatos 1960: 42; Kavadias 1984: 134; Matzanas 2000: 3; Foss 2002: 98, 99, 106, 108; Stratouli & Metaxas 2008: 315; Andreasen forthcoming).

The present study focuses on the detailed mineralogical, petrographic and geochemical analysis of ten chert artefacts recovered from the Late Neolithic and Early Chalcolithic layers from within the cave, dated to between the mid-6th to mid-5th millennia cal BC. Preliminary inspection of chert from the site, based



Figure 10. Cylindrical and discoid beads made of talc, a material not found on the island of Kefhalonia



Figure 11. A button-like ornament made of talc (right) amongst other beads made of shells and talc

mainly on colour, suggested the presence of four to five main varieties, along with other exotic types (Foss 2002: 82–83; Stratouli & Metaxas 2008: 315; Andreasen forthcoming). In terms of linking this material with potential sources, the obvious starting point was to investigate those outcrops or deposits closest to the cave. The archaeological chert samples were compared with 15 from natural geological sources at six locations on Kefhalonia. This has allowed us to locate the sources of raw materials used for the manufacture of artefacts at Drakaina, to investigate how they were collected or quarried, to define their characteristics and, finally, to identify the networks by which they were transported to the cave.

The geological setting

The island of Kefhalonia is characterised by extensive deposits of exposed Cretaceous limestone (Figs 12–13) belonging to two geotectonic zones of the External Hellenides: the Ionian and the Paxos or Pre-Apulian zones, deposited at the margin of the Apulian plate (see British Petroleum Co *et al.* 1985; Lekkas *et al.* 2001; Van Hinsbergen *et al.* 2006). During the Mesozoic, the area was covered by the Tethys Ocean as part of the Alpine geosyncline. By the end of the Mesozoic, a period of intense crustal movement began, influencing the whole of the Tethys region. The Ionian Islands, including Kefhalonia, emerged gradually as a result of these tectonic movements, which still continue today (Van Hinsbergen *et al.* 2006: 475, 481).

The Ionian and Paxos or Pre-Apulian zones are separated by a major thrust that transects several Ionian Islands. The Ionian zone which occurs in southeastern Kefhalonia is represented by various types of limestones (calcitic and dolomitic), as well as shales and breccias of Upper Triassic to Eocene age (200–40Ma). Intercalations of multi-coloured layers and nodules of chert within limestone strata often occur. The rocks of the Paxos or Pre-Apulian zone which cover the major part of the island were deposited from the Lower Cretaceous (141Ma) to the Upper Miocene (7Ma). They consist mainly of pelagic to reefal limestones which include chert beds and nodules of various colours, mainly greyish to reddish. Dolomites, marls, conglomerates and brecciated limestones are also found.

The sedimentary features and microfacies included in the rocks of Kefhalonia point to deposition within shallow pelagic marine conditions. During the Cenomanian (Upper Cretaceous), a restricted lagoonal high energy paleoenvironment is indicated by the low-manganese calcite ooid formations (Hagmaier *et al.* 2004; Van der Land *et al.* 2004). Megabreccias of redeposited platform margin limestone blocks in a matrix of hemipelagic mudstone of Eocene age are also reported (Hagmaier *et al.* 2004). The fossil-rich limestones of Upper Tortonian (Miocene) age found

on the Paliki Peninsula were deposited in a tropical to subtropical marine environment (see Georgiadou-Dikeloulia 1965; Symeonidis & Schultz 1968; Pomoni-Papaoannou *et al.* 2000). They represent a pelagic calcium carbonate formation of well-sorted and fine-grained packstones, rich in planktonic foraminifera (*Globigerinidae*). Microcrystalline phosphate peloids of fluorapatite composition are also present. Terrigenous material is lacking or occurs rarely (Pomoni-Papaoannou *et al.* 2000: 56).

Cherts in limestone are related to the extended radiolarian cherts of Mesozoic (mostly Middle to Late Jurassic) age that are common in pelagic deposits found within the tectonic units of Mediterranean orogenic belts, such as the Tethys Ocean (Aiello *et al.* 2008: 33). Pliocene to Pleistocene sediments and alluvial deposits of up to 300m in thickness overlie the calcareous series (limestones) of both geotectonic zones. They occur mainly in the western and the southern parts of the island (Fig. 12), including the Paliki Peninsula and a narrow zone (10–15km wide) across the sea shore from Argostoli to Poros. They consist mainly of Plakentian (~2 Ma) conglomerates, sandstones, marls, limestones, travertines and gypsum (see Georgiadou-Dikeoulia 1965; Symeonidis & Schultz 1968; British Petroleum Co *et al.* 1985; Lekkas *et al.* 2001; Triantaphyllou 2001).

Chert artefacts and sampling

The Drakaina chipped stone artefacts were made of chert and included cores and core fragments, as well as rejuvenation flakes. In addition, there were scrapers and projectile points, along with blades and bladelets and other debitage (see Stratouli & Metaxas 2008; Andreasen forthcoming). One third of the cores were very small or exhausted, while many were burnt (Andreasen forthcoming). Patination was only present on blades, cores and tools, while a significant proportion of the projectile points were either burnt or patinated (Metaxas forthcoming), suggesting a more complex life history than the majority of the debitage. The material showed no major changes in tool composition, technological characteristics or raw material use throughout the stratigraphic sequence (Andreasen forthcoming; Metaxas forthcoming).

Macroscopic qualitative classification of the chert artefacts on the basis of colour identified five broad categories including red, brown, yellow, grey and black, although it was impossible to establish clear boundaries between them (Andreasen forthcoming). Yellow chert, including the so-called honey flint, was the commonest category (63.5%), fine grained and of high flaking quality with few irregularities. There is a tendency within the archaeological assemblage for retouched blades and blade tools to preferentially be made of this yellow chert. Reddish and brown cherts (9.3% and 4.5%, respectively) were of good

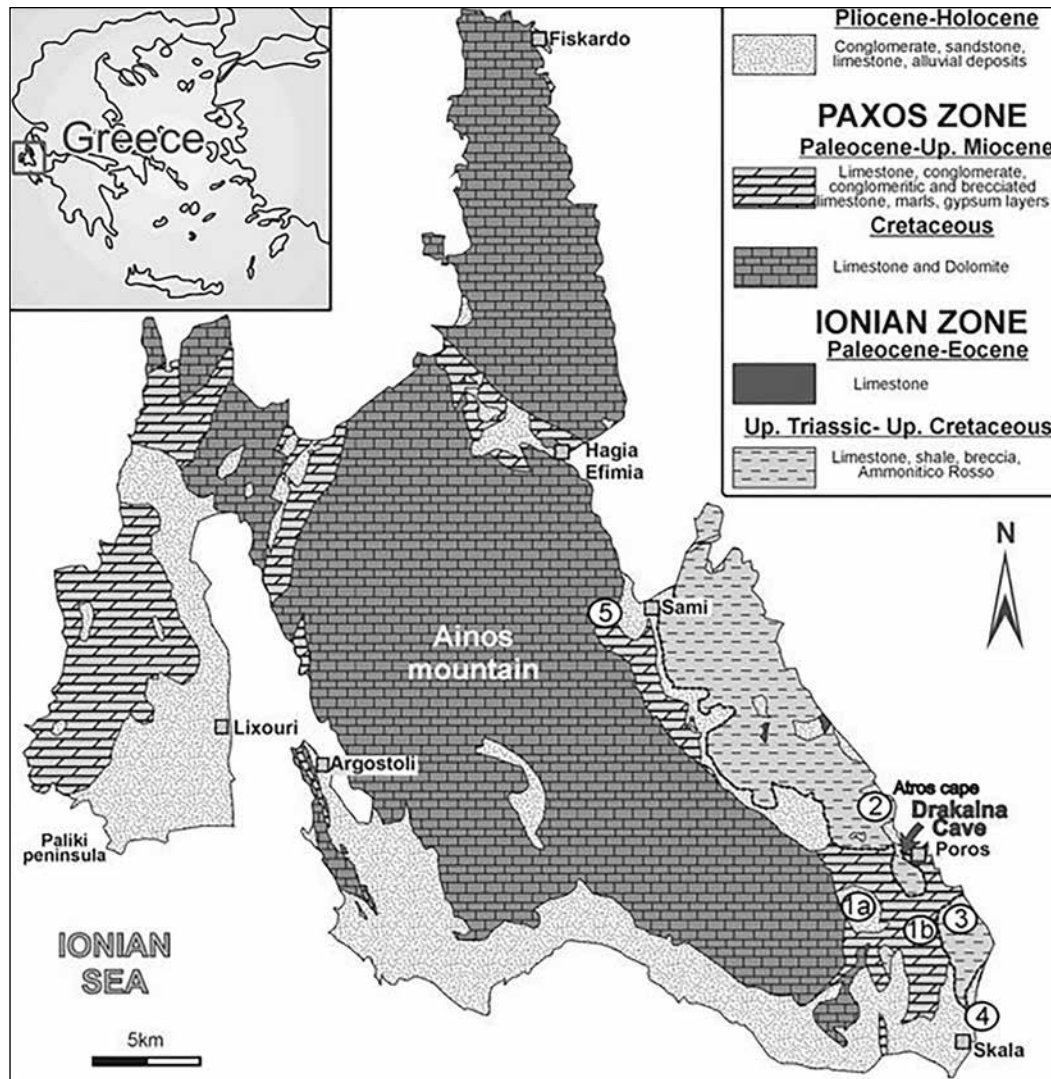


Figure 12. Simplified geological map of Kefalonia (modified after British Petroleum Co et al. 1985; Lekkas et al. 2001). Drakaina Cave and the sampling sites are also displayed (1a Kampitsata; 1b Anninata; 2 Atros cape; 3 Megali Rachi hill; 4 Skala; 5 Sami)

quality and were used at the site mainly for the manufacture of flakes and bifacial points. Grey chert was frequently used for flake scrapers and retouched flakes (Andreasen forthcoming). Ten pieces of chert chipped stone debitage from the archaeological assemblage were selected for petrographic and geochemical analyses. The samples themselves were small, approximately one by two centimetres across. Sampling was carried out with special authorisation provided by the Hellenic Ministry of Culture. Burnt pieces were avoided because the effect of extreme heat on chemical composition is unknown. The samples were chosen to represent the range of colour types identified in the macroscopic analysis, including red (KEF 5120, KEF 4331), brown (KEF 5119, KEF 5110), yellow (KEF 4333, KEF 4329), grey (KEF 23, KEF 1724) and black (KEF 5114, KEF 4332).

Natural chert occurrences

Chert outcrops in western Greece and the Ionian Islands, including Kefalonia, are widespread and associated with sedimentary rocks of the external Hellenides geotectonic zones. Field observation (Figs 12–13), especially in the broader area of Poros, identified bedded limestone containing nodules and layers of chert (Fig. 14a). Most nodules were up to 10cm in diameter, with some up to 50cm in length and 15cm across. The length of the layers exceeded 3m, while their colours ranged from grey to black, yellow, brown and red. Colour variation within the same nodule indicates that other criteria should also be used to identify the chert sources (Crandell 2005: 140). No fossils or mineral inclusions were recognised macroscopically in the investigated material. High

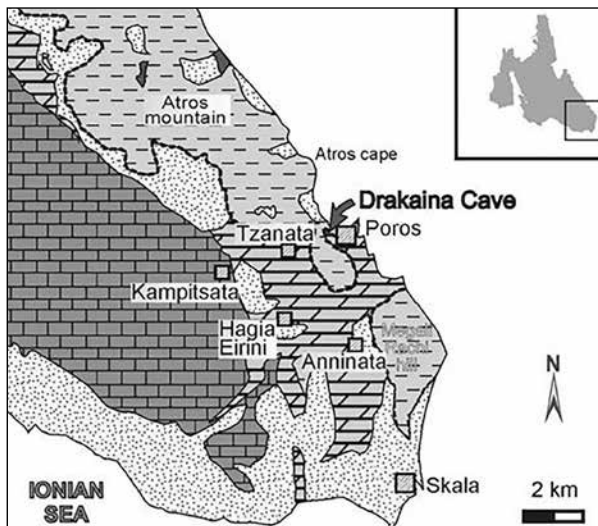


Figure 13. Simplified geological map of the area of Poros and Drakaina Cave on Kephallonia. For key to geological formations see the legend of Figure 12 (modified after British Petroleum Co et al. 1985; Lekkas et al. 2001)

quality large chert nodules were found within the platy and bedded limestones close to Atros cape (Fig. 13).

Pliocene to Holocene sediments and alluvial deposits, which cover the Paxos and Ionian zones, were also potential sources for chert gathered during the Neolithic (Fig. 12). These reworked deposits contain small pieces of less than 10cm and now outcrop within conglomerates (Fig. 14b). In some cases, natural enrichment of good quality chert was observed in recent beach and river gravel deposits; the result of continuous reworking and winnowing of smaller sand-sized fractions. The colour variation within these gravel bodies reflects that of the chert found in primary limestone contexts with grey, black, yellow, red and brown types. Several locations with chert gravels have been observed in eastern Kephallonia, around Agia (Hagia) Efimia and particularly Sami (Fig. 12). Other similar deposits are located in the southeast in the areas of Anninata, Megali Rachi hill and Skala south of Poros, and in Agia (Hagia) Eirini and Kampitsata west of Poros (Fig. 13). The gravels of the Vohinas River which flows along the Poros Gorge where Drakaina Cave is located, as well as the broader area of the Tzannata basin, contain hardly any chert larger than 10cm and the deposits are all generally small scale.

In order to identify the geological sources of the material used to make the archaeological chipped stone artefacts, we collected a total of 15 samples of chert from five *in situ* outcrops or deposits. These were selected on the basis of quantities of material and the presence of comparable colours to those found at Drakaina Cave (Figs 12–13).

1. Kampitsata and Anninata

Poorly sorted Pliocene and Holocene sediments spread in the broader area of Poros, including some relatively



Figure 14. (a) Chert nodules within the bedded limestones of Atros cape. (b) Unsorted chert gravel-rich strata within Pliocene-Holocene sediments in the area of Skala

large and good quality cherts as wash-out residuals. One grey sample was collected from sediments close to Kampitsata (KEF 2), 4km to the west of Drakaina, and one black piece close to Anninata (KEF 3), 4km southwest of Drakaina.

2. Atros cape

Within platy bedded limestone close to Atros cape, 2km north of Poros, nodules and layers of chert of a variety of colours can be found; mainly brown, red and grey and in some cases yellow and black. One yellow sample (KEF 6) was collected.

3. Megali Rachi hill

A single brown chert nodule (KEF 4) was collected on top of Megali Rachi hill, 5km southeast of Poros. Material was found on top as well as on the eastern slopes of the hill, in the form of nodules weathered and eroded from limestone bedrock, mainly brown in colour and of poor quality.

4. Skala

Chert gravels eroded from Pliocene conglomerates are found 1km north of Skala village. Colours range from black to grey and from yellow to brown and red. One sample each of black (KEF 15B), grey (KEF 15G) and

brown (KEF 15BR) chert were collected, along with two samples each of red (KEF 15R, KEF 5) and yellow (KEF 15Y, KEF 15). This location was suggested as a possible source of good quality chert raw materials during previous prehistoric field survey in the area by Foss (2002: 99).

5. Sami

Weathering of the limestone bedrock has left residual chert nodules on the surface, 3km west of Sami. Worked flakes and cores are spread across the area and, according to Foss (2002), the site has probably been exploited for chert since the Middle Palaeolithic, although no shafts or extraction pits were identified. Sampling from this location was a key objective of the present study and four were collected, one each of black (KEF 18B), yellow (KEF 18Y), red (KEF 18R) and brown (KEF 18BR).

Methods of analysis

Ten polished thin sections made from chipped stone debitage from Drakaina Cave, along with 15 from the sampled natural geological outcrops and deposits were studied, using optical microscopy and scanning electron microscopy (SEM) at Aristotle University in Thessaloniki. The aim was to identify mineralogical

inclusions and mineral phase relationships, as well as the presence of fossils. Mineralogical composition was also assessed using X-ray diffraction (XRD). A goniometer system and Cu anode tube ($\lambda=1.540\text{\AA}$) were used, operating at 40kV/30mA, with a scanning angle of 2θ between 3 and 63° . To determine the major elements, trace elements and rare earth elements (REE), 25 chemical analyses were undertaken using inductively coupled plasma and inductively coupled plasma mass spectrometry at Activation Laboratories in Ontario and ALS Chemex in Vancouver, Canada.

Mineralogy and petrography

Microscopic examination and X-ray diffractometry of the geological samples from the five chert colour groups (grey, black, yellow, red, brown), along with the chipped stone artefacts from the cave, identified microcrystalline quartz as the main mineral component. Others were also observed, although they were only present locally and in small concentrations. These included calcite, pyrite and iron hydroxides (goethite), while microfossils were present in all samples (Tables 1–2). Quartz is defined as microcrystalline due to the small size of the grains within its groundmass, mostly less than $10\mu\text{m}$ and in some cases even smaller than $1\mu\text{m}$ (Fig. 15a). Amorphous silica was not observed in the XRD diagrams and therefore the presence of opal

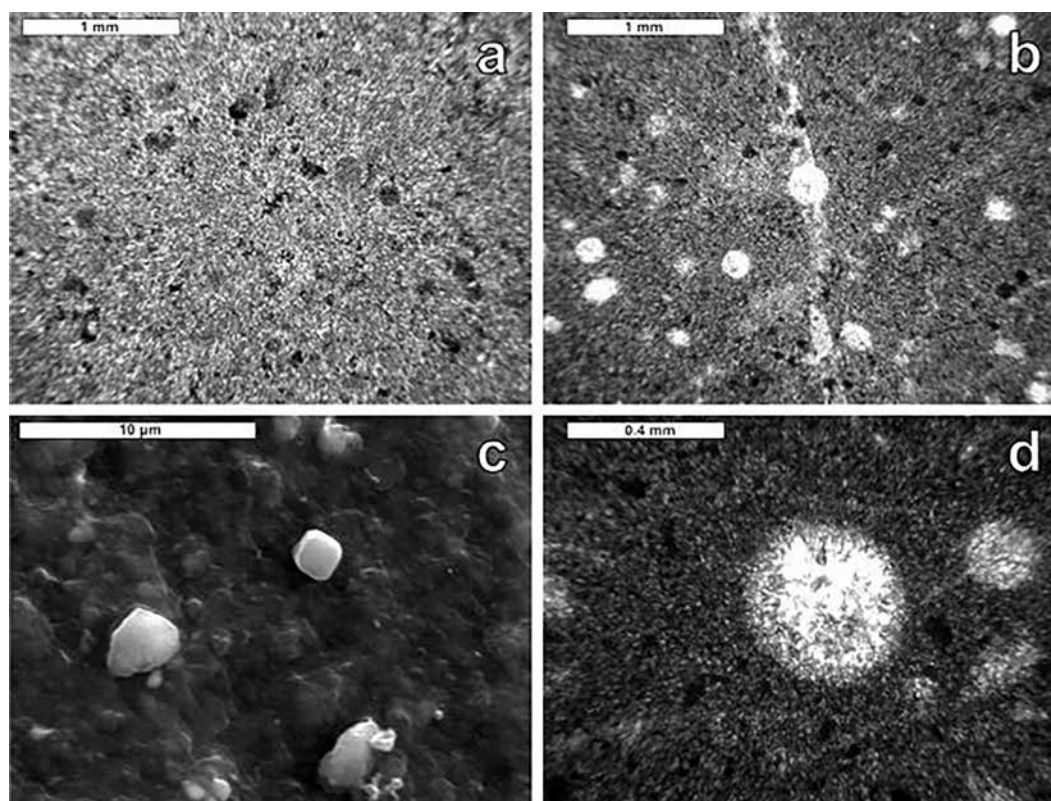


Figure 15. Photomicrographs showing typical textures of cherts from the island of Kefalonia. (a) Micro-crystalline quartz (KEF 4333), thin section, +N. (b) Veinlet of calcite formed during the sediment diagenesis and rounded microfossils, Radiolaria, in microcrystalline quartz (KEF 3), thin section, +N. (c) Pyrite micro-crystals (white-grey) within microcrystalline quartz (KEF 5), SEM. (d) Rounded Radiolaria consisting of chalcedony within organic material (dark colour) (KEF 3), thin section, +N

Sample	Colour	Minerals	Grain size	Fossils	Organic matter
Kef 2	grey	m-qu, ca, qu, py	<10µm, rarely up to 30µm	<i>Radiolaria</i>	Yes
Kef 3	black	m-qu, ca, py	<10µm	<i>Radiolaria Echinodermata</i>	Yes
				<i>Lamellibranchiata</i>	
				<i>Porifera</i>	
Kef 4	brown	m-qu, py, Fe-oxides	<10µm	<i>Radiolaria</i>	Yes
				<i>Lamellibranchiata</i>	
Kef 5	red	m-qu, ca, py, Fe-oxides	<1µm	<i>Radiolaria</i>	—
				<i>Lamellibranchiata</i>	
Kef 6	yellow	m-qu, ca, py	<10µm	<i>Radiolaria Echinodermata</i>	Yes
Kef 15B	black	m-qu, ca, py	<5µm, rarely up to 20µm	<i>Radiolaria Echinodermata</i>	Yes
				<i>Lamellibranchiata</i>	
Kef 15G	grey	m-qu, ca, py	<10µm	<i>Radiolaria Lamellibranchiata</i>	Yes
				<i>Foraminifera</i>	
Kef 15R	red	m-qu, ca, py, Fe-oxides	<10µm	<i>Radiolaria Foraminifera</i>	Yes
				<i>Gastropoda</i>	
Kef 15Y	yellow	m-qu, py	<10µm	<i>Radiolaria Foraminifera</i>	Yes
Kef 15BR	brown	m-qu, ca, py, Fe-oxides	<1µm	<i>Radiolaria Echinodermata</i>	Yes
				<i>Lamellibranchiata</i>	
Kef 18Y	yellow	m-qu, ca, Fe-oxides	<1µm	<i>Radiolaria</i>	Yes
				<i>Foraminifera</i>	
Kef 18R	red	m-qu, py, Fe-oxides	<1µm	<i>Radiolaria</i>	—
				<i>Foraminifera</i>	
Kef 18B	black	m-qu, ca, py	<1µm	<i>Radiolaria</i>	—
				<i>Foraminifera</i>	
Kef 18BR	brown	m-qu, py, Fe-oxides	<1µm	<i>Radiolaria</i>	—
				<i>Foraminifera (Globotruncana)</i>	

Table 1. Microscopic characteristics of the different chert types from the natural occurrences in eastern and southeastern Kephallonia (m-qu: microcrystalline quartz, qu: quartz, ca: calcite, py: pyrite)

should be excluded. Despite its macroscopic colour, microscopically the quartz is generally colourless. Locally its colour under the microscope is dark or pale brown or red, due to inclusions of variable amounts of iron hydroxide. In grey cherts, the different colour tints observed indicate the degree of organic matrix content, which increases from a semi-transparent to whitish grey types. Similar tint variations were noted in all chert types depending on organic material content. In many cases, chert slices contained a central massive core and a milky white margin known as cortex. Based on microscopic examination, this cortex consists of micro-crystalline quartz and is exactly the same as the core, with no differences in their structure and mineralogical composition.

Calcite was present in all chert types as disseminated grains or as veinlets up to 50µm wide (Fig. 15b), formed during diagenesis. Occasionally

it is found in the form of fossil remnants, such as *Lamellibranchiata*, *Echinodermata*, *Porifera* or *Foraminifera*. Pyrite grains in the form of micro-spheroids or micro-crystals (Fig. 15c) are also disseminated, reflecting local reducing conditions during their formation. The concentration of pyrite spheroids is very dense in the red cherts. The presence of this texture is indicative of biogenic environments during pyrite formation and the spherical form is attributed to a replacement or filling up of organic globules by pyrite (Rickard 1970: 281, 286). Organic matter probably plays an important role in the formation and the preservation of spheroids. The availability of iron and sulphur is necessary for the formation of pyrite spheroids and microcrystals and it can be of organic or inorganic origin. In sedimentary environments the source of iron is detrital iron minerals or $\text{Fe}(\text{OH})_3$. Sulphur comes from H_2S produced by the reduction of water sulphates by reducing bacteria

Tool	Colour	Minerals	Grain size	Fossils	Organic matter
Kef 1724	grey	m-qu, py	<10µm	<i>Radiolaria Foraminifera</i>	-
Kef 23	grey	m-qu, ca	<10µm	<i>Radiolaria</i>	Yes
Kef 4329	yellow	m-qu, py, Fe-oxides	<1µm	<i>Radiolaria</i>	Yes
				<i>Foraminifera</i>	
Kef 4331	red	m-qu, py, Fe-oxides	<1µm	<i>Radiolaria</i>	—
				<i>Foraminifera</i>	
Kef 4332	black	m-qu, ca, py	<1µm, rarely up to 20µm	<i>Radiolaria Echinodermata</i>	Yes
				<i>Lamellibranchiata</i>	
Kef 4333	yellow	m-qu, py	<20µm	<i>Radiolaria</i>	Yes
				<i>Foraminifera (Globotruncana)</i>	
Kef 5110	brown	m-qu, py, Fe-oxides	<1µm	<i>Radiolaria</i>	—
				<i>Foraminifera</i>	
Kef 5114	black	m-qu, ca	<1µm	<i>Radiolaria</i>	—
				<i>Lamellibranchiata</i>	
Kef 5119	brown	m-qu, ca, py, Fe-oxides	<1µm	<i>Radiolaria</i>	—
				<i>Lamellibranchiata</i>	
Kef 5120	red	m-qu, ca, Fe-oxides	<10µm	<i>Radiolaria Echinodermata</i>	—
				<i>Lamellibranchiata</i>	
				<i>Porifera</i>	

Table 2. Microscopic characteristics of the different chert types from the Neolithic deposits in Drakaina Cave, Kephallonia (m-qu: microcrystalline quartz, ca: calcite, py: pyrite)

(Massaad 1974: 88). Iron hydroxides, mostly goethite, occur in red, brown and yellow cherts and are attributed to pyrite oxidation. Red cherts contain more iron hydroxides than brown and yellow varieties, resulting in observed colour differences. Iron hydroxides were rarely observed in grey and black cherts.

The chert samples contained tiny fossils (Fig. 15d), mainly *Radiolaria*, as well as fragments of *Lamellibranchiata*, *Echinodermata*, *Porifera*, *Foraminifera*, and *Gastropoda* (Tables 1–2). These siliceous and calcareous fossils are mainly found in the microcrystalline quartz and are very well preserved. The *Foraminifera* are occasionally *Globotruncana*, characteristic of Late Cretaceous. In the case of *Radiolaria*, skeletal elements of these silicious unicellular organisms are usually rounded, although in some cases they appear elongated due to deformation during diagenesis. Most fossils were made up of microcrystalline quartz (<1µm), but recrystallised examples were also observed. In these cases the cores were of macrocrystalline fibrous quartz, for example of chalcedony of up to 30µm in diameter, with a microcrystalline outer shell which may have preserved the fossils from deformation. Similar radiolarian cherts have been described from Neolithic sites in northwestern Greece, in particular Makrygialos, Dispilio and Megalo Nisi Galanis (see

Skourtopoulou 1999; Dimitriadis & Skourtopoulou 2001, 2003). It has been suggested that these raw materials were gathered from the broader area of the sites, since radiolarian cherts are very common rock types in western and northwestern Greece.

Based on the mineralogical features of the chert from the archaeological deposits and geological samples, it is clear that there are significant similarities and that any grouping is impossible. Identifying the exact sources in relation to the mineralogical composition of the fossils is therefore currently impossible.

Geochemistry

Geochemical approaches to the study of sedimentary cherts need to take into consideration the influence of complex geological processes on chemical signatures, including transport, deposition, diagenesis and alteration. Rare earth elements (REE) and trace elements such as Zirconium (Zr), Hafnium (Hf) and Thorium (Th) are regarded as the most reliable immobile elemental components in the sedimentary cycle (see Piper 1974; Murray 1994). They are relatively stable during post-depositional processes such as diagenesis and weathering and, in addition, their chemical composition can help to establish similarities between samples and therefore to suggest potential source areas.

Major and trace elements were identified within the 15 samples of representative chert types from the five geological outcrops or deposits in eastern and southeastern Kephallonia (Table 3), along with the ten pieces of debitage from Drakaina Cave (Table 4). Bivariate plots of major and trace elements as well as spider diagrams of the REE were used to examine the correlation between variables, to identify obvious groups and to detect outlier specimens. The geochemical results indicated that, of the major elements, only SiO₂ was abundant (95.44 to 98.40wt%), whereas all others appeared in small concentrations only (<0.96wt%). The samples were therefore almost pure silica, with only minor impurities.

The amount of Fe₂O₃ was generally very low and did not exceed 0.22wt% (Tables 3–4). This compound is partly related to the presence of iron hydroxides, mainly goethite. The content within red chert tended to be high (0.13 to 0.22wt%), while yellow varieties were lower (0.15wt%), along with brown and black (0.05 to 0.17wt%) and grey (0.08wt%). The very low concentration of Fe₂O₃ and the lack of MnO indicate that the samples formed far from an oceanic spreading centre. Iron and manganese are especially enriched in metalliferous, ridge-proximal sediments and can be used as an indicator of hydrothermal input at the

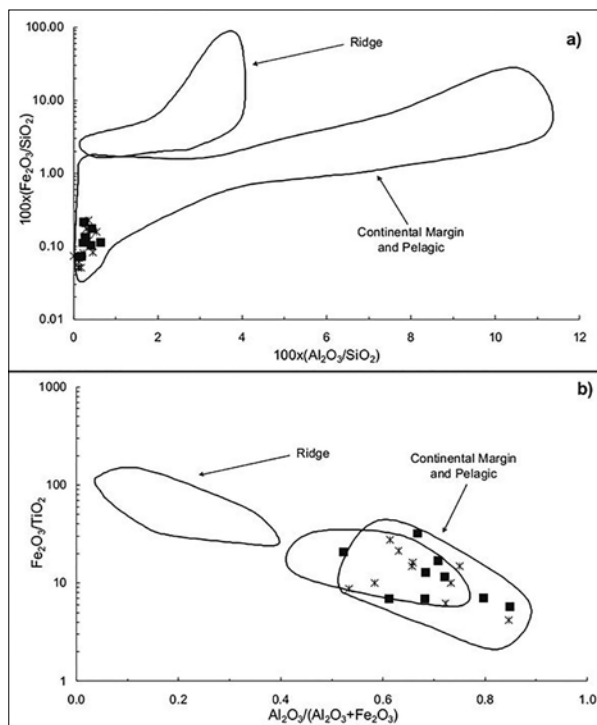


Figure 16. Plots of selected major element ratios in the geological (*) and archaeological (■) chert samples. (a) Al₂O₃ versus Fe₂O₃, both normalised to SiO₂ to minimise the diagenetic dilution by SiO₂, which produced relatively good separation between ridge-proximal chert and continental margin and pelagic. (b) Major oxide ratios indicating the influence of terrigenous (Al₂O₃ and TiO₂) and metalliferous (Fe₂O₃) end-member sources

spreading centre (Murray *et al.* 1990: 268; Murray 1994: 215, 220). Since both these compounds were rare or absent in our samples, we can assume that they were not formed in these types of environment. This is well documented in the binary diagrams of 100x(Al₂O₃/SiO₂) versus 100x(Fe₂O₃/SiO₂) and Al₂O₃/(Al₂O₃+Fe₂O₃) versus Fe₂O₃/TiO₂ (Murray 1994: 220–221, figs 2a, 2c), generated from the geological and archaeological samples (Fig. 16). These discrimination diagrams indicate that the samples have a well-defined signature of ridge-distant cherts. However, a separation between continental margin and pelagic environments is not obvious and therefore the exact depositional environment of the samples cannot be identified using major oxide ratios. The presence of remnants of calcareous fossils is responsible for the incorporation of CaO in the chemical composition of the cherts, but only in small quantities (0.01 to 0.96wt%).

A positive correlation between Al₂O₃ and Na₂O+K₂O can be seen in Figure 17a, indicating an increase of the alkali oxides Na₂O and K₂O with the increase of the Al₂O₃ content, which is possibly related to the presence of trace quantities of clay minerals such as illite. In the Al₂O₃ and Zr binary diagram (Fig. 17b), two groups were distinguished amongst both the archaeological and geological samples: those with low Zr content (4–34ppm) and those with higher levels (521–10,000ppm). The low Zr group included four archaeological samples (KEF 23, KEF 5114, KEF 5120 and KEF 5119) and four geological samples (KEF 2, KEF 3, KEF 4 and KEF 5). The high Zr group included six archaeological

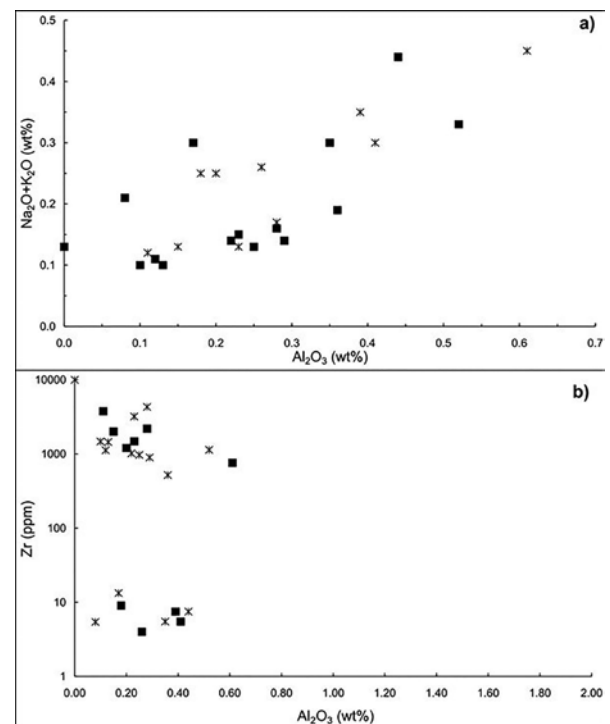


Figure 17. Plots for the geological (*) and archaeological (■) chert samples. (a) Al₂O₃ versus Na₂O+K₂O. (b) Al₂O₃ versus Zr

Sample	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF
	2	3	4	5	6	15	15B	15G	15R	15Y	15BR	18Y	18R
Colour	Grey	Black	Brown	Red	Yellow	Yellow	Black	Grey	Red	Yellow	Brown	Yellow	Red
wt %													
SiO ₂	97.45	95.44	97.01	96.71	98.1	97.21	97.8	98.3	98.1	95.7	98.2	98.3	97.8
Al ₂ O ₃	0.17	0.08	0.44	0.35	0.36	0.52	0.29	0.22	0.28	0.23	0.13	0.12	0.25
Fe ₂ O ₃	0.05	0.07	0.08	0.22	0.12	0.15	0.17	0.08	0.2	0.12	0.05	0.06	0.13
MnO	0.01	bd	bd	bd	bd	0.02	bd	bd	bd	bd	bd	bd	bd
MgO	0.04	0.04	0.04	0.12	0.01	0.03	0.02	0.02	0.04	0.02	0.01	0.01	0.01
CaO	0.18	0.96	0.06	0.4	0.15	0.03	0.22	0.22	0.15	0.27	0.01	0.02	0.05
Na ₂ O	0.22	0.18	0.26	0.23	0.08	0.15	0.08	0.07	0.08	0.08	0.07	0.07	0.07
K ₂ O	0.08	0.03	0.18	0.07	0.11	0.18	0.06	0.07	0.08	0.07	0.03	0.04	0.06
TiO ₂	bd	0.01	0.02	0.01	0.01	bd	0.01	0.01	0.02	0.01	0.01	bd	0.01
P ₂ O ₅	0.02	0.02	0.03	0.04	bd	0.02	0.05	bd	0.02	0.05	bd	bd	0.06
LOI	2.17	3.01	1.91	1.87	1.66	1.32	1.12	1.46	1.56	2.25	1.38	1.88	1.76
Total	100.39	99.84	100.03	100.02	100.6	99.63	99.82	100.45	100.53	98.8	99.89	100.5	100.2
ppm													
Sc	bd	bd	bd	2	bd	bd	bd	bd	bd	bd	bd	bd	bd
Cu	bd	bd	18	18	13	20	10	7	9	8	5	5	9
Zn	bd	bd	bd	41	7	bd	bd	bd	5	bd	bd	bd	bd
Ga	bd	bd	bd	bd	1.2	1	0.8	1	1	1.1	0.6	0.9	0.9
Rb	bd	bd	3.2	2.5	2.1	5	1.8	1.1	2	1.3	0.6	0.4	1.6
Sr	8.1	9.4	7.1	5	5.5	7	6.8	6.4	17.5	12.7	5.1	5.5	18.6
Y	1.7	bd	7.6	8.1	3.6	bd	6.2	27.7	9.5	4.5	5.5	85.8	53.2
Zr	13	5	7	5	521	1134	898	1020	4320	3210	1450	1120	971
Nb	1.1	bd	bd	bd	0.2	bd	0.2	bd	0.5	0.2	bd	bd	0.2
Sn	4	bd	3	2	1	3	1	1	1	1	bd	bd	bd
Ba	57	55	224	34	13.8	6	19.8	12.9	7.8	8.7	3.1	6.5	57.4
Hf	0.2	bd	0.2	bd	11.5	bd	19.8	23.2	99.5	72.2	33	24.6	22.3
Th	0.14	0.12	0.39	0.38	0.42	0.2	0.32	0.21	0.32	0.27	0.11	0.08	0.22
U	1.43	0.92	0.29	0.12	0.21	0.5	0.6	1.76	0.73	0.33	0.19	0.47	0.66
ppm													
La	3.3	0.6	7.38	5.37	2.2	0.8	5.2	24.2	7.1	2.4	3.9	23.5	15.8
Ce	0.86	0.51	2.62	3.77	2.4	1	2.8	4.7	3.9	2.4	1.7	4.8	4.1
Pr	0.64	0.15	2.16	1.69	0.28	0.19	1.33	6.15	1.35	0.3	0.65	7.25	3.8
Nd	2.4	0.6	9	7.2	1.3	0.8	5.7	25.9	6	1.6	2.9	35.5	19.2
Sm	0.45	0.14	2.03	1.64	0.25	0.2	1.06	5.23	1.01	0.24	0.58	8.48	4.61
Eu	0.1	bd	0.46	0.41	0.06	bd	0.27	1.27	0.34	0.06	0.14	2.28	1.3
Gd	0.48	0.1	2.03	1.79	0.34	0.2	1.12	5.45	1.38	0.26	0.56	10.2	5.83
Tb	bd	bd	0.29	0.26	0.01	bd	0.13	0.77	0.16	bd	0.05	1.64	0.92
Dy	0.3	0.11	1.45	1.35	0.2	0.2	0.78	4.45	1.07	0.2	0.49	9.8	5.88
Ho	bd	bd	0.26	0.25	0.01	bd	0.12	0.83	0.2	0.02	0.06	2.22	1.35
Er	0.14	bd	0.69	0.65	0.11	0.1	0.39	2.2	0.62	0.12	0.23	6.13	3.87
Tm	bd	bd	0.1	0.09	bd	bd	0.02	0.27	0.06	bd	bd	0.83	0.51
Yb	0.12	bd	0.56	0.5	0.13	bd	0.3	1.63	0.48	0.1	0.19	5.16	3.16
Lu	bd	bd	0.09	0.08	bd	bd	0.02	0.21	0.04	bd	bd	0.77	0.5
ΣREE	8.14	2.06	26.58	23.05	6.98	3.3	17.77	76.01	22.1	5.51	10.74	108.26	65.17
Lan/Cen	8.31	2.55	6.07	3.07	1.98	1.72	4	11.1	3.92	0.86	4.94	10.55	8.31
Ce/Ce*	0.14	0.39	0.15	0.27	0.69	0.57	0.24	0.09	0.27	1.18	0.23	0.07	0.11

Table 3. Chemical analyses of the different chert types from the natural occurrences in eastern and southeastern Kephallonia (Fe₂O₃ = Fe total, LOI = loss on ignition, bd = below detection)

9. Raw material and provenance identification of Late Neolithic and Chalcolithic chert artefacts from Drakaina Cave, Kefalonia

Sample	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF	KEF
	1724	23	4329	4331	4332	4333	5110	5114	5119	5120
Colour	Grey	Grey	Yellow	Red	Black	Yellow	Brown	Black	Brown	Red
wt %										
SiO ₂	98.4	96.34	95.7	97.2	97.7	96.36	97.3	96.48	96.99	96.31
Al ₂ O ₃	0.11	0.18	0.15	0.23	0.2	0.61	0.28	0.39	0.41	0.26
Fe ₂ O ₃	0.07	0.07	0.07	0.21	0.11	0.11	0.13	0.1	0.17	0.13
MnO	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
MgO	0.02	0.03	0.11	0.06	0.01	0.08	0.03	0.06	0.1	0.03
CaO	0.1	0.25	0.09	0.07	0.35	0.25	0.5	0.1	0.34	0.86
Na ₂ O	0.07	0.19	0.07	0.07	0.19	0.36	0.09	0.24	0.22	0.21
K ₂ O	0.05	0.06	0.06	0.06	0.06	0.09	0.08	0.11	0.08	0.05
TiO ₂	0.01	0.01	0.01	0.01	bd	0.02	0.01	0.01	0.01	bdl
P ₂ O ₅	bdl	0.02	0.06	0.06	0.1	0.03	0.12	0.02	0.04	0.04
LOI	1.37	2.69	2.87	1.82	1.97	2.17	2.07	2.13	1.35	2.57
Total	100.2	99.84	99.19	99.79	100.69	100.08	100.61	99.64	99.71	100.46
ppm										
Sc	bd	bd	bd	8	bd	bd	bd	bd	bd	bd
Cu	7	bd	15	bd	bd	59	42	14	bd	bd
Zn	bd	bd	bd	1	bd	122	7	bd	bd	bd
Ga	1	bd	1.5	1.1	bd	1.2	1	bd	bd	bd
Rb	0.5	bd	3.3	49.5	3.7	5.4	1.5	3.2	3	bd
Sr	12.5	7	6.5	8.5	9.8	5	11	7.1	7	10
Y	3.1	3	8.8	53.8	5.7	1.8	22.5	7	8.1	bd
Zr	3780	9	2005	1485	1207	759	2200	7	5	4
Nb	bd	1.1	1.4	0.3	bd	bd	0.2	bd	bd	bd
Sn	bd	3	0.5	0.5	bd	2	bd	2	bd	bd
Ba	11	45	109	220	67	10	13	174	57	50
Hf	86.2	0.2	11.4	21.2	15.4	0.2	49.1	0.2	bd	bd
Th	0.09	0.18	0.34	0.21	0.21	1.08	0.24	0.34	0.4	0.15
U	0.97	1.5	0.66	0.72	0.55	2	0.25	0.3	0.15	0.77
ppm										
La	1.8	3.19	4.2	16.2	5.1	0.67	7.1	5.96	5.25	0.55
Ce	1.5	0.8	3.3	4.5	2.7	1.83	3.6	3.8	3.68	0.49
Pr	0.19	0.62	bd	bd	bd	0.2	1.01	2.34	1.62	0.14
Nd	0.9	2.2	3.6	19.9	5.6	0.8	4.8	7.3	7.2	0.6
Sm	0.15	0.44	0.66	4.68	1	0.22	0.88	1.73	1.6	0.13
Eu	0.04	0.1	0.18	1.5	0.23	bd	0.29	0.43	0.38	bd
Gd	0.18	0.41	0.9	6.01	1.09	0.23	1.14	1.91	1.75	0.09
Tb	bd	bd	0.08	0.99	0.11	bd	0.14	0.24	0.23	bd
Dy	0.17	0.26	0.74	5.94	0.74	0.34	1	1.38	1.3	0.1
Ho	bd	bd	bd	bd	bd	bd	0.22	0.3	0.21	bd
Er	0.06	0.13	0.49	3.89	0.31	0.21	0.7	0.66	0.6	bd
Tm	bd	bd	bd	bd	bd	bd	0.07	0.32	0.08	bd
Yb	0.05	0.1	0.33	3.23	0.2	0.2	0.53	0.51	0.44	bd
Lu	bd	bd	0.03	0.6	0.01	bd	0.06	0.1	0.07	bd
ΣREE	4.85	7.68	14.51	67.44	17.09	4.48	20.24	23.98	22.49	1.95
Lan/Cen	2.59	8.59	2.74	7.76	4.07	0.79	4.25	3.38	3.07	2.43
Ce/Ce*	0.51	0.14	0.39	0.28	0.23	1.15	0.28	0.26	0.27	0.39

Table 4. Chemical analyses of the different chert types from the Neolithic artefacts in Drakaina Cave, Kefalonia (Fe₂O₃ = Fe total, LOI = loss on ignition, bd = below detection)

samples (KEF 1724, KEF 4329, KEF 4331, KEF 4332, KEF 4333 and KEF 5110) and 11 geological samples (KEF 6, KEF 15, KEF 15B, KEF 15G, KEF 15BR, KEF 15R, KEF 15Y, KEF 18B, KEF 18Y, KEF 18R and KEF 18BR). More detailed discrimination between specific samples was not possible. It is clear that on the basis of bivariate plots of chemical compounds and components, including SiO_2 , Al_2O_3 , Fe_2O_3 , TiO_2 , Na_2O , K_2O and Zr, we are unable to separate the groups of cherts and therefore to distinguish possible raw material sources. Furthermore, although samples of various colour cherts were analysed, no significant variations in their element composition proportions were identified.

The abundance and distribution of REE are a useful geochemical tool for the study of sedimentary rocks and especially marine cherts, as they are relatively immobile during post-depositional processes such as diagenesis and metamorphism (see Piper 1974; Shimizu & Masuda 1977; McLennan 1982; Murray *et al.* 1990; Murray 1994). The patterns of enrichment or depletion of light and heavy REE or the existence of positive or negative anomalies, for example in Ce or Eu, can also be diagnostic of the depositional environment and petrogenesis of sedimentary cherts. The patterns observed in the Kephallonia samples are shown in **Figure 18**. The standard chosen for normalising the REE concentrations is the North American Shale Composite (NASC) (Gromet *et al.* 1984). Comparing the patterns in **Figure 18a** and **18b** we see that, apart from KEF 15Y and KEF 4333, the archaeological and geological samples have a notable negative Ce anomaly. The mode of the Ce anomalies can be a good indicator of the marine environment in which cherts were formed. It has been demonstrated that in deep-water conditions, chert is subjected to selective Ce removal relative to other REE, resulting in a negative Ce anomaly (Shimizu & Masuda 1977: 347). This occurs because in newly formed organogenic cherts the primary pore water signal is preserved, along with the REE signature, and therefore the associated Ce anomalies are potentially sensitive indicators of bottom water redox potential (Liu *et al.* 1988: 1362). The negative Ce anomalies observed in the Kephallonia cherts ($\text{Ce}/\text{Ce}^* = 0.07$ to 0.69 , **Tables 3–4**) are therefore attributed to deep-water depletion of Ce.

In contrast, an important result as seen in **Figure 18a** and **18b**, is that two yellow chert samples (KEF 15Y and KEF 4333) produced slightly positive anomalies. In shallow water areas, Ce may occur as suspended solid particles and behave in the same way as other REE (Shimizu & Masuda 1977: 347). Such depositional environments exist along the continental margins and can be identified by the relative Ce levels in terms of the shale normalised La/Ce ratio (La_n/Ce_n) (Murray 1994: 223) and the Ce anomaly (Ce/Ce^*) (Murray *et al.* 1990: 270). Based on these ratios ($\text{La}_n/\text{Ce}_n = 0.79$ and 0.86 , $\text{Ce}/\text{Ce}^* = 1.15$ and 1.18), it can be determined that

yellow cherts, KEF 4333 and KEF 15Y respectively, were formed along a continental margin. Cherts formed in a regime with high sedimentation, such as continental margins, will have low total REE, because rapid burial will limit seawater exposure time and restrict the sediment's capacity to absorb REE. Results from both geological (KEF 15Y) and archaeological (KEF 4333) samples of yellow chert indicate low total REE concentrations (5.51 and 4.48ppm respectively) and therefore point to formation along a continental margin. The relative increase in total REE content (1.95–108.26ppm) in the chert samples from Kephallonia is responsible for the parallel arrangement of the REE patterns which can be observed in **Figure 18a** and **18b**.

The observed geochemical signatures, based upon the abundance and distribution of major and trace elements as well as REE, clearly separate into two distinct groups, suggesting different depositional environments for the Kephallonia cherts. The geological and archaeological samples, apart from the two yellow pieces (KEF 4333 and KEF 15Y), have well defined deep water signatures, between the continental margin and ocean floor. Conversely, the geochemical signature of the two yellow cherts reveals a chemically discrete group, indicative of formation in shallow-water conditions along a continental margin.

Discussion

The complexity and variability of the rocks throughout Greece offered a wide variety of raw materials for prehistoric stone tool production. However, rocks suitable for the manufacture of these artefacts were not always available close to settlements. This resulted in different modes of circulation and redistribution of exotic lithic raw materials, sometimes over long distances (Perlès 1992; Perlès & Vitelli 1999).

In the case of Drakaina Cave on Kephallonia, exotic raw materials were used for limited and/or specific types of artefacts. Gabbro and talc from the Pindos Mountain range were used as raw materials for stone celts and beads (see Stratouli & Melfos 2008), whereas obsidian from Melos in the Aegean was the raw material for a restricted number of chipped stone artefacts (Stratouli 2005: 129). An artefact found at Drakaina was made from white marble of Cycladic origin, possibly from the island of Naxos (Melfos forthcoming). All of these different types of rock were transported to Kephallonia through inter-regional networks (Stratouli 2005). The large numbers (over 12,500) of chert chipped stone artefacts and debitage found in the Late Neolithic and Chalcolithic layers of Drakaina indicate more local raw material sources (Andreasen forthcoming). Several raw material collection sites in use since the Middle Palaeolithic on Kephallonia have been documented or suggested so far (Marinatos 1960: 42; Matzanas 2000: 3; Foss 2002: 81–83; Andreasen forthcoming; Metaxas

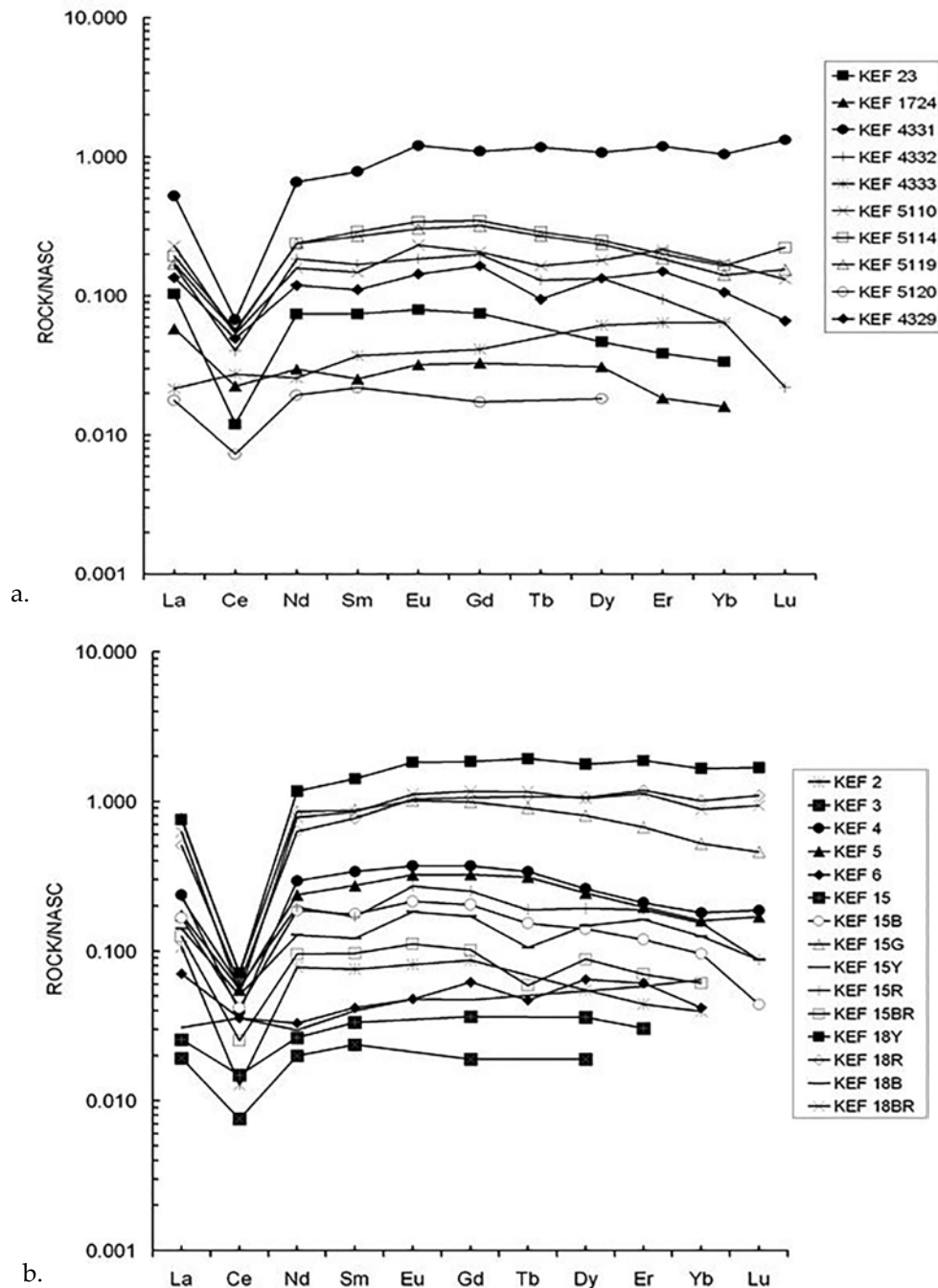


Figure 18. 'North America Shale Composite' (NASC) normalised REE abundance patterns in the geological (a) and archaeological (b) chert samples from the island of Kephallonia and Drakaina Cave (NASC normalised values after Gromet et al. 1984: tables 3–4)

forthcoming). However, this assumption needs to be confirmed through petrographic and geochemical study, comparing the archaeological material with geological samples.

The study presented here has allowed us to document analytically the geological chert types found over a large part of Kephallonia, particularly in the locations of Kampitsata, Anninata, Atrios cape, Megali Rachi hill, Skala and Sami, and to establish a database of mineralogical and geochemical results.

These locations appear to be potential sources for the lithic material used by the Neolithic inhabitants of Drakaina. Based on the mineralogical signatures of the chert artefacts compared to those of the geological samples, it is clear that there are significant similarities between the materials, but that drawing definite links is impossible. The mineral composition of the five chert colour types (brown, yellow, red, grey and black) was constant in all samples, with microcrystalline quartz being the main constituent with traces of calcite,

pyrite, iron hydroxides (goethite) and microfossils, mainly *Radiolaria*. This means that the raw materials used were probably collected from local chert sources on Kephallonia, although the exact provenance of collection sites cannot be determined either through mineralogical composition or microfossils.

Chemical characterisation of the samples, based mainly on REE, also pointed to probable local collection of raw materials. The REE results (Fig. 18a–b) indicate that the majority of the geological and archaeological samples were formed in deep water, apart from the yellow chert which appears to have been formed in shallower conditions along the continental margin. In order to improve the results, we compared the REE signature of each archaeological sample with the whole pattern sequence of the geological samples (Figs 19–21), assuming that the database of geological samples was representative and that the patterns show slight differences amongst the various geological sample sites. We observed that there was complete overlap of REE results for specific archaeological samples with either unique or single geological sources. Three archaeological samples (KEF 23, KEF 5120 and KEF 5114) overlapped perfectly with geological samples KEF 2 from Kampitsata, KEF 3 from Anninata and KEF 4 from Megali Rachi hill, respectively (Fig. 19). Five artefacts (KEF 1724, KEF 4332, KEF 4333, KEF 5110 and KEF 5519) overlapped with five geological samples (KEF 15BR, KEF 15B, KEF 15Y, KEF 15R and KEF 5), all from Skala (Fig. 20). Archaeological samples KEF 4329 and KEF 4331 had identical REE patterns to geological samples KEF 18B and KEF 18R, both from Sami (Fig. 21).

These results indicate that local cherts from sources in southeastern Kephallonia are predominant within the archaeological assemblage and that there

is no evidence for long distance transport (see also Andreassen forthcoming). The distances covered from these sources to Drakaina Cave varied between 3 and 17km. The Neolithic inhabitants preferred to obtain chert raw materials from reworked sediments, mainly the conglomerates from Kampitsata, Anninata, Megali Rachi hill, Skala and Sami, rather than quarrying *in situ* limestone as at Atros cape. Chert pebbles from secondary deposits are more accessible (Andreassen forthcoming) as opposed to primary deposits and it is assumed that such material was available on the surface or immediately below, with no need for deep quarrying (see also Foss 2002; Andreassen forthcoming; Metaxas forthcoming).

The REE signatures of the two yellow cherts, one geological and the other archaeological, point to different geochemical affiliations compared to the other chert samples, and therefore to a different depositional and formation environment. They are possibly identical to *honey flint*, which is considered as one of the best quality chert raw materials for knapping (Perlès 1992, 1994; Perlès & Vitelli 1999). Based on extensive archaeological survey carried out on Kephallonia, it has been suggested that, ‘the so-called honey flint does not occur naturally on the island and must have been imported’ (Foss 2002: 82). Honey flint was also considered to be an imported material at Franchthi Cave in the Peloponnese (Mitropoulos *et al.* 1990: 494) and in Neolithic sites in Thessaly, where it was described as ‘tertiary flint from lacustrine deposits’, derived from the Ionian geological series of western Greece or Albania. Bulgaria and Romania have also been suggested as possible source areas (Kardulias 1992). Despite this, yellow chert deposits with nodules resembling honey flint have previously been reported from the Skala area in southeastern

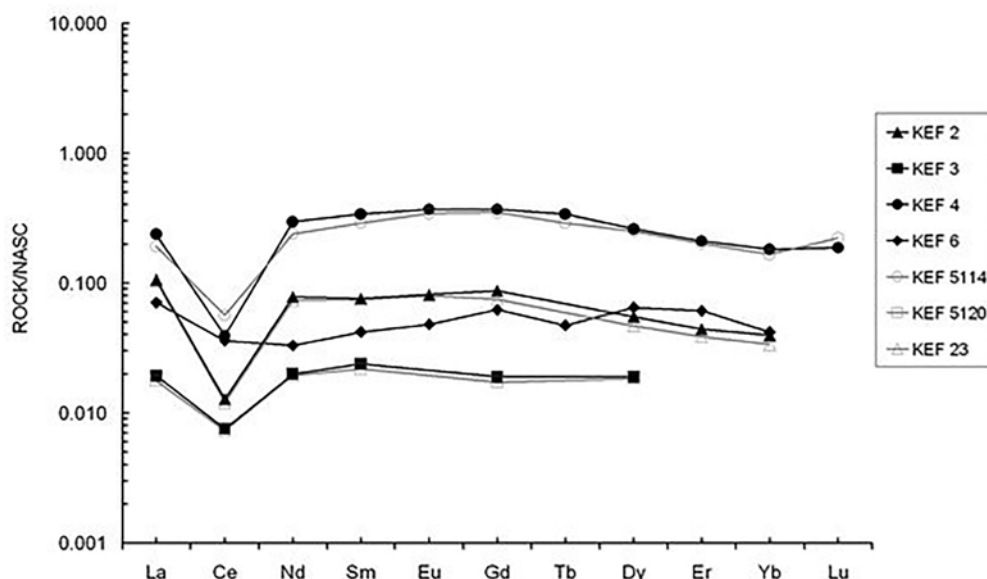


Figure 19. NASC normalised REE patterns of three archaeological artefacts (KEF 23, KEF 5120, KEF 5114) compared with geological samples from Kampitsata (KEF 2), Anninata (KEF 3), Megali Rachi hill (KEF 4) and Cape Atros (KEF 6)

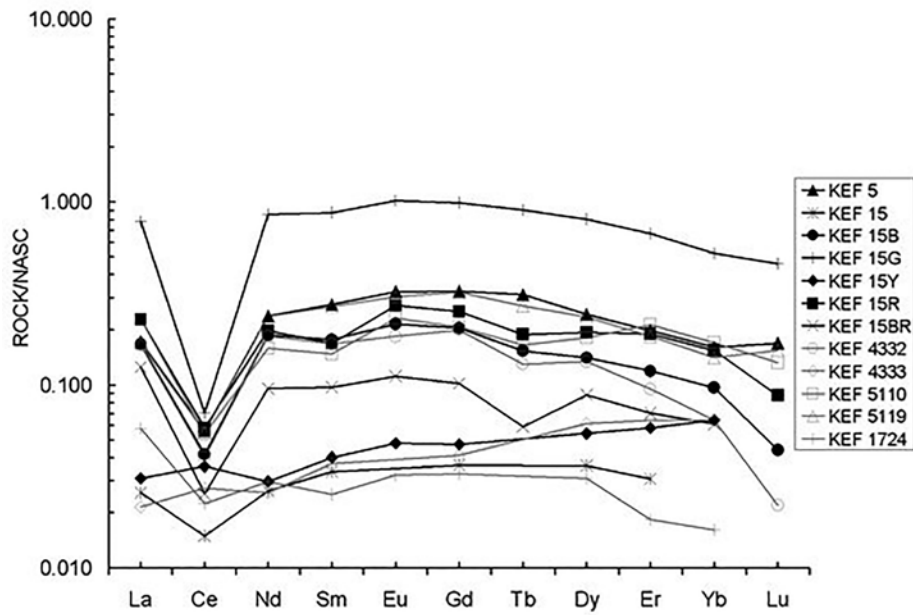


Figure 20. NASC normalised REE patterns of five archaeological artefacts (KEF 1724, KEF 4332, KEF 4333, KEF 5110, KEF 5519) compared with geological samples from Skala (KEF 5, KEF 15B, KEF 15G, KEF 15Y, KEF 15R, KEF 15 BR)

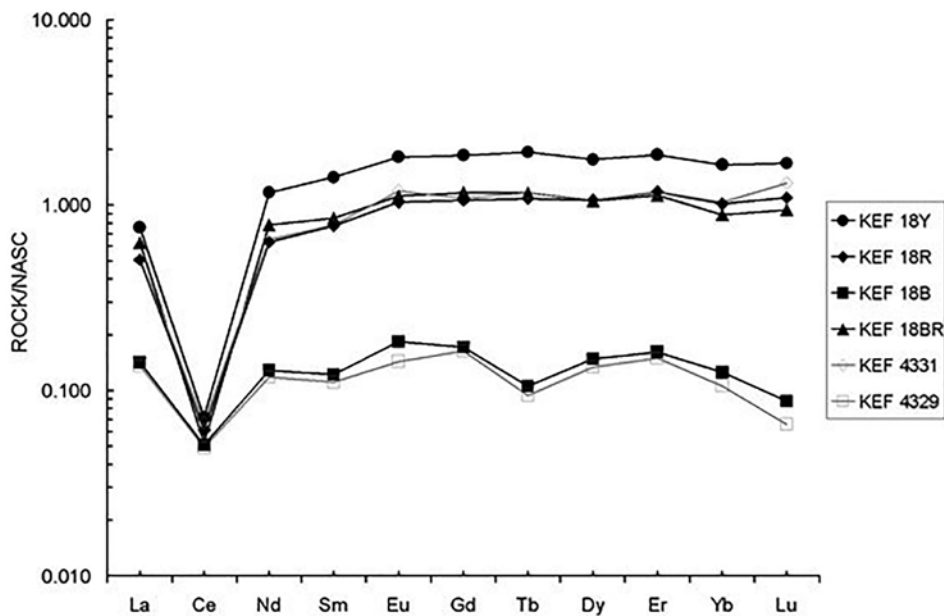


Figure 21. NASC normalised REE patterns of two archaeological artefacts (KEF 4329, KEF 4331) compared with geological samples from Sami (KEF 18Y, KEF 18R, KEF 18B, KEF 18BR)

Kephallonia (Marinatos 1960: 42; Matzanas 2000: 3). The fact that 63.5% of all chipped stone material found in the Late Neolithic and Chalcolithic layers at Drakaina was made of yellow and yellowish-brown chert indicates that the source of this material is probably on the island (Andreasen forthcoming; Metaxas forthcoming). This is in agreement with the present study and in particular the REE results, which indicate that the raw material used to make the one yellow chert or honey flint artefact (KEF 4333) probably came from Skala (KEF 15Y).

Conclusions

The geological chert samples from Kephallonia and the Neolithic chipped stones from Drakaina Cave were grouped into five colour categories: red, brown, yellow, grey and black. The mineral composition of these indicated that they mainly consist of microcrystalline quartz with traces of calcite, pyrite, iron hydroxides (goethite) and microfossils (mainly *Radiolaria*). Based on the mineralogical features, it was obvious that there were significant similarities between the

geological and archaeological samples, strongly suggesting that the raw materials used at Drakaina were collected locally. The REE patterns pointed to a deep water geochemical signature for the geological and archaeological samples, with formation between the continental margin and ocean floor, apart from two yellow pieces which were characterised by shallow water formation along a continental margin. Detailed comparison of the REE results from the artefacts, with the pattern sequence of the geological samples confirmed that the raw materials were acquired from Kampitsata (1 sample), Anninata (1 sample), Megali Rachi hill (1 sample), Skala (5 samples) and Sami (2 samples). Collection of pebbles from sedimentary deposits was preferred during the Neolithic, rather than quarrying the primary chert nodules or layers from *in situ* limestones. The distances covered from the sources to Drakaina Cave varied between three and 17km.

The REE patterns of one yellow chert implement resembling the so-called honey flint were identical to those of a yellow sample from Skala in southeastern Kefhalonia, confirming probable local provenance. Previously suggested models of long distance transport or trading of yellow chert are no longer necessary in order to explain the presence of this material on Kefhalonia.

The distribution of the chert raw materials used for the Drakaina chipped stone artefacts strongly suggests that the users of the cave were mainly active in southeastern Kefhalonia, probably within a few kilometres of the cave and its surrounds; this is most likely the area in which the principal Neolithic settlements in the vicinity of the gorge of Poros will be found. Furthermore, the identification of the raw material sources exploited by the cave users during the Late Neolithic and Chalcolithic has provided unequivocal evidence for interaction between Neolithic communities at least within the southeastern and the central part of Kefhalonia. In addition, considering the significant number of exotic items uncovered in the Neolithic and Chalcolithic deposits of Drakaina Cave, originating mainly from the Greek mainland (e.g. the Pindos range) and some islands in the Aegean Archipelago (e.g. Melos, Naxos), there is no doubt that the Neolithic inhabitants in the environs of the gorge of Poros were engaged in well-established exchange and communication networks connecting Kefhalonia primarily with the adjacent mainland.

Acknowledgments

This study was predominantly funded by the Institute for Aegean Prehistory (INSTAP), which is gratefully acknowledged. Significant support was obtained from the former Municipality of Eleios-Pronnoi, Kefhalonia. Niels Andreasen and Odysseas Metaxas

are greatly acknowledged for their thorough and helpful comments as well as their assistance at various stages of the project and subsequently with this paper. Further, we would like to thank Dr Antonios Stais for his assistance in the identification of the fossils. Dr Gilbert Marshall and Dr Nick Kardulias are greatly acknowledged for their constructive comments and suggestions, resulting in significant improvement of this paper.

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