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PETROGRAFSKA I GEOKEMIJSKA KORELACIJA ARTEFAKTA IZ MEZOLITIČKIH NASLAGA VELE SPILE I MAGMATSKIH STIJENA SREDNJODALMATINSKOGA OTOČJA

PETROGRAPHIC AND GEOCHEMICAL CORRELATION BETWEEN ARTIFACTS FROM THE MESOLITHIC LAYERS OF VELA SPILA AND THE MAGMATIC ROCKS OF CENTRAL DALMATIAN ISLANDS

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U ovom se radu predstavlja petrografska i geokemijska analiza artefakta iz groba 2 otkopanoga u mezolitičkim naslagama Vele spile. Stijena od koje je sastavljen magmatskog je porijekla, što znači da ne potječe s Korčule, a izbor lokacija sužen je na samo nekoliko jadranskih vulkanskih otočića. Rezultat komparativne analize artefakta iz Vele spile i uzoraka sličnoga kamena s Palagruže, Brusnika, Jabuke i iz Komiže s velikom sigurnošću upućuje na Palagružu kao lokaciju odakle je valutak gabrodiorita donesen na Korčulu. Ovaj je podatak najstarija potvrda plovidbe Jadranom i ukazuje na to da je smjer Gargano – Palagruža – Korčula bio važan za nabavljanje sirovine, a vjerojatno i kao pravac širenja mezolitičke (i još starije) populacije.

Ključne riječi: mezolitik, Vela spila, Palagruža, gabrodiorit, magmatske stijene, plovidba.

This work presents a petrographic and geochemical analysis of artifacts from grave 2 excavated in the Mesolithic layers of Vela spila. The rock from which it is composed is magmatic in origin, which means that it is not originally from Korčula, so that the selection has been narrowed to only a few Adriatic volcanic islets. The results of comparative analysis of the artifacts from Vela spila and samples of similar rocks from Palagruža, Brusnik, Jabuka and Komiža largely indicate that Paragruža is the site from which the round gabbro-diorite stone was brought to Korčula.

This data is the oldest confirmation of navigation on the Adriatic Sea and indicates that the Gargano-Palagruža-Korčula route was vital for procuring raw materials, and probably as an avenue for the spread of the Mesolithic (and even earlier) populations.

Key words: Mesolithic, Vela spila, Palagruža, gabbro-diorite, magmatic rock, navigation

Grob br. 2. iz 1986. i artefakt od gabrodiorita

Tijekom iskopavanja 1986. u Veloj su spili, poznatom pretpovijesnom lokalitetu iznad Vele Luke na otoku Korčuli, otkrivena tri, odnosno četiri slična

Grave no. 2. from 1986 and the gabbro-diorite artifact

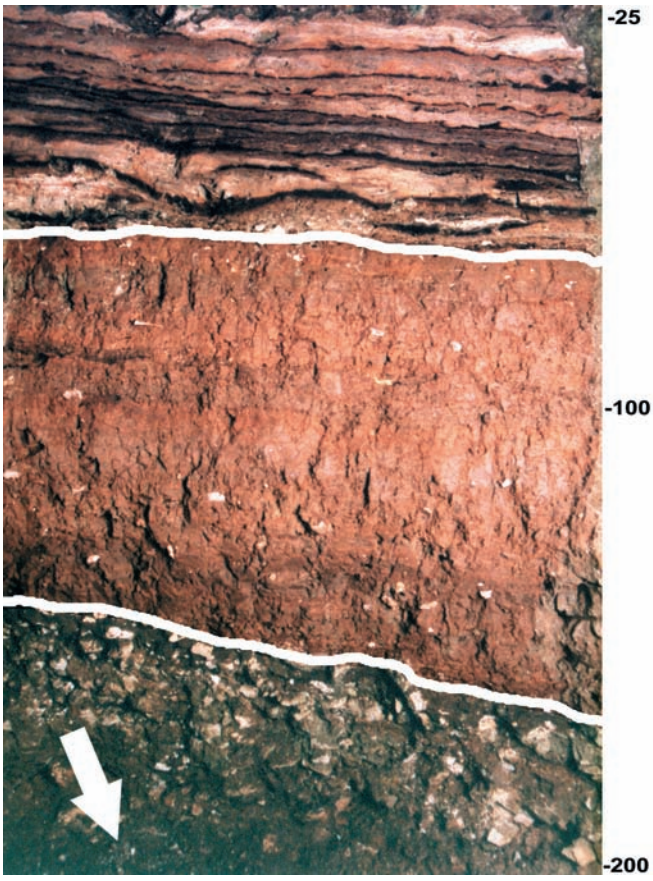
During excavations conducted in 1986 in Vela spila, a well-known prehistoric site overlooking Vela Luka

groba (Čečuk & Radić 1995: 16; 2001: 81–82; 2003: 23–24; monografski prikaz lokaliteta je u tisku). Grobovi su nađeni u najdubljemu dijelu špilje, u kvadrantu b–f x 20–24, na dubini od 180 do 220 cm (detaljnije u spomenutim radovima, posebno Čečuk & Radić 2003: 24).

U ovom se radu bavimo samo Grobom br. 2, nađenim 20. rujna 1986, odnosno ovalnim kamenim artefaktom tamne boje nađenim u neposrednoj blizini. Grob 2 otkopan je na dubini od 1,8 do 2 m i sadržavao je dobro uščuvane ostatke djeteta starog od 1,5 do 2,5 godine.[1] Ruke i noge pokojnika bile su zgrčene, a tijelo je bilo položeno na desni bok. Raspored okolnoga kamenja upućuje na postojanje elementarne arhitekture. Grob 1 udaljen je od Groba 2 oko 50 cm.

U spomenutim se radovima nedvosmisleno ističe da nastanak svih četiriju grobova treba smjestiti u vrijeme između kraja paleolitika i početka starijeg neolitika. Radiokarbonski nadnevak iz sonde s grobom 2, dobiven analizom uzorka drvenoga ugljena uzetog s dna naslaga *impresso* neolitika (s dubine od 164 cm; **Sl. 1**), početak neolitika smješta na kraj sedmoga tisućljeća.[2] Mezolitičko razdoblje (odnosno 7. faza u razvitku materijalne kulture) u Veloj je spili stratigrafski jasno razdvojeno od neolitika (**Sl. 1**, donja crta), a zastupljeno je naslagama debelim preko 1,5 m. Te se naslage dijele na gornji i donji dio, odnosno na stariji siromašniji i mlađi bogatiji razvojni stupanj (Čečuk & Radić 2003). Popratni predmeti nađeni prilikom iskopavanja svih četiriju grobova s velikom sigurnošću upućuju na njihovu pripadnost mlađem razdoblju, iznimno bogatom ostacima hrane iz mora (riblje kosti, školjke, puževi…). Ove činjenice, kao i datumi do kojih smo došli analizom radioaktivnog ugljika C^{14} iz drugih sonda, omogućuju nam da nastanak grobova smjestimo u vrijeme prije polovice sedmog tisućljeća prije Krista[3], no precizniji datum odredit će buduća istraživanja.

Kameni artefakt nađen je u grobu br. 2, odnosno u njegovoj neposrednoj blizini. Budući da se nalazi oko 50 cm istočnije od glave pokojnika, možemo zaključiti da je riječ o grobnome prilogu, a ne o slučajno izgubljenom predmetu. Radi se o vrlo pravilnom, prvobitno ovalnom i naknadno obrađe-



Slika 1. *Slojevi Vele spile u sondi b – f x 20 – 24. Gornja crta razdvaja naslage srednjeg od starijeg neolitika; ispod donje crte mezolitičke su naslage. Strelica pokazuje približan položaj groba 2 (snimio Dino Cetinić).*

Figure 1. *Layers in Vela spila in probe b – f x 20 – 24. The upper line separates middle and older Neolithic layers; Mesolithic layers are beneath the lower line. The arrow shows the approximate position of grave 2 (photo by Dino Cetinić).*

on the island of Korčula, three or four similar graves were discovered (Čečuk & Radić 1995: 16; 2001: 81–82; 2003: 23–24; a monograph presenting the site is at press). The graves were found in the deepest part of the cave, in quadrant b–f x 20–24, at a depth of 180 to 220 cm (more details in the aforementioned works, esp. Čečuk & Radić 2003: 24).

In this work the authors only deal with grave no. 2, found on September 20, 1986, and the oval dark-colored stone artifact found in its immediate vicinity. Grave 2 was unearthed at a depth of 1.8 to 2 m and it contained the well-preserved remains of a child between 1.5 and 2.5 years of age.[1] The arms

[1] Analizu ljudskih kostiju obavio je dr. Mario Šlaus s Odsjeka za arheologiju HAZU. Rezultati analize izneseni su u Šlaus 2004.

[2] Institut "Ruđer Bošković", Zagreb, broj 1967, drveni ugljen, C^{14} starost 7300±120 BP, kalibrirana starost 6230– 6000 BC.

[3] VERA – 2344, Vela Spilja 9, Holzhohle, 8230 ± 35 bp; VERA – 2341, Vela Spilja 8C, Holzhohle, 8200 ± 30 bp; VERA – 2340, Vela Spilja 7 Holzhohle, 7000 ± 30 bp (vidi Čečuk&Radić 2003: 32–33).

[4] Težina je prije analize iznosila oko 1800 g, a za potrebe analize dio kamena je potrošen.

[1] Analysis of human bones was conducted by Dr. Mario Šlaus from the Archeology Department of the Croatian Academy of Arts and Science. The results were released in Šlaus 2004.

Slika 2. *Gabrodioritni valutak iz groba br. 2 (snimio Boško Lugović).*

Figure 2. *Gabbro-diorite round stone from grave no. 2 (photo by Boško Lugović).*

nom morskom valutku teškom 1570 g[4], čije dimenzije iznose oko 17 cm x 12,3 cm x 6,4 cm (**Sl. 2**). S donje je strane prirodno zaglađen utjecajem valova, a s gornje je potpuno gladak. Kako se radi o kamenu velike čvrstoće, bilo je potrebno dugotrajno i intenzivno trenje uslijed kojeg je dio kamena jednostavno abradirao, a to je rezultiralo nastankom izoštrenih bočnih rubova. Nije nam poznata namjena ovog oruđa očito prilagođenog krupnijoj ljudskoj šaci. Pretpostavljamo da je moglo biti korišteno kao gornji dio inačice prvobitnoga mlina, odnosno kao pomična ploha pri pretvaranju u prah nekog minerala ili, možda, hrane.[5]

Razlog zbog kojeg smo odlučili posvetiti posebnu pažnju upravo ovom predmetu leži u činjenicama da je njegov stratigrafski položaj neupitan te da kamen od kojeg je napravljen ne potječe s otoka Korčule. Određivanje ležišta iz kojeg je sirovina uzeta moglo bi nam olakšati preciznije određenje puteva razmjene u vrijeme mezolitika. Već je preliminarnom analizom utvrđeno da se radi o magmatskoj stijeni pa je i pitanje njenog porijekla suženo na samo nekoliko mogućih položaja.

and legs of the deceased child were bent, and the body was laid on its right flank. The arrangement of the surrounding rocks indicates the existence of rudimentary architecture. Grave 1 is approximately 50 cm from grave 2.

In the aforementioned works, it is unambiguously asserted that the appearance of these four graves should be placed during the period between the end of the Paleolithic and the beginning of the early Mesolithic. Radiocarbon dating from a probe with grave 2, obtained by analysis of a sample of charcoal taken from the bottom of an Impresso Neolithic sediment (with a dept of 164 cm; **Fig. 1**), places the beginning of the Neolithic at the end of the seventh millennium.[2] The Mesolithic (the seventh phase in the development of material culture) in Vela spila is stratigraphically very clearly separate from the Neolithic (Fig. 1, lower line), and it is present in sediments over 1.5 m thick. These sediments have been divided into upper and lower portions or, more precisely, into an older poorer, and younger richer developmental phase (Čečuk & Radić 2003). The accompanying items found during excavation of all four graves indicate with great certainty that they belong to the younger period, exceptionally rich in the remains of seafood (fish bones, shells, snails…). These facts, as well as the dates that we obtained using radioactive carbon C^{14} from the other probe, made it possible for us to set the appearance of this grave at a time prior to the second half of the seventh millennium BC,[3] but a more precise date will only be determined by future research.

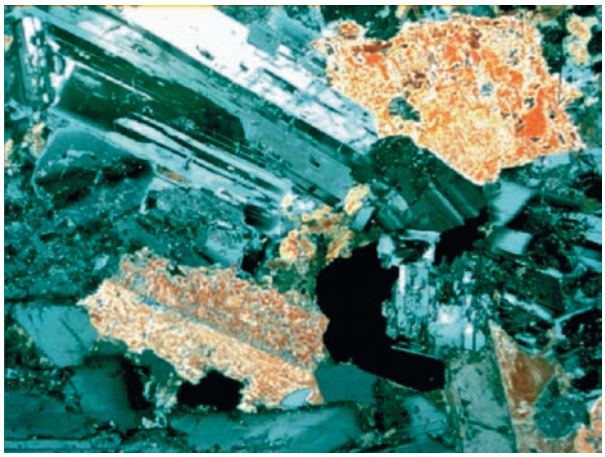
A stone artifact was found in grave 2, or rather in its immediate vicinity. Since it was found approximately 50 cm east of the head of the deceased, we can conclude that it is a grave good rather than an item lost by chance. It is a very regular, initially oval and subsequently worked round stone from the sea weighing 1,570 g,[4] with dimensions of roughly 17 cm x 12.3 cm x 6.4 cm (**Fig. 2**). The bottom has been naturally smoothed by waves, while the top is completely smooth. Since this is a highly solid rock, long-term and intense friction was required which resulted in part of the rock simply abrading, and this in turn produced sharpened lateral edges. The purpose of this implement, obviously meant for a larger human hand, could not be determined. We

[5] U Veloj spili nađeno je više desetaka komada morskih valutaka od istog ili vrlo sličnog kamena, kugla-satirača koje dolaze zajedno s vapnenačkim recipijentima (Čečuk&Radić 2005: 148, crtež 16) i raznih drugih ulomaka od valutaka eruptivnog porijekla, ali isključivo u neolitičkim naslagama. Slični valuci, uglavnom slomljeni, uobičajeni su na prapovijesnim gradinama na svim srednjodalmatinskim otocima, a u više navrata nalazili smo ih i na prostorima rimskih rustičnih vila.

[2] Ruđer Bošković Institute', Zagreb, no. 1967, charcoal, C^{14} age 7300±120 BP, calibrated age 6230–6000 BC.

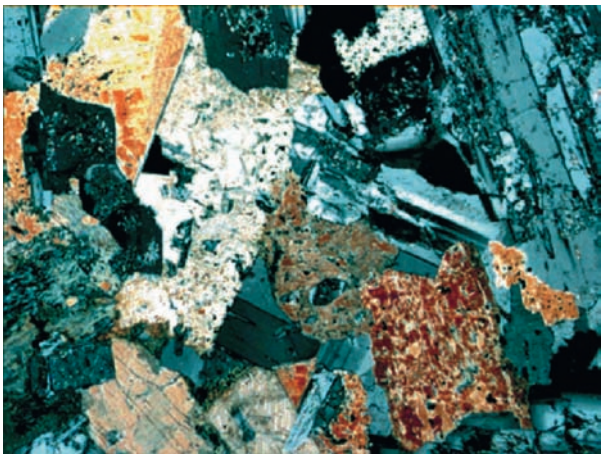
[3] VERA – 2344, Vela Spilja 9, Holzhohle, 8230 ± 35 bp; VERA – 2341, Vela Spilja 8C, Holzhohle, 8200 ± 30 bp; VERA – 2340, Vela Spilja 7 Holzhohle, 7000 ± 30 bp (see Čečuk & Radić 2003: 32–33).

[4] Weight prior to analysis was approximately 1,800 g; a piece of it was spent for analysis.



Slika 3. *Mikrofotografija uzorka artefakta iz Vele spile. Širina vidnog polja iznosi 2,7 mm. Struktura uzorka stijene kreće se od idiomorfno do hipidiomorfno zrnate s rijetkim mikrodomenama koje imaju krupnozrnatu, intergranularnu i ofitnu strukturu (dijabazna struktura). Plagioklasi i monoklinski pirokseni glavni su mineralni sastojci i zastupljeni su u približno podjednakoj količini. Ponekad se pojavljuju u obliku sraslaca dvojaca. Plagioklasi su uglavnom svježi, a monoklinski pirokseni samo djelomično alterirani u uralit. Stijena sadrži relativno obilno hipidiomorfno razvijene opâke minerale, a alotriomorfnog kvarca ima u značajnoj količini. Stijena je određena kao srednjozrnati gabrodiorit (snimio Boško Lugović).*

Figure 3. *Micro-photographs of a sample from the Vela spila artifact. The field of vision is 2.7 mm wide. The structure of the rock sample ranges from idiomorphic to hypidiomorphic grainy with rare micro-zones that have a coarse-grain, intergranular and ofite structure (diabasic structure). Plagioclases and monoclinic pyroxenes are the primary mineral components and they are present in relatively equal quantities. Sometimes they appear in the form of twin crystals. The plagioclases are generally fresher, while the monoclinic pyroxenes have partially altered into uralites. The rock contains relatively abundantly hypidiomorphically formed opaque minerals, and there is a considerable quantity of allotriomorphic quartz. The rock has been designated as a medium-grain gabbro-diorite (photo by Boško Lugović).*



Slika 4. *Mikrofotografija uzorka s Brusnika. Širina vidnoga polja iznosi 2,7 mm. Struktura uzorka valutka iz konglomerata s otoka Brusnika također se kreće od idiomorfno do hipidiomorfno zrnate s mikrodomenama krupnozrnate dijabazne strukture. Plagioklasi su obilnije zastupljeni u odnosu na monoklinske piroksene. Udio opâkih minerala je značajan. Stijena, za razliku od ostalih, pokazuje albitizaciju plagioklasa i relativno veći stupanj alteracije. Dosta često zapaža se pseudomorfoza aktinolita po monoklinskim piroksenima i izdvajanje epidota/coisita i kalcita unutar albitiziranih plagioklasa. Stijena je određena kao djelomično albitizirani gabrodiorit (snimio Boško Lugović).*

Figure 4. *Micro-photograph of sample from Brusnik. The field of vision is 2.7 mm wide. Structure of round stone from conglomerate rock from island of Brusnik also ranges from idiomorphic to hypidiomorphic grainy with micro-zones of coarse-grain diabasic structure. Plagioclases are more abundantly present in comparison to monoclinic pyroxenes. The share of opaque minerals is considerable. As opposed to others, this rock exhibits albitization of plagioclases and a relatively high degree of alteration. Pseudomorphosis of actinolites on the monoclinic pyroxenes and separation of epidotes/coisites and calcites within albitized plagioclases are very frequently observed. The rock has been designated as partially albitized gabbro-diorite (photo by Boško Lugović).*

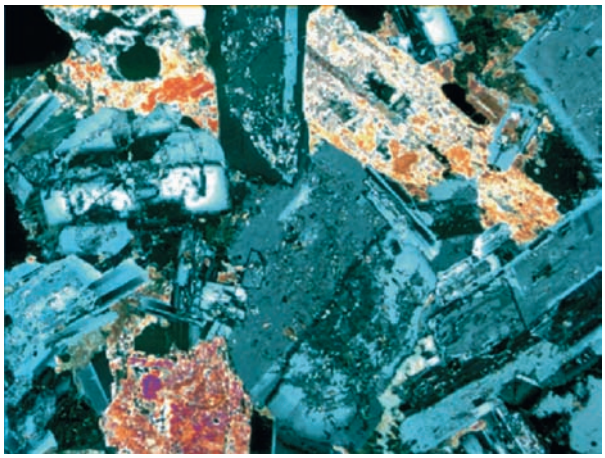
Magmatske stijene na Jadranu

Neki pučinski dalmatinski otoci predstavljaju izuzetak svojom geološkom građom jer su djelomično ili u potpunosti sastavljeni od magmatskih stijena. Pouzdano je utvrđeno da magmatske stijene postoje na Jabuci i na Brusniku, koji su u potpunosti sastavljeni od njih, te na Visu unutar trijaske vulkanogeno-sedimentne sukcesije (Barić 1961; Golub & Vragović 1975). Završni stadij kristalizacije, odnosno starost intruzije magme određuje se metodom K-Ar i Ar-Ar i iznosi oko 200 milijuna godina (Balogh *et al.* 1994).

have assumed that it could have been used as the upper part of an early variant of a millstone, or as the movable piece of a surface for turning a mineral or, perhaps, food, into powder.[5]

The reason we have decided to specifically focus on precisely this item lies in the fact that its stratigraphic position is unequivocal and that the rock from which it was made was not originally from Korčula.

[5] Over a dozen pieces of round stone originally from the sea were found in Vela spila made of the same or very similar rock, a grindstone which came together with its limestone receptacles (Čečuk & Radić 2004: 146, sketch 16) and various other fragments of round igneous stones, but exclusively in Neolithic deposits. Similar round stones, generally broken, are customary in prehistoric hillforts on all central Dalmatian islands, and on several occasions they were found in the rooms of Roman rustic villas.



Slika 5. *Uzorak valutka s Palagruže. Širina vidnoga polja iznosi 2,7 mm. Uzorak stijene je strukturno i mineraloški gotovo identičan uzorku iz Vele spile. Razlika je u jačoj sericitizaciji plagioklasa, uralitizaciji monoklinskih piroksena i ponešto manjem udjelu opâkih minerala. Plagioklasi i monoklinski pirokseni dosta često se pojavljuju u obliku tabularnih sraslaca dvojaca. Stijena je određena kao srednjozrnati gabrodiorit (snimio Boško Lugović).*

Figure 5. *Round stone sample from Palagruža. The field of vision is 2.7 mm wide. The rock sample is structurally and minerologically almost identical to the sample from Vela spila. The difference is in the more intense sericitization of plagioclases, uralitization of monoclinic pyroxenes and a slightly lower share of opaque minerals. The plagioclases and monoclinic pyroxenes quite frequently appear in the form of tabular twin crystals. The rock has been designated as a medium-grain gabbro-diorite (photo by Boško Lugović).*

Prvi pouzdani podaci o stijenama na Brusniku potječu od Hauera (1882), a na Jabuci od Foullona (1883). Prema relativno brojnim podacima iz postojeće literature, na ostalim otocima nema izdanaka magmatskih stijena. Recentna istraživanja ukazuju na značajno rasprostiranje magmatskih stijena u obliku hridi u podmorju oko spomenutoga otočja (Prelogović 2004: usmeno priopćenje). U blizini Jabuke postoji gabroidna hrid na dubini od 6 m čiji promjer iznosi oko 180 m (Juračić *et al.* 2004).

U publikacijama su magmatske stijene nazivane različitim imenima, a to je ovisilo o mišljenjima autora jesu li stijene vulkanske, hipabisalne ili intruzivne (pregledni prikaz u: Crnjaković 1998). U novijim radovima većina analiziranih uzoraka dobiva imena intruzivnih stijena, tj. gabrova (Balogh *et al*. 1994; Juračić *et al.* 2004).

Da bi se otkrilo mjesto uzimanja uzorka artefakta iz Vele spile, pomoću korelativnih su petrografskih i geokemijskih karakteristika analizirane stijene s pri-

The determination of the vein from which the raw material was taken may facilitate a more precise determination of exchange routes during the Mesolithic. A preliminary analysis already ascertained that it is a magmatic rock and that the matter of its origin has been narrowed to only several possible sites.

Magmatic rock on the Adriatic coast

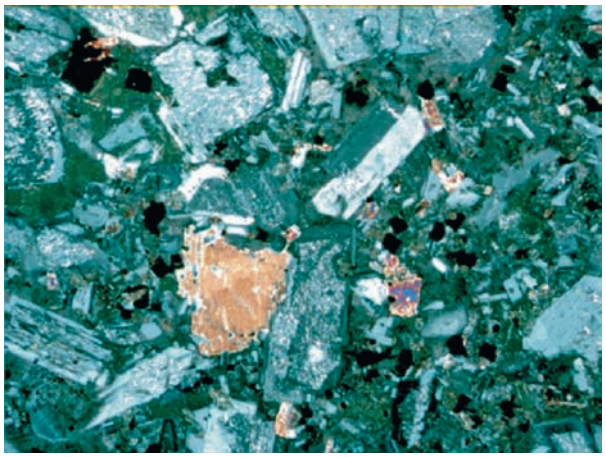
Some high-sea Dalmatian islands are exceptional in terms of their geological composition, as they are partially or completely made of magmatic rock. It has been reliably established that magmatic rock exists on Jabuka and Brusnik, which are formed completely from this type of rock, and on Vis within a Triassic igneous-sediment succession (Barić 1961; Golub & Vragović 1975). The final phase of crystallization, i.e. the age of magma intrusion, was determined using the K-Ar and Ar-Ar and is approximately 200 million years (Balogh *et al.* 1994).

The first reliable data on the rocks on Brusnik come from Hauer (1882), while those on Jabuka were provided by Foullon (1883). Based on relatively copious data from the existing literature, there are no traces of magmatic rock on other islands. Recent research indicates that there is range of magmatic rock in the form of undersea crags around the aforementioned islands (Prelogović 2004: verbal communication). There is a gabbroid crag near Jabuka at a depth of 6 m and a diameter of approximately 180 m (Juračić *et al.* 2004).

Magmatic rocks are referred to by various names in publications, and this depended on the author's opinion as to whether the rocks were igneous, hypabyssal or intrusive (see Crnjaković 1998 for a broad overview). In more recent works, most of the analyzed samples are referred to as intrusive rocks, i.e. gabbroidal (Balogh *et al.* 1994; Juračić *et al.* 2004).

In order to detect the location of extraction of the samples for the artifacts from Vela spila, correlative petrographic and geochemical characteristics were used to analyze rocks from the primary deposits on the islands of Brusnik (**Fig. 4**), Jabuka and Vis, near Komiža (Mušter site; **Fig. 6**) and one round stone from a secondary deposit on the island of Palagruža (Fig. 5).[6] Most of the samples macroscopically showed relatively coarse-grain structure and a massive, homogenous texture that recalls intrusive rocks.

[6] The analyzed round stone from Palagruža was brought to us by Jadranko Oreb, then the lighthouse-keeper on the island. Several times we have ourselves came upon some rocks on the Palagruža beach similar to those analyzed.



Slika 6. *Uzorak hawaiita s primarnoga ležišta Mušter u blizini Komiže. Širina vidnoga polja iznosi 2,7 mm. Stijena je porfirne strukture s puno fenokristala (polifirna struktura). Fenokristali su pretežno četverouglasti idiomorfni plagioklasi, a rjeđe idiomorfni i hipidiomorfni monoklinski pirokseni koji pojavnošću odgovaraju dijalagu. Plagioklasi znaju biti blago sericitizirani, a dijalag neznatno kloritiziran. Matriks je intersertalne strukture sa neorijentiranim štapićastim plagioklasima, monoklinskim piroksenima i relativno obilno zastupljenim opâkim mineralima. U intersticijama u matriksu nalazi se crvenkastosmećkasta prozirna kriptokristalasta masa s ponešto hematita koja predstavlja devitrificirano vulkansko staklo. U matriksu se nalaze gnijezda ispunjena prehnitom ili kloritom, vjerojatno ranije vezikule popunjene sekundarnim mineralima. Stijena je na temelju mikroskopskih opažanja određena kao andezit (snimio Boško Lugović).*

Figure 6. *Hawaiite sample from the primary deposit at Mušter, near Komiža. The field of vision is 2.7 mm wide. The rock has a porphyric structure with many phenocrystals (polyphyric structure). The phenocrystals are predominantly quadrilateral idiomorphic plagioclases, and less often idiomorphic and hypidiomorphic monoclinic pyroxenes which in terms of appearance correspond to diallages. The plagioclases can be slightly sericitized, and the diallages insignificantly chloritized. The matrix has an intersertal structure with non-oriented columnar plagioclases, monoclinic pyroxenes and relatively abundantly present opaque minerals. There is a reddish brown transparent cryptocrystalline mass in the interstices in the matrix with some hematites that represent devitrified volcanic glass. There is a nest in the matrix filled with prehnite and chlorite, probably an earlier vesicle filled with secondary minerals. Based on microscopic observation, the rock has been designated as andesite (photo by Boško Lugović).*

marnih ležišta na otocima Brusniku (**Sl. 4**), Jabuci i Visu u okolici Komiže (lokalitet Mušter; **Sl. 6**) te jedan valutak iz sekundarnoga ležišta s otoka Palagruže (**Sl. 5**).[6] Većina uzoraka makroskopski pokazuje

[6] Analiziran valutak s Palagruže donio nam je Jadranko Oreb, tadašnji svjetioničar na otoku. U više smo navrata i sami na palagruškom žalu među ostalim kamenjem nailazili na poneki identičan analiziranom.

Petrographic analysis of magmatic rocks

The micro-physiographic features of the rock samples were analyzed with the help of a polarization microscope. The artifact sample from Vela spila, the sample from Brusnik and the round stone sample from Palagruža display a very similar, typically hypidiomorphic structure, while the sample from Komiža has a hypohyaline porphyric structure. The Mušter site at Komiža can definitely be excluded as a possible source for the artifacts. Generally the rock samples are very fresh and largely composed of plagioclases, monoclinic pyroxenes and opaque minerals. Among the alterations, the uralitization of the monoclinic pyroxenes is significant, while the albitization of the plagioclases is only very rarely noted. There is brown volcanic glass in the hawaiite sample from the Mušter area.

Since not one analyzed rock sample shows signs of accumulation of crystallized minerals and thereby does not constitute a cumulate, it can be assumed that the rocks are original magma that crystallized on a sub-volcanic level. The chemical composition of such rocks can be shown in diagrams otherwise used to classify and designate the nomenclature of effusive rocks (**Fig. 7** and **8**).

Geochemical analysis of magmatic rocks

The chemical analysis of the samples are provided in Table 1. The principal elements (in mass percentage), standard trace elements and rare earth elements (in ppm units) are analyzed. Based on a comparison of concentrations of the major diagnostic elements in the Vela spila artifact and the other samples, the origin, or site of extraction of raw materials to make the artifact, can be very reliably ascertained.

Diagram ($Na_2O + K_2O$) – SiO_2 serves to classify and designate extrusive, i.e. igneous and superficially deposited sub-igneous rock. The artifact from Vela spila, the round stone sample from Palagruža and the sample from Jabuka exhibit exceptional geochemical correspondence and they are within the range of basaltic andesites. The pebble sample from Brusnik has been projected at the very boundary of basaltic andesites, while the sample from Komiža is in the range of hawaiites (**Fig. 7**).

In diagram K_2O – SiO_2, rocks are classified and grouped based on whether they belong to a corresponding series of rocks. The samples from Vela spila, Palagruža and Jabuka, together with the data

Tablica 1. Kemijske analize uzoraka stijena / Table 1. Chemical analysis of rock samples					
Uzorak/Sample	Vela spila	Palagruža	Brusnik	Komiža	Jabuka
SiO_2	52,97	53,48	53,88	53,86	52,10
TiO_2	0,95	0,74	0,85	0,71	0,90
Al_2O_3	18,27	19,98	19,45	19,26	16,70
Fe_2O_3	9,61	8,51	8,41	8,81	11,16
MnO	0,14	0,16	0,09	0,12	0,21
MgO	2,81	2,38	2,46	3,05	4,56
CaO	9,57	9,19	8,61	5,48	7,64
Na_2O	2,84	2,99	4,79	4,42	3,11
K_2O	1,58	1,53	0,66	2,04	1,37
P_2O_5	0,18	0,17	0,19	0,16	0,18
G.Ž.	1,00	1,05	0,71	2,18	2,19
Ukupno / Total (%)	99,92	100,18	100,10	100,09	100,12
Sadržaj u ppm-jedinicama mase (μg/g) / Content in ppm mass units (μg/g)					
Cs	0,77	1,06	0,78	1,21	1,44
Rb	27	33	11	46	38
Ba	448	469	216	488	329
Th	5,03	5,05	4,80	5,46	4,42
U	1,21	1,18	1,08	1,17	1,20
Ta	0,14	0,14	0,15	0,13	0,16
Nb	4,31	7,83	5,27	3,39	2,60
Pb	<5	<5	12,88	6,29	<5
Sr	395	439	398	389	302
Zr	67	73	66	63	69
Hf	2,03	2,18	2,14	1,82	1,69
Y	21	18	19	20	21
Cr	20	<20	<20	<20	60
Ni	22	>20	<20	<20	20
Sc	32	27	29	28	38
V	286	208	247	182	n.o.
Co	22,42	22,75	19,10	20,42	n.o.
Cu	19,05	31,57	46,15	29,34	n.o.
Zn	54,93	85,80	33,68	72,22	n.o.
Ga	18,53	19,07	19,36	17,43	n.o.
Ge	1,20	1,27	1,35	1,03	n.o.
La	14,14	10,00	10,57	14,83	14,90
Ce	28,90	21,87	22,89	30,51	30,00
Pr	3,56	2,91	3,06	3,74	n.o.
Nd	15,13	12,93	13,41	14,88	13,60
Sm	3,69	3,36	3,38	3,54	3,70
Eu	0,99	1,02	1,00	0,93	1,03
Gd	3,79	3,44	3,52	3,36	3,50
Tb	0,66	0,60	0,61	0,59	0,60
Dy	3,89	3,45	3,58	3,44	n.o.
Ho	0,82	0,73	0,76	0,72	0,83
Er	2,31	2,13	2,18	2,09	n.o.
Tm	0,35	0,32	0,33	0,31	0,34
Yb	2,26	2,05	2,18	1,96	2,10
Lu	0,36	0,33	0,34	0,32	0,30

Fe_2O_3 – ukupno željezo u trovalentnom obliku; **G.Ž.** – gubitak mase uzorka pri žarenju;
n.o. – nije određivano; < – manje od (granica detekcije);

Fe_2O_3 – total iron in trivalent form; **G.Ž.** – loss of mass when super-heated;
n.o. – not specified; < – less than (detection threshold).

relativno krupnozrnatu strukturu i masivnu, homogenu teksturu te podsjeća na intruzivne stijene.

Petrografska analiza magmatskih stijena

Mikrofiziografske značajke uzoraka stijena analizirane su pomoću polarizacijskog mikroskopa. Uzorak artefakta iz Vele spile, uzorak s Brusnika i uzorak valutka s Palagruže pokazuju vrlo sličnu, tipičnu hipidiomorfnu strukturu, a uzorak iz Komiže ima hipohijalinu porfirnu strukturu. Lokalitet Mušter kod Komiže može se pouzdano isključiti kao moguće izvorište artefakta. Općenito, uzorci stijena vrlo su svježi i pretežno su izgrađeni od plagioklasa, monoklinskog piroksena i neprozirnih (opâkih) minerala. Od alteracija značajna je uralitizacija monoklinskih piroksena, dok se albitizacija plagioklasa opaža vrlo rijetko. U uzorku hawaiita iz okoline Muštera ima smeđeg svježeg vulkanskog stakla.

Budući da nijedan analizirani uzorak stijena ne pokazuje znakove kumulacije kristaliziranih minerala te zbog toga ne predstavlja kumulatne stijene, može se pretpostaviti da stijene predstavljaju originalnu magmu koja je kristalizirala na subvulkanskoj razini. Kemijski sastav takvih stijena može se prikazati u dijagramima koji se i inače koriste za klasifikaciju i nomenklaturu efuzivnih stijena (**Sl. 7** i **8**).

Geokemijska analiza magmatskih stijena

Kemijske analize uzoraka dane su u **Tablici 1**. Analizirani su glavni elementi (u masenim postocima), standardni elementi u tragovima i elementi rijetkih zemalja (u ppm-jedinicama). Na temelju usporedbe koncentracija važnih dijagnostičkih elemenata u artefaktu Vele spile i ostalih uzoraka može se vrlo pouzdano utvrditi podrijetlo odnosno lokacija uzimanja sirovine za izradbu artefakta.

Dijagram ($Na_2O + K_2O$) – SiO_2 služi za klasifikaciju i nomenklaturu ekstruzivnih, tj. vulkanskih i plitko položenih subvulkanskih stijena. Artefakt iz Vele spile, uzorak valutka s Palagruže i uzorak s Jabuke pokazuju iznimnu geokemijsku podudarnost i nalaze se u polju bazaltičnih andezita. Uzorak valutice s Brusnika projicira se točno na granici bazaltičnih andezita, dok se uzorak iz Komiže nalazi u polju hawaiita (**Sl. 7**).

U dijagramu K_2O – SiO_2 stijene se klasificiraju i razvrstavaju s obzirom na pripadnost odgovarajućoj seriji stijena. Uzorci iz Vele spile, s Palagruže i s Jabuke zajedno s podacima iz literature formiraju contained in the literature, form a clear trend from basalt to basaltic andesites of the calcium-alkali series of rock. The Komiža effusive rocks are members of the high-potassium calcium-alkali series, while the eruptive rocks from Brusnik generally belong to the low-potassium series of rock.

Based on the position of the points of analyzed rock samples in the aforementioned diagrams, it can be concluded that Palagruža and Jabuka are possible sources of the artifacts from Vela spila.

The diagram in Figure 9 shows the *relative* concentration of analyzed principal elements and trace elements. Elements are arranged left to right according to rising atomic numbers, and standardized based on the concentration in the sample from the Vela spila artifact. It is clear from the diagram that the sample from the Vela spila artifact is rich in Mg, Sc, Mn, Rb and Cs, with meager amounts of Al, K, Ca, Sr, Nb, Ba in comparison to the artifact sample from Jabuka. The most similar chemical composition can be found in the pebble from the secondary deposit on Palagruža.[7] The high correspondence of concentrations of heavy rare metals, from Sm to Lu and other elements to the right, indicate a genetic link between all analyzed samples. All of them belong to the same magmatic mass.

Conclusion

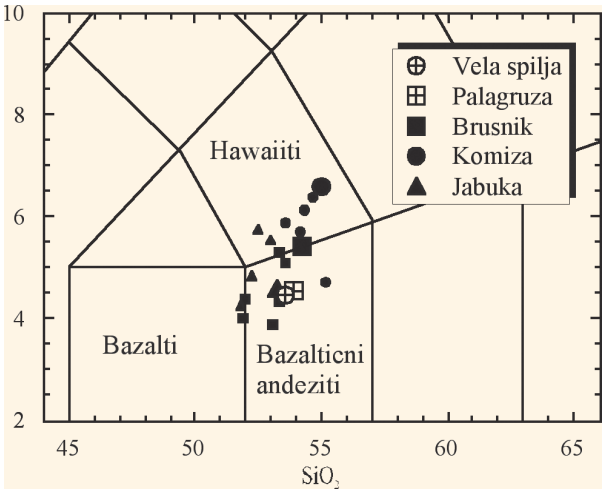
Based on the macroscopic and microscopic features of the analyzed samples of rock and the geochemical properties, we can conclude that the sample from the secondary deposit from Palagruža is the most similar to the sample from the Vela spila artifact.

The find of an artifact in Vela spila made of rock from Palagruža, 42 nautical miles away, unambiguously confirms the existence of navigation between these two points during the Mesolithic. Based on knowledge of geographic relations (**see Fig. 10**) and navigation in somewhat more recent periods, we assume that Palagruža was only a stopover on routes between the eastern and western Adriatic coast (Radić 2003: 305–308).[8]

At the end of the Pleistocene (and the early Stone Age) an already well-known climatic disorder occurred which led to drastic warming and a rise in the

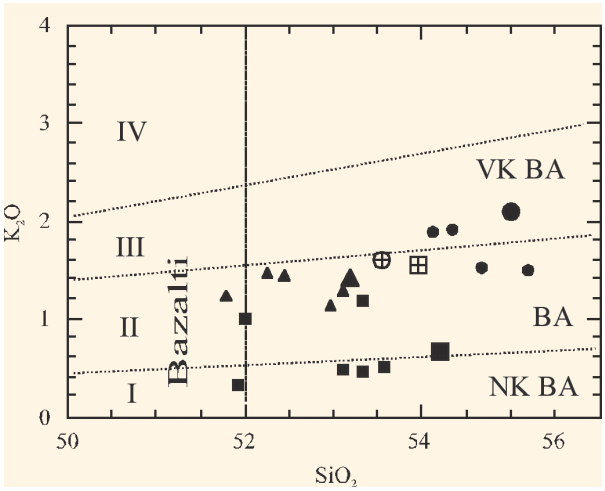
[7] Palagruža is not a volcanic island, so the round stone comes from one of the nearby undersea crags which were visible during the Mesolithic, or the round stone was simply tossed ashore by waves.

[8] The distance between Palagruža and Gargano is approximately 28 nautical miles, and with moderate visibility this Apennine mountain, over 1 km high, can be easily seen from Palagruža.



Slika 7. *Prikaz analiziranih uzoraka u dijagramu ($Na_2O + K_2O$) – SiO_2 (IUGS TAS dijagram; le Bas* ***et al.*** *1986). Također su, manjim simbolima, prikazani relevantni i pouzdani podaci analiza navedeni u ranijim publikacijama (Golub & Vragović 1975; Balogh* ***et al.*** *1994). Analizirani uzorci s Palagruže, Jabuke i iz Vele spile blisko se projiciraju u polju bazaltičnih andezita, uzorak s Brusnika u graničnom području, a uzorak iz Komiže u polju hawaiita (autor: Boško Lugović).*

Figure 7. *Analyzed samples in the diagram ($Na_2O + K_2O$) – SiO_2 (IUGS TAS diagram; Le Bas* ***et al.*** *1986). Also shown, in smaller symbols, are the relevant and reliable data of analyses cited in earlier publications (Golub & Vragović 1975; Balogh* ***et al.*** *1994). The analyzed samples from Palagruža, Jabuka and Vela spila are closely projected in the range of basaltic andesites, while the sample from Brusnik is at the boundary, and the sample from Komiža is in the hawaiite range (by Boško Lugović).*



Slika 8. *Prikaz analiziranih uzoraka u dijagramu K_2O – SiO_2 za nomenklaturu ekstruzivnih stijena i njihovo razvrstavanje s obzirom na pripadnost seriji stijena (Peccerillo & Taylor 1976). Simboli su: NK i I – nisko-kalijska serija stijena; II – kalcijsko-alkalijska serija stijena; VK i III – visoko-kalijska kalcijsko-alkalijska serija stijena; IV – šošonitna serija stijena, BA = bazaltični andeziti. Uzorci s Palagruže, Jabuke i iz Vele spile blisko se projiciraju u polju bazaltičnih andezita, uzorak s Brusnika u granično polje prema nisko-kalijskim bazaltičnim andezitima, a uzorak s Visa nalazi se u polju visoko-kalijskih kalcijsko-alkalijskih bazaltičnih andezita (autor: Boško Lugović).*

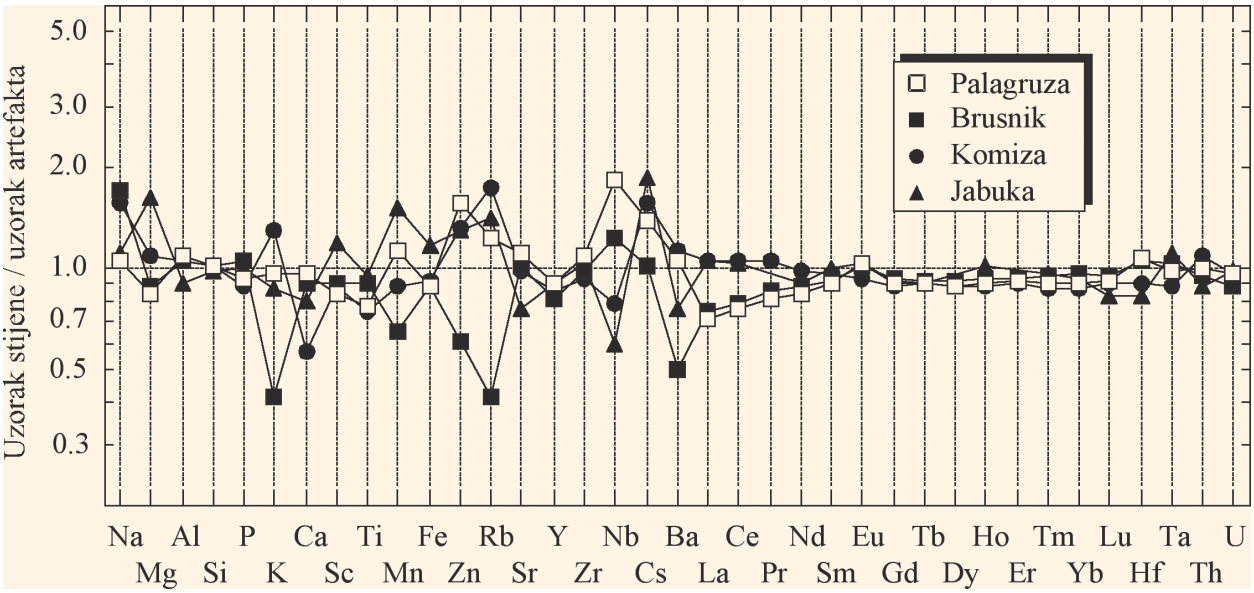
Figure 8. *Samples analyzed in diagram K_2O – SiO_2 for extrusive rock nomenclature and their classification with regard to affiliation with a rock series (Peccerillo & Taylor 1976). The symbols are: NK i I – low-potassium rock series; II – calcium-alkali rock series; VK i III – high-potassium calcium-alkali rock series; IV – shoshonite rock series, BA = basaltic andesites. Samples from Palagruža, Jabuka and are closely projected in the range of basaltic andesites, while the sample from Brusnik is at the boundary with low-potassium basaltic andesites, and the sample from Vis is in the range of high-potassium calcium-alkali basaltic andesites (by Boško Lugović).*

ju jasan trend od bazalta do bazaltičnih andezita kalcijsko-alkalijske serije stijena. Komiške efuzivne stijene članovi su visoko-kalijske kalcijsko-alkalijske serije, a eruptivi s Brusnika uglavnom pripadaju nisko-kalijskoj seriji stijena.

Na temelju položaja točaka analiziranih uzoraka stijena u navedenim dijagramima može se zaključiti da su Palagruža i Jabuka moguća izvorišta artefakta iz Vele spile.

U dijagramu na slici 9 prikazana je *relativna* koncentracija analiziranih glavnih elementa i elemenata u tragovima. Elementi su poredani slijeva nadesno po rastućemu atomskom broju i normirani su prema koncentraciji u uzorku artefakta iz Vele spile. Iz dijagrama se vidi da je uzorak artefakta iz Vele spile bogat elementima Mg, Sc, Mn, Rb i Cs, a siromašan elementima Al, K, Ca, Sr, Nb, Ba u odnosu na uzorak artefakta s Jabuke. Najsličniji kemijski sastav ima valutica sa sekundarnoga nalazišta na Palagru-

level of the Adriatic by over ten meters (van Andel & Shackleton 1982; Forenbaher 2002). These considerable changes led to the flooding of some former large plains, the withdrawal of river mouths and the disappearance of Paleolithic fauna and Paleolithic big animal hunters (see Basler 1983: 32 and further; Mithen 1994; Čečuk & Radić 2003: 28–29). At the start of the Mesolithic, the process of formation of the coast and islands, when they assumed their current configuration and karst character, was largely complete. Under these new circumstances, the sea divided a once unified space, so that mastery of sailing and navigation became necessary to recreate this former link. The details of this process have still not been ascertained, particularly the technical de-



Slika 9. *Kemijski sastav stijena normiran s obzirom na artefakt iz Vele spile radi usporedbe geokemijskih karakteristika te pronalaženja sličnosti i mjesta podrijetla. Taj je artefakt najsličniji valutici s Palagruže (autor: Boško Lugović).*

Figure 9. *Chemical system standardized with regard to the artifact from Vela spila for comparison of geochemical characteristics and determination of similarities and point of origin. This artifact is most similar to the pebble from Palagruža (by Boško Lugović).*

ži.[7] Velika podudarnost koncentracija teških rijetkih zemalja, od Sm do Lu i ostalih elemenata udesno, ukazuje na genetsku povezanost svih analiziranih uzoraka. Svi oni pripadaju istoj magmatskoj svojti.

Zaključak

Na temelju makroskopskih i mikrofiziografskih značajki analiziranih uzoraka stijena te geokemijskih svojstava možemo zaključiti da je uzorak valutka sa sekundarnog nalazišta s Palagruže najsličniji uzorku artefakta iz Vele spile.

Nalaz artefakta od kamena s Palagruže u Veloj Spili, udaljenoj 42 nautičke milje, nedvosmisleno potvrđuje plovidbu tijekom mezolitika između tih dviju točaka. Na temelju poznavanja zemljopisnih relacija (vidi **Sl. 10**) i navigacije u nešto mlađim razdobljima, pretpostavljamo da je Palagruža bila samo postaja na putu između istočne i zapadne obale Jadrana (Radić 2003: 305–308).[8]

Slika 10. *1 – Vela spila, 2 – Palagruža, 3 – Komiža, 4 – Brusnik i 5 – Jabuka (autor: Dino Cetinić).*

Figure 10. *1 – Vela spila, 2 – Palagruža, 3 – Komiža, 4 – Brusnik and 5 – Jabuka (by Dino Cetinić).*

[7] Palagruža nije vulkanski otok pa valutak potječe s neke bliske podmorske hridi koja je tijekom mezolitika bila vidljiva ili su valovi jednostavno izbacili valutak na žalo.

[8] Udaljenost između Palagruže i Gargana iznosi oko 28 nautičkih milja i za osrednje vidljivosti s Palagruže se lako može vidjeti ta Apeninska gora visoka jedan kilometar.

tails tied to the construction of seafaring craft, their size and maritime qualities. The planned petrographic analysis of items from the Paleolithic (Epi-

Krajem pleistocena (i starijega kamenog doba) zbio se poznat klimatski poremećaj uslijed kojeg je došlo do naglog zatopljenja i do uzdizanja razine Jadranskoga mora za više desetaka metara (van Andel & Shackleton 1982; Forenbaher 2002). Te značajne promjene dovode do potapanja nekadašnjih velikih ravnica, povlačenja ušća rijeka te nestanka paleolitičke faune i paleolitičkih lovaca na krupne životinje (vidi Basler 1983: 32 i dalje; Mithen 1994; Čečuk & Radić 2003: 28–29). Početkom mezolitika uglavnom je već završen proces oblikovanja obale i otoka koji poprimaju današnju konfiguraciju i krški karakter. U novim okolnostima more razdvaja nekadašnji cjelovit prostor pa ga uvođenjem plovidbe i navigacije treba ponovo povezati. Detalji tog procesa nisu nam još poznati, posebno tehničke pojedinosti vezane uz konstrukciju plovila, njihovu veličinu i maritimna svojstva. Planirana petrografska analiza predmeta iz paleolitičkih (epigravetijenskih) i mezolitičkih naslaga s naše i suprotne obale (uz komparativnu studiju kamene industrije) pokazat će koliko su korištena ista ležišta[9], a iz njihovog podudaranja mogu proizaći implikacije na društvene odnose i smjer širenja tadašnje populacije.

gravettian) and Mesolithic strata from the Croatian and opposite coasts (with comparative analysis of the rock industries) will show the extent to which the same deposits were used,[9] and correspondence between them may indicate implications for social relations and the directions in which the population of the time spread.

[9] Poznata je činjenica da poluotok Gargano obiluje brojnim ležištima kvalitetnog kremena koji je korišten tijekom prapovijesti (usporedi sa Spataro 2002: 11). Ležišta rožnjaka lošije kvalitete poznata su i na Palagruži, ali i na samoj Korčuli.

[9] It is a well-known fact that the Gargano Peninsula is abundant in deposits of quality flint which was used during prehistory (cf. Spataro 2002: 11). Lower quality chert deposits are also known to exist on Palagruža, and on Korčula itself.

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