Dinko RADIĆ, Boško LUGOVIĆ & Ljerka MARJANAC

Napuljski žuti tuf (NYT) iz pleistocenskih naslaga u Veloj spili na Korčuli: dragocjeni marker prijelaza iz paleolitika u mezolitik

Neapolitan Yellow Tuff (NYT) from the Pleistocene sediments in Vela Spila on the island of Korčula: a valuable chronostratigraphic marker of the transition from the Palaeolithic to the Mesolithic

Izvorni znanstveni članak / Original scientific paper

UDK: 902.035:551.217(497.5 Korčula)"632/633"
Primljeno / Received: 8. 12. 2006.
Prihvaćeno / Accepted: 4. 6. 2007.

Dinko Radić
Centar za kulturu – Arheološka zbirka
HR – 20270 Vela Luka
dinkoradic@net.hr

Boško Lugović
Rudarsko-geološko-naftni fakultet
Pierottijeva 6
HR – 10000 Zagreb
blugovic@rgn.hr

Ljerka Marjanac
Zavod za paleontologiju
i geologiju kvartara HAZU
A. Kovačića 5
HR – 10000 Zagreb
ljerka@hazu.hr

Sivo-pepeljasti sloj i pepeljasta leća otkopani u Veloj spili na Korčuli na dubini od oko 5,80 m, odnosno 6,25 m, sastoje se od vulkanskoga pepela izbačenoga tijekom erupcije napuljskoga žutog tufa (NYT) prije približno petnaest tisuća godina i tijekom erupcije piroklastike Ponti Rossi prije šesnaest tisuća godina na Flegrejskim poljima pokraj Napulja. Na spomenutome području, ali i na drugim vulkanskim područjima, dobro su istražene i radioizotopnim metodama K-Ar i $^{40}Ar/^{39}Ar$ izravno datirane brojne erupcije čiji distalno istaloženi prah i pepeo (tefra) mogu poslužiti za realnije datiranje arheoloških događaja od dosad uobičajenih načina. Sloj NYT stratigrafski je smješten na vrhu pleistocenskih taložina vrlo bogatih ostacima koji ukazuju na ljudsko djelovanje. Te su taložine po sadržaju i po svojstvima potpuno drukčije od sloja nastaloga u ranome holocenu. U kulturnome smislu sloj NYT smještamo na kraj paleolitika. Sloj iznad njega pripada samomu kraju paleolitika, a naredni označava početak mezolitika. Kraj pleistocena posebno je zanimljiv jer označava vrijeme tijekom kojega se uzdiže razina mora, mijenjaju se klima te biljni i životinjski svijet, zbog čega dolazi do značajnih promjena u egzistenciji ljudske zajednice, koja je morala mijenjati strategiju preživljavanja. Kao posebno se

The layer of grey ash and ash-lens excavated in Vela Spila Cave on the island of Korčula at a depth of approximately 5.8 m, and 6.25 m, consist respectively of volcanic ash ejected during the eruption of Neapolitan Yellow Tuff (NYT) roughly 15 ka ago and during eruption of the Ponti Rossi pyroclastics 16 ka ago in the Phlegraean Fields near Naples. In this area, and in other volcano zones, a number of eruptions have been thoroughly examined and directly dated by K-Ar and $^{40}Ar/^{39}Ar$ dating methods, and their distal deposited dust and ash (tephra) can serve to date archaeological events more accurately than previously customary methods. The NYT layer is stratigraphically situated atop Pleistocene sediments rich in remains indicating human activity. The composition and properties of these sediments make them entirely different from the layers deposited in the Early Holocene. In the cultural sense, the NYT layer is placed at the end of the Palaeolithic. The layer above it belongs to the uppermost Palaeolithic, while the subsequent layer marks the beginning of the Mesolithic. The end of the Pleistocene is particularly interesting as it indicates an era when sea levels rose and the climate, flora and fauna underwent changes, which in turn led to significant change in the existence of human communities, which had to adjust their survival strategies. A particular question that arises is the impact of cataclysmic volcanic *pitanje nameće utjecaj kataklizmičkih erupcija na okoliš, a samim time i na razvitak ljudske zajednice, odnosno pojedinih prapovijesnih kultura.*

Ključne riječi: distalna tefra, napuljski žuti tuf, piroklastika Ponti Rossi, arheološki markeri, pleistocen, epigravetijen, Vela spila, Korčula, Hrvatska

eruptions on the ecology of the environment and, consequently, on the development of human communities and individual prehistoric cultures.

Key words: distal tephra, Neapolitan Yellow Tuff, Ponti Rossi pyroclastics, archaeological markers, Pleistocene, Epigravettien, Vela Spila, Korčula, Croatia

Uvod

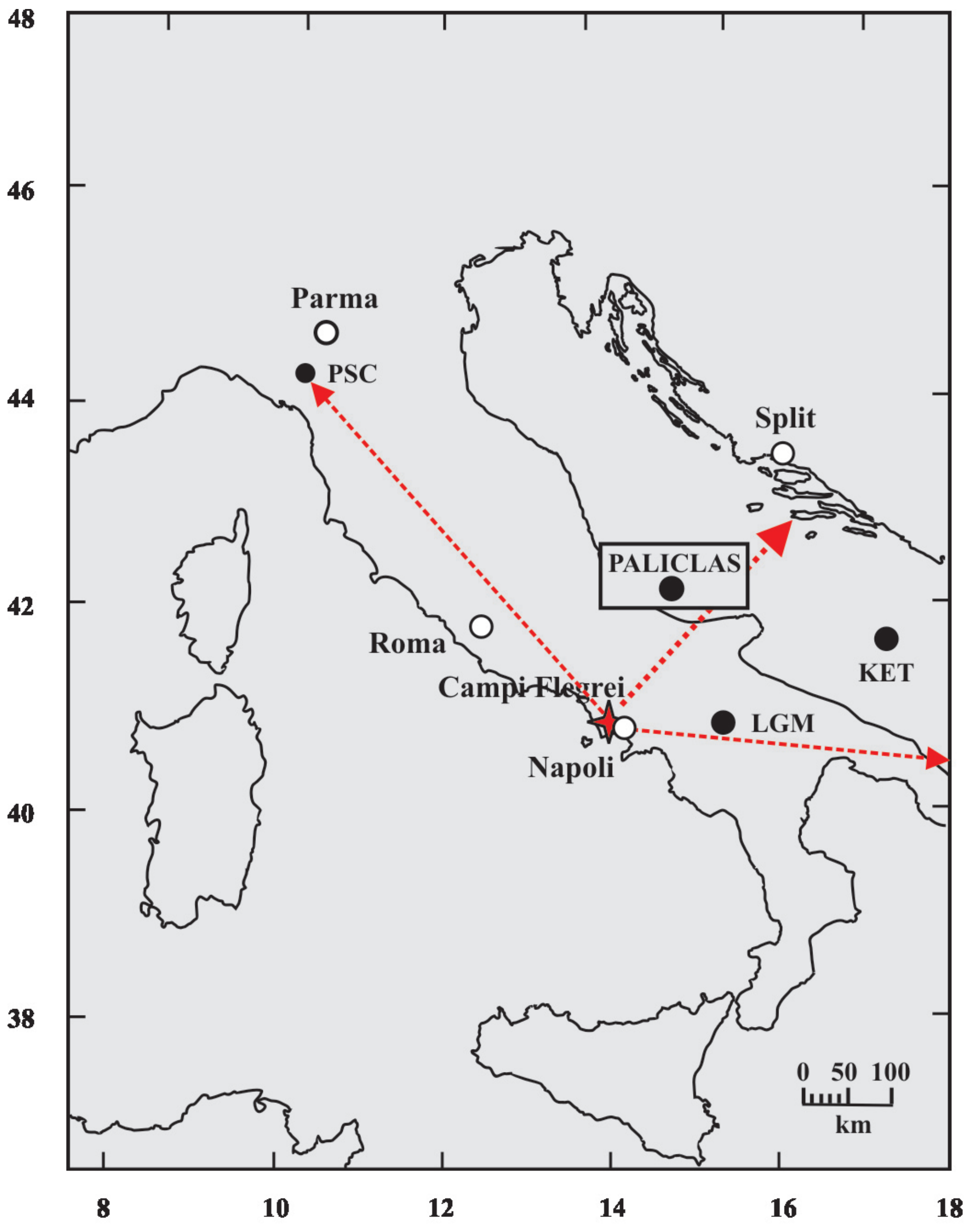
Vulkanska erupcija predstavlja, u geološkome poimanju vremena, vrlo kratkotrajan čin. Jačina erupcije i količina izbačenoga vulkanskog materijala znatno varira ovisno o odnosu fizikalno-kemijskih parametara unutar magmatskoga ognjišta. Freatoplinijske i freatomagmatske erupcije mogu imati kataklizmičke razmjere pri čemu se vulkanski prah i pepeo talože na velikoj površini, vrlo daleko od matičnoga vulkana (distalna tefra). Kako svaka vulkanska erupcija ima posebne geokemijske karakteristike, analizom kemijskoga sastava vitričnih krhotina relativno je lako odrediti izvorno vulkansko područje i matični vulkan te na taj način posredno doznati vrijeme taloženja tefre. Pri određivanju starosti rezultati dobiveni za interstratificirani (anorganski) vulkanski materijal ne zahtijevaju kalibraciju izmjerene vrijednosti i zato realnije odražavaju datirane događaje u odnosu na starost dobivenu analizom ^{14}C AMS na uzorcima organskoga materijala pronađenoga na natačoženome vulkanskom materijalu ili ispod njega. Ta se spoznaja koristi za datiranje mlađih geoloških i starijih arheoloških događaja, naročito onih izvan vremenski pouzdanoga dosega metode ^{14}C AMS, i tako promiče naslage tefre u savršeni kronološki marker u regionalnim razmjerima.

Predmet ovoga rada dvije su pojave tefre u slijedu pleistocenskih naslaga koje predstavljaju završni dio paleolitika i smjenu epigravetijena najstarijom mezolitičkom kulturom u Veloj spili na otoku Korčuli. Na temelju geokemijskih i morfoloških obilježja čestica tefre nedvojbeno je identificirano matično vulkansko izvorište u području Flegrejskih polja (*Campi Flegrei – Phlegrean Fields*) zapadno od Napulja, a time je determinirano i vrijeme taloženja vulkanskoga pepela u tefri. S obzirom na silinu erupcije zabilježenu jasno vidljivim slojem tefre udaljenom više od 350 km od matičnoga vulkana, na primjeru Vele spile analizira se odraz tektonskih zbivanja i klimatskih promjena na paleookoliš, a time i na ljudsku djelatnost prije približno 14,9 tisuća godina, odnosno krajem zadnje pleistocenske oledbe. To prijelazno razdoblje (sve do početka holocena) u središnjemu sredozemnom prostoru obilježeno je erupcijom napuljskoga žutog tufa (NYT).

Introduction

In the geological meaning of time, a volcanic eruption is a very brief event. The intensity of an eruption and the quantity of volcanic materials ejected vary considerably depending on the physical and chemical parameters within the magmatic chamber. Phreatoplinian and phreatomagmatic eruptions can achieve cataclysmic proportions, and the volcanic dust and ash then accumulate over a large area, very far from the erupting volcano (distal tephra). Since each volcanic eruption has specific geochemical characteristics, an analysis of the composition of vitric particles makes it relatively simple to determine the original volcanic provenience and the original volcano and thus indirectly ascertain the time of tephra deposition. When computing age, the results obtained for interstratified volcanic materials do not require calibration of measured values and thus more realistically reflect dates of events compared to the age obtained by ^{14}C accelerator mass spectometry (AMS) analysis on samples of organic materials found in overlying or underlying sediments. This knowledge is used to date more recent geological and older archaeological events, particularly those outside of the chronologically reliable limits of the ^{14}C AMS method, thus promoting tephra deposits into a perfect chronological marker in regional sense.

The subject of this paper are two appearances of tephra in the sequence of Pleistocene sediments which constitute the uppermost Palaeolithic and the turn of the Epigravettien into the oldest Mesolithic culture in Vela Spila Cave on the island of Korčula. Based on the geochemical and morphological features of the tephra particles, the original volcanic source was identified in the Phlegraean Fields (Campi Flegrei) west of Naples, Italy, and, consequently, the time of deposition of the volcanic ash into tephra was also inferred. Concerning the intensity of the eruption, indicated by the thick, clearly visibly tephra layer over 350 km from the original volcano, the Vela Spila site is used to analyse the impact of tectonic events and climate change on the palaeo-environment, and thereby on human activity roughly at 14.9 thousand years ago, i.e. at the end of the last Pleistocene glaciation. This transition period (up to the beginning of the Holocene) was



Karta 1. Lokacije tefre raspršene u smjeru sjeverozapad – istok pripisane erupciji napuljskoga žutog tufa (NYT) iz kaldere locirane u Flegrejskim poljima. Područje raspršenja omeđeno je nalazištima NYT-a u sjevernim Apeninima (pozicija PSC; Davies et al. *2002), u sedimentima jezera Lago Grande di Monticchio (pozicija LGM; Wulf 2000) i ekvivalentnim markerima tefre C2 nabušenima u središnjemu (Calanchi* et al. *1998; projekt PALIKLAS) i južnome jadranskom podmorju (pozicija KET; Paterne* et al. *1988). Strelicom je prikazan položaj Vele spile na Korčuli (autor: B. Lugović, 2005).*

Map 1. Location of tephra dispersed in the north-west/easterly direction addressed to the eruption of Neapolitan Yellow Tuff (NYT) from the caldera located in the Phlegraean Fields. The dispersal zone is encountered by findings of NYT in the northern Apennines (position PSC; Davies et al. *2002), in the deposits of Lago Grande di Monticchio (position LGM; Wulf 2000) and the C2 tephra equivalent markers drilled in the central (Calanchi* et al. *1998; PALIKLAS Project) and southern Adriatic Sea-floor (position KET; Paterne* et al. *1988). The position of Vela Spila Cave is indicated by an arrow (author: B. Lugović, 2005).*

Stratigrafija naslaga taloženih krajem pleistocena i početkom holocena

Intenzivnija istraživanja predneolitičkih razdoblja u Veloj spili započela su 1998, i to u sondi površine od svega šest kvadratnih metara (*f-g x 5-7*), u kojoj je 2002. dosegnuta dubina od -7,45 m, a 2004. dubina od -8,85 m[1] (vidi Čečuk & Radić 2005: 21–68).

marked in the central Mediterranean by the eruption of Neapolitan Yellow Tuff (NYT).

Stratigraphy of deposits of Late Pleistocene and Early Holocene deposits

More intense research into the pre-Neolithic eras in Vela Spila Cave began in 1998, in a test pit covering

U daljnjemu tekstu donosimo kratak opis predneolitičkih naslaga.

-8,85 do -5,70 m. Najdublje[2] dosegnute naslage nastale su tijekom kasnoga würmskog razdoblja[3], a sastoje se od gotovo čistoga, sitnijeg, pločasto oštrobridoga vapnenca pomiješanoga s neznatnom količinom ostataka koji potvrđuju ljudsku nazočnost. Količina tragova života povećava se sa smanjivanjem dubine iskopa, pa se malo iznad 7 m nalaze bogati, a na oko 6 m izrazito bogati slojevi tamne boje, što je posljedica velike koncentracije organskih tvari, posebno životinjskih kostiju, ugljena i pepela miješanoga sa sitnim oštrobridim kamenčićima. Te naslage obiluju ostacima koji potvrđuju da je ondje boravio čovjek, tj. u svakome kvadratnom metru sonde nađeno je po nekoliko stotina kremenih alatka, nekoliko tisuća ostalih kremenih predmeta, velika količina životinjskih kostiju, prvenstveno ostataka jelena, polumagarca (*equus hydruntinus*), divljega goveda itd. (Čečuk & Radić 2005; Miculinić 2006).

-5,70 do -5,80 m. Duž cijele sonde iznad spomenutih naslaga proteže se do desetak centimetara debeo sloj tefre pepeljastoga izgleda (sl. 1), NYT. Djelomično je pomiješan s naliježućim slojem smeđega tla tvoreći plamene strukture, pa mu debljina doseže i 30 cm (na terenu je ova taložina označavana kao sloj 11, a u publikacijama kao sloj 8/6). Iz ovoga sloja potječe analizirani uzorak pepela. Drugi uzorak vulkanskoga pepela uzet je iz taložine oblika leće (debljine 2–3 cm, širine 20-ak cm) koja se nalazila na dubini od oko 6,25 m (sl. 1), PRT. U ovome sloju gotovo i nema tragova života, odnosno količina nalaza znatno je manja.

-5,80 do -5,30 m. Naslage su svjetlije boje, bez značajnije prisutnosti organskih tvari.[4] Neposredno nad slojem tefre zapažen je veći broj kamenih gromada teških od nekoliko desetaka do nekoliko stotina kilograma. Prostor između kamenja ispunjen

[1] Nulta točka nalazi se na ulazu u špilju; približno odgovara vrhu naslaga.

[2] Ujesen 2006. postojeća je sonda proširena i produbljena, pa istražena površina iznosi oko 18 m². Iskapanja su počela na dubini od oko 5 m, a na manjoj je površini dosegnuta dubina od 10,2 m. Rezultati će biti publicirani nakon detaljne obrade velike količine nalaza. Na temelju uvida u iskopan materijal izvjesno je da se osnovne stratigrafske postavke neće mijenjati.

[3] VERA 2338 (drveni ugljen) i VERA 2339 (životinjska kost). Uzorci su uzeti na dubini od oko 7,45 m i malo iznad te dubine. Kalibrirana starost prvoga uzorka iznosi 18.000–16.700 god. pr. Kr, a drugoga 17.500–16.200 god. pr. Kr.

[4] Na temelju preliminarnoga uvida u materijal iz sonde iz 2006. pretpostavljamo da je život postupno jenjavao, a ne da se naglo i potpuno prekinuo. Ipak, razlika u količini nalaza iz slojeva iznad i ispod sloja tefre ukazuje na znatne kvantitativne i izrazite kvalitativne promjene svih promatranih parametara (usp. Miracle *et al*. 2000).

a surface of only six square meters (*f-g x 5-7)*, which reached a depth of -7.45 m in 2002, and a depth of -8.85 m in 2004[1] (see: Čečuk & Radić 2005: 21–68).

A brief description of the pre-Neolithic sediments is provided hereinafter.

-8.85 to -5.70 m. The deepest[2] sediments reached were deposited during the late Würm period,[3] and they consist of platy, sharp-edged limestone debris (scree) mixed with an insignificant quantity of remains confirming a human presence. The quantity of traces of life increase as the depth reduces, so at little above 7 m there are rich, and at about 6 m, very rich dark-coloured layers, which is the result of a large quantity of organic matter, particularly animal bones, charcoal and ash mixed with tiny sharp-edged stones. These layers abound in remains that confirm that humans lived here, i.e. several hundred flint tools, several thousand other flint items, a large quantity of animal bones, primarily remains of deer, European ass (*Equus hydruntinus*), wild cattle, etc. (Čečuk & Radić 2005; Miculinić 2006) were found here.

-5.70 to -5.80 m. A layer of tephra with ashy appearance reaching thicknesses of up to 10 cm extends along the entire length of the test pit above the aforementioned sediment (Fig. 1), NYT. It is partly mixed with overlying brown soil forming flames, so its total thickness reaches nearly 30 cm (in the field this sediment was designated as layer 11, and as layer 8/6 in publications). The analysed ash sample is from this layer. The other sample of volcanic ash was taken from the lens-shaped deposit (thickness 2–3 cm, width ca 20 cm) located at a depth of roughly 6.25 m (Fig. 1), PRT. There are almost no signs of life in this layer, as the quantity of finds is considerably smaller.

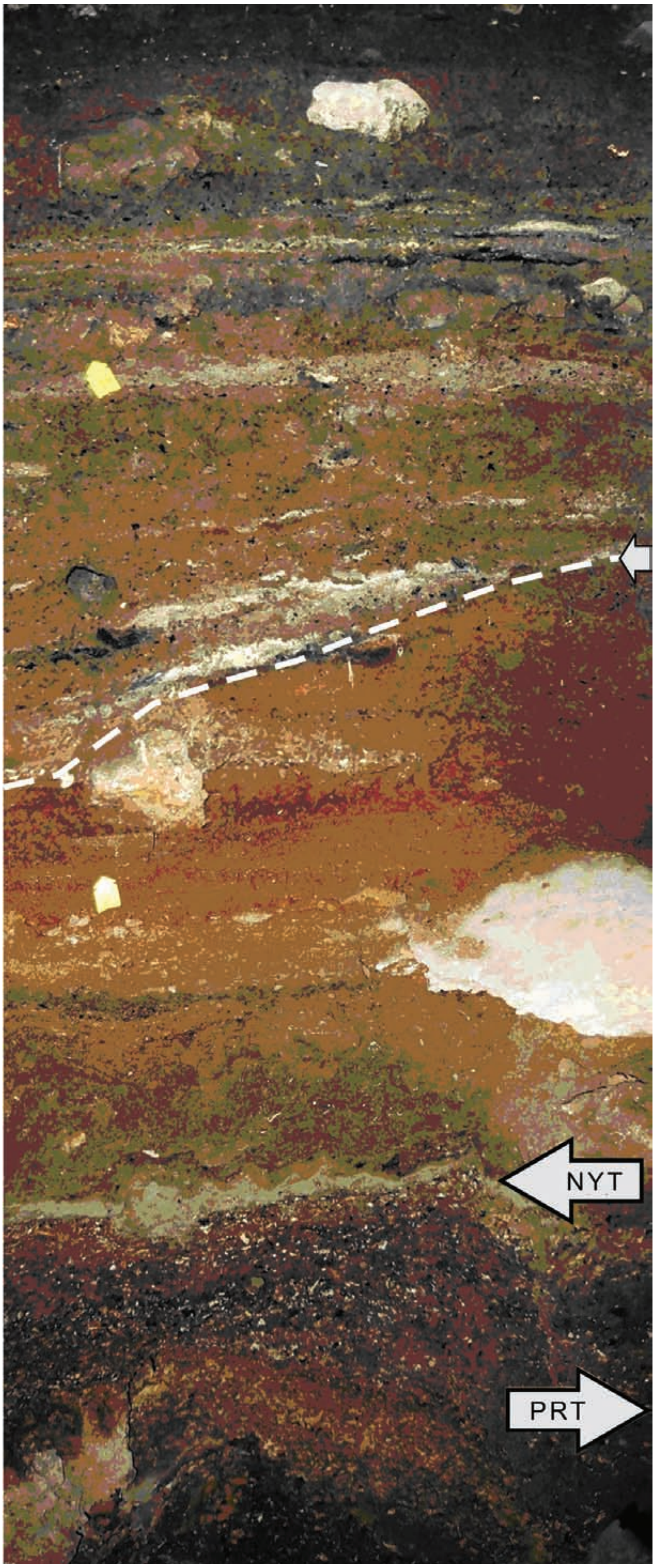
-5.80 to -5.30 m. The sediments have a lighter colour, without any significant presence of organic matter.[4] Just above the tephra layer there is a number

[1] The zero point is at the cave's entrance; it roughly corresponds to the apex of the sediment.

[2] In autumn 2006, the existing test trench was expanded and deepened, so the researched surface covers approximately 18 m². Excavations commenced at a depth of roughly 5 m, and over a smaller surface a depth of 10.2 m was reached. The results will be published after a detailed analysis of a large quantity of finds. Based on a review of excavated materials, it is certain that the basic stratigraphic postulates will not change.

[3] VERA 2338 (charcoal) and VERA 2339 (animal bone). The samples were taken at depths of approximately 7.45 m and slightly above this depth. The calibrated age of the former is 18,000–16,700 BC, and 17,500–16,200 BC for the latter.

[4] Based on a preliminary review of the material from the 2006 test pit, we assume that habitation gradually waned, rather than ending abruptly and completely. Nonetheless, the difference in the quantity of finds from the layers above and below the tephra layer indicate considerable quantitative and remarkable qualitative changes in all observed parameters (cf. Miracle *et al*. 2000).



of stone chunks weighing several dozen to several hundred kilograms each were observed. The space between the stones is filled with red soil and gravel with only negligible signs of life, which disables a rather close cultural determination (Radić 2005: 330–331).

-5.30 to -4.20 m. Approximately above -5.30 m the quantity of finds begins to increase, so the layers are relatively rich, particularly in food remains. Diets had changed entirely, and they were based on consumption of a large quantity of fish, shellfish and terrestrial snails. Finds of animal bones are rare, and these are usually the remains of smaller animals (hares, roe deer, tiny mammals, birds). Stone and bone artefacts are also relatively few in number and superficially worked (see: Radić 2005: 332 and *passim*). Several graves were discovered in these sediments in earlier years (Radić & Lugović 2004).

Slika 1. Jugozapadni profil sonde u Veloj spili prikazuje slijed pleistocenskih i holocenskih naslaga koje su u diskordantnome odnosu. Unutar slijeda pleistocenskih sedimenata nalazi se sloj tefre debeo od 2 do 10 cm (NYT) i tanka leća tefre (PRT). Pleistocenski sedimenti ispod sloja tefre pretežno se sastoje od vapnenačkoga kršja i sadrže dosta koštanoga materijala. Pleistocenski sedimenti iznad sloja tefre drugačiji su, izrazito sitnozrnati, s mnogo manjim udjelom vapnenačkoga kršja i koštanoga materijala. Na njih kutno diskordantno naliježu holocenski sedimenti izrazito izmijenjeni zbog čovjekove prisutnosti i aktivnosti. Isprekidana linija označava granicu pleistocena i holocena (snimila: Lj. Marjanac, 2003).

Figure 1. The south-west profile of the test pit in Vela Spila shows the sequence of Pleistocene and Holocene sediments in a discordant relationship. Within the sequence of Pleistocene sediments there is a tephra layer between 2 to 10 cm thick (NYT) and a thin tephra lens (PRT). The Pleistocene sediments below the tephra layer largely consist of limestone debris and contain bone materials. The Pleistocene sediments above the tephra layer are different, markedly fine-grained, with a much smaller share of limestone debris and bone materials. Holocene sediments, greatly altered due to human presence and activity, overlay at distinct angular unconformity. The broken line designates the boundary between the Pleistocene and the Holocene (photograph: Lj. Marjanac, 2003).

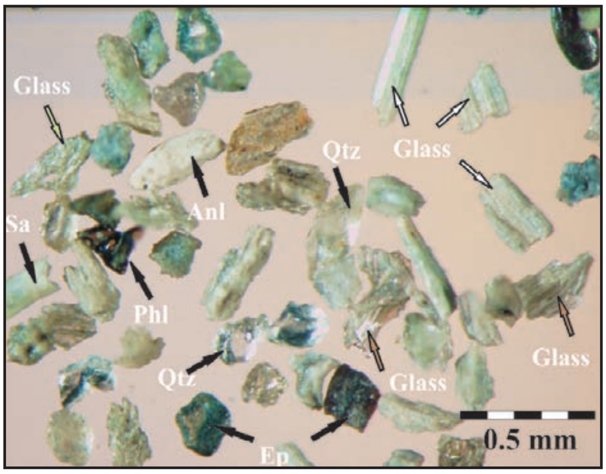
je crvenicom i šljunkom s tek neznatnim tragovima života, što onemogućava njihovu pobližu kulturnu determinaciju (Radić 2005: 330–331).

-5,30 do -4,20 m. Približno iznad -5,30 m količina nalaza počinje se povećavati, pa su slojevi razmjerno bogati, naročito ostacima hrane. Prehrana se potpuno promijenila, a zasnivala se na konzumiranju velike količine riba, školjaka te kopnenih i morskih puževa. Nalazi su životinjskih kostiju rijetki i riječ je gotovo isključivo o ostacima manjih životinja (zečeva, srna, sitnih zvijeri, ptica). Kameni i koštani artefakti također su razmjerno malobrojni i površno obrađeni (vidi Radić 2005: 332 i dalje). U ovim je naslagama ranijih godina otkriveno nekoliko grobova (Radić & Lugović 2004).

-4,20 do -2,10 m. Naslage su taložene tijekom neolitika, a one pliće tijekom eneolitika.

Taložine vulkanskoga porijekla i analitičke metode

Pepeljasto sivi sloj tefre na dubini od -5,80 m (sl. 1, NYT) i pepeljasta leća na dubini od -6,25 m (sl. 1, PRT) sadrže čestice vulkanskoga podrijetla (tefre) među kojima prevladavaju krhotine bezbojnoga, svijetlo smeđega i zelenkastoga stakla uz podređene kristaloklaste sanidina, flogopita i diopsida (sl. 2). Stakla, svježa ili blago alterirana u analcim, morfološki su vrlo različiti fragmenti plovućca (sl. 3).



Slika 2. Fotografija čestica iz sloja tefre načinjena u prolaznoj svjetlosti. Glass = *čestice stakla; boja strelice odražava boju stakla;* Sa = *sanidin;* Phl = *smeđi tinjac, flogopit;* Anl = *analcim;* Qtz = *kvarc;* Ep = *epidot (snimio: B. Lugović, 2005).*

Figure 2. Photograph of particles from the tephra layer taken in transparent light. Glass = *glass particles; colour of arrow indicates the colour of the glass;* Sa = *sanidine;* Phl = *brown mica, phlogopite;* Anl = *analcime;* Qtz = *quartz;* Ep = *epidote (photograph: B. Lugović, 2005).*

-4.20 to -2.10 m. Deposits accumulated during the Neolithic, and the more shallow ones during the Eneolithic.

Description of volcanic deposits and analytical methods

The grey tephra layer at the depth of -5.8 m (Fig. 1, NYT) and the ash lens at the depth of -6.25 m (Fig. 1, PRT) contain particles of volcanic origin dominated by fragments of colourless, light brown and greenish glass with subordinate sanidine, phlogopite and diopside crystalloclast (Fig. 2). Glasses, fresh or slightly altered into analcime, are morphologically very different fragments of pumice (Fig. 3). No stratification of glass fragments was noted within the tephra layer in terms of fragment colour or size, which indicates that they originated from a single, short-lived eruption. Non-volcanic materials include aeolian clasts of quartz, epidote, muscovite, granate, omphacite, amphibole and adularia, which are very common in Late Pleistocene and Holocene loess in the Adriatic region. Coal particles are abundantly present in both tephras, demonstrating the occupation of the cave during their deposition.

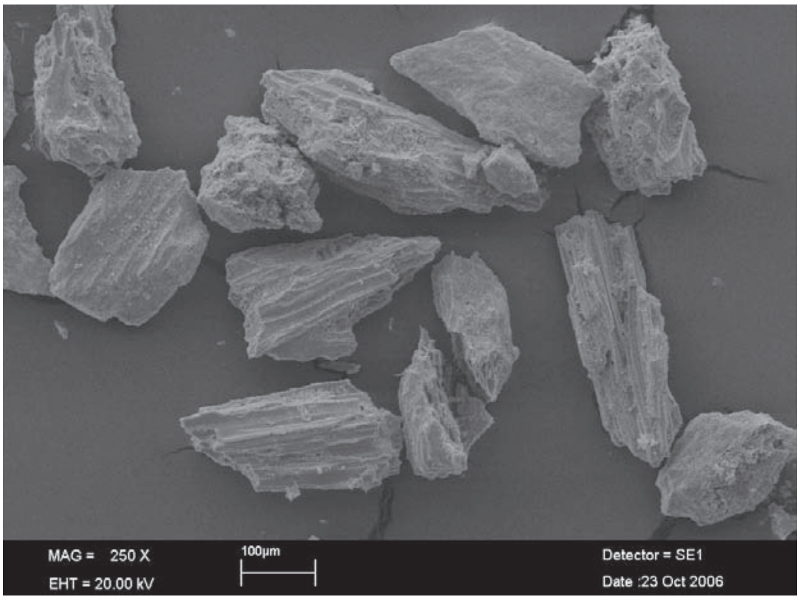
The quantitative chemical composition of the particles (< 34, < 64, and < 125 μm) separated from the tephra layer and lens by wet sieving was determined on polished thin sections using *Cameca SX51* electron microprobe equipped with five wavelength-dispersive spectrometers in the Institute of Mineralogy at the University of Heidelberg. Minerals were analysed using an accelerating voltage of 15 kv, beam current of 20 nA and beam width of 5 - 10 μm for glass and ~ 1 μm for other particles. The counting time for impulses of all elements was limited to 10 seconds. Natural minerals, oxides (corundum, spinel, haematite and rutile) and silicates (albite, orthoclase, anorthite and wollastonite) were used for calibration. A summary of chemical composition of the particles is shown in Table 1.

Microprobe analysis has revealed a broad compositional variation of individual vitric fragments ranging from mafic (*Glass III*), identified only in the tephra layer, to various evolved (*Glass II* and *I*), present by similar composition in the tephra layer and lens. The abundance of individual glass particles of different groups in the bulk tephra samples is approximately uniform. The mafic glass particles have a tephriphonolite-latite composition, while the evolved particles have a bimodal composition within the phonolite-trachyte classification field (Fig. 4). All analysed glass particles have a K-alkaline geochemical affinity (Fig. 5) with a characteristically

Unutar sloja tefre nije primijećena stratifikacija krhotina stakla s obzirom na boju ili veličinu fragmenata, što ukazuje na podrijetlo iz jedne, kratkotrajne, eruptivne epizode. Nevulkanski materijal uključuje eolske čestice kvarca, epidota, muskovita, granata, omfacita, amfibola i adulara, uobičajene u sastavu kasnopleistocenskoga i holocenskoga lesa u jadranskome području. Čestice ugljena relativno su obilno zastupljene u objema teframa dokazujući zaposjednutost špilje tijekom njihova taloženja.

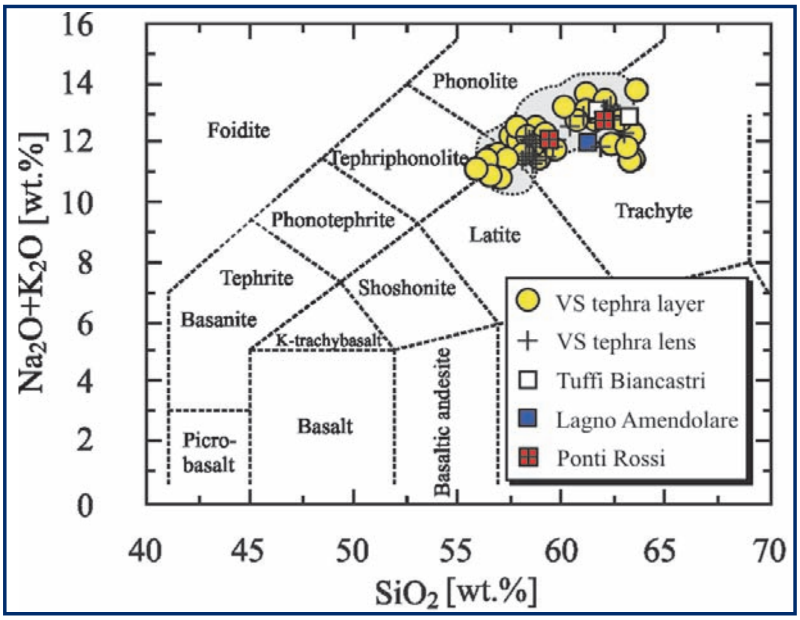
Kvantitativni kemijski sastav čestica (< 34, < 64 i < 125 µm) izdvojenih iz sloja i leće tefre mokrim prosijavanjem određen je na poliranim izbruscima elektronskom mikrosondom *Cameca SX51* u Mineraloškome institutu Sveučilišta u Heidelbergu. Korištena je metoda analize disperzije valnih duljina (WDS) pri energiji pobuđivanja od 15 kv uz jakost struje od 20 nA, širinu elektronskoga snopa od 5 do 10 µm za stakla i ~ 1 µm za preostale čestice. Vrijeme prikupljanja impulsa za sve elemente bilo je ograničeno na 10 sekunda. Za kalibraciju su korišteni prirodni minerali, oksidi (korund, spinel, hematit i rutil) i silikati (albit, ortoklas, anortit i volastonit). Sažeti prikaz rezultata određivanja kemijskoga sastava čestica prikazan je u Tablici 1.

Kemijske analize mikrosondom otkrile su širok raspon varijacije sastava pojedinačnih vitričnih krhotina od mafitnih (*Glass III*), identificiranih samo u sloju tefre, do različito evoluiranih (*Glass II* i *I*) prisutnih u sličnome sastavu u sloju i leći tefre. Učestalost pojedinačnih čestica stakla različitih skupina u globalnim uzorcima tefre približno je jednaka. Mafitne čestice stakla imaju sastav tefrifonolita-latita, dok su čestice evoluiranoga kemizma bimodalnoga sastava unutar klasifikacijskoga polja fonolita-trahita (sl. 4). Sve analizirane krhotine stakla imaju kalijsko-alkalijski geokemijski afinitet (sl. 5) s karakterističnim, visokim omjerom



Slika 3. SEM-fotografija čestica stakla iz sloja tefre. Uočljivi su različiti oblici stakla s prevladavajućom cjevastom vezikularnom ('pipe-vesicular') morfologijom (snimio: B. Lugović, 2005).

Figure 3. SEM-photograph of glass particles from the tephra layer. Different forms of glass with the predominant pipe-vesicular morphology are visible (photograph: B. Lugović, 2005).



Slika 4. Dijagram ($Na_2O + K_2O$) – SiO_2 za nomenklaturu vulkanskih stijena po preporuci IUGS (Le Bas et al. *1986) s projekcijom sastava analiziranih čestica stakla iz Vele spile (VS) i relevantnih slojeva tefra arhiviranih na istraženoj poziciji LGM (Wulf 2000; karta 1) i piroklastičnih naslaga lokaliteta Ponti Rossi u sjevernim predgrađima Napulja (Pappalardo* et al. *1999). Za stijene u nizu od K-trahibazalta do trahita korišteno je nazivlje za seriju stijena obogaćenu kalijem. Točkasto omeđeno polje predstavlja varijaciju sastava čestica stakla u ekvivalentima NYT-a raspršenima u smjeru sjeverozapad – istok (usp. kartu 1) (autor: B. Lugović, 2005).*

Figure 4. Diagram ($Na_2O + K_2O$) – SiO_2 for the nomenclature of volcanic rock based on the IUGS recommendation (Le Bas et al. *1986) with projection of the composition of the analyzed glass particles from Vela Spila (VS) and the relevant tephra layers archived at research location LGM (Wulf 2000; Map 1) and the pyroclastic deposits of the Ponti Rossi site in the northern suburbs of Naples (Pappalardo* et al. *1999). The nomenclature for the K-enriched rock series was used for rock in the series from K-tracybasalt to trachyte. The field encountered by the dotted line represents a compositional variation of glass particles in NYT equivalents dispersed in the north-west/easterly direction (cf. Map 1) (author: B. Lugović, 2005).*

$K_2O/Na_2O \geq 2$ (tab. 1). Čestice stakla fonolit-trahitnoga sastava u sloju i leći tefre u Veloj spili, premda različite stratigrafske razine, imaju napadno sličan bimodalni kemijski sastav, što ukazuje na to da potječu iz iste vulkanske mikroprovincije.

Vulkanski kristali nalaze se kao mikrofenokristali u fragmentima stakla ili pojedinačni kristaloklasti samo u uzorku sloja tefre. Najzastupljeniji je sanidin ($Or_{69,1-88,0}Ab_{10,0-25,7}An_{0,1-5,2}$), manje biotit (Mg# = 65,8 – 66,5; TiO_2 = 5,1 mas.%) i vrlo slabo zonirani diopsid sastava jezgre $Ca_{48,2-48,3}Mg_{30,5-33,8}Fe_{17,9-21,2}$ (Al_2O_3 = 7,5 – 9,2 mas.%; TiO_2 = 1,6 – 1,7 mas.%). Vrsta mikrofenokristala i njihov kemijski sastav tipičan je za visoko kalijske, relativno slabo evoluirane magme.

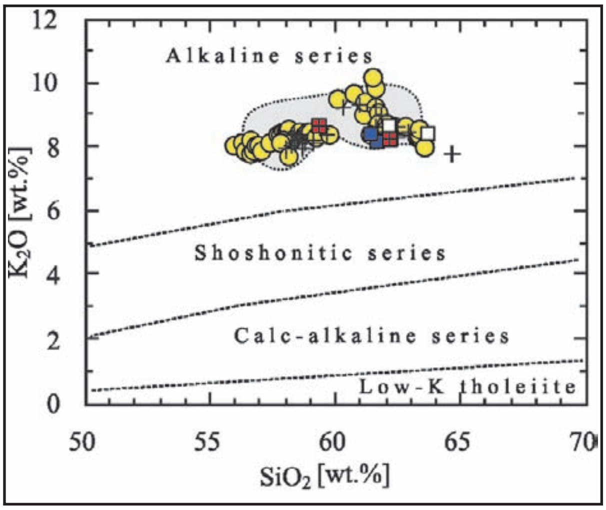
Kemijska analiza globalnoga uzorka sloja tefre iz Vele spile gotovo odražava srednji sastav analiziranih čestica stakla (tab. 1), što potvrđuje virtualni dojam da je onečišćenje tefre stranim materijalom bilo minimalno te da sastav globalnoga uzorka u velikoj mjeri odražava sastav matične magme pred erupciju. Krivulje relativne koncentracije elemenata u tragovima prema primitivnome plaštu (*spider-dijagram*) i elemenata rijetkih zemalja prema hondritu (nije prikazano) imaju oblik i razinu relativne koncentracije identične piroklastičnim stijenama u Kampanijskoj nizini (*Campanian Plane*), čije se erupcije vežu za vulkansku aktivnost tijekom zadnje glacijacije (usp. npr. Pappalardo *et al*. 1999).

Izvorište tefre

Sudeći po veličini i morfologiji vitričnih čestica te njihovoj visokoj vezikularnosti, naslage analizirane tefre u Veloj spili vezane su za freatoplinijsku erupciju. U vremenu bliskome radiokarbonskoj starosti naslaga u podini sloja tefre najjače relevantne freatoplinijske erupcije odigravale su se unutar Kampanijske vulkanske provincije u području Flegrejskih polja zapadno od Napulja.

Flegrejska polja vulkanski su aktivna unatrag 300.000 godina (300 ka)[5] s dvjema kataklizmičkim plinijskim erupcijama i nekoliko snažnih međuerupcija tijekom zadnjega ledenog doba koje obilježavaju biokulturne i klimatske promjene u širemu Sredozemlju. Erupcija kampanijskoga ignimbrita (*Campanian Ignimbrite* = CI) prije 39,28 ± 0,11 ka (De Vivo *et al.* 2001) najjača je poznata erupcija u sredozemnome prostoru s piroklastičnim materijalom trahitno-fonolitnoga sastava razasutim na površini od 30.000 km² u količini usporedivoj s volumenom od 150 km³ magmatskih stijena (DRE = *dry*

[5] Oznaka *ka* odnosi se na starost mjerenu tisućama godina (*kiloanni*); isto je *kyr*.



Slika 5. Dijagram K_2O – SiO_2 s poljima i nomenklaturom serija vulkanskih stijena prema Peccerillo & Taylor 1976. Simboli su kao i na sl. 4 (autor: B. Lugović, 2005).

Figure 5. Diagram K_2O – SiO_2 with fields and nomenclature in a series of volcanic rock according to Peccerillo & Taylor 1976. Symbols are as in Fig. 4 (author: B. Lugović, 2005).

high $K_2O/Na_2O \geq 2$ ratio (Table 1). The glass particles showing phonolite-trachyte composition in the tephra layer and lens in Vela Spila, although at different stratigraphic levels, have a strikingly similar bimodal chemical composition, which indicates that they originated in the same volcanic microprovince.

Volcanic crystal can be found as micro-phenocrysts in glass fragments or individual crystalloclasts only in the tephra layer. The most common is sanidine ($Or_{69.1-88.0}Ab_{10.0-25.7}An_{0.1-5.2}$), biotite is less abundant (Mg# = 65.8 – 66.5; TiO_2 = 5.1 wt.%), while zoned diopside showing core composition $Ca_{48.2-48.3}Mg_{30.5-33.8}Fe_{17.9-21.2}$ (Al_2O_3 = 7.5 – 9.2 wt.%; TiO_2 = 1.6 – 1.7 wt.%) is accessory. The type of micro-phenocrysts and their chemical composition are typical for high-K, relatively slightly evolved magma.

The chemical analysis of the bulk sample of the tephra layer from Vela Spila almost reflects the average composition of analysed glass particles (Tab. 1), which confirms the virtual impression that contamination of the tephra by foreign materials was minimal and that the composition of the bulk sample reflects, in large part, the composition of the original magma prior to eruption. The concentration of trace elements normalised to the primitive mantle in *spider*-diagram and the concentrations of rare earth elements normalised to chrondrite (not shown) have a form and level of relative concentration identical to the pyroclastic rock in the Campanian Plain, whose eruptions are related to the volcanic activity during the Last Glaciation (cf. e.g. Pappalardo *et al*. 1999).

	Sloj tefre / Tephra layer			Leća tefre / Tephra lens		WR
Tip / Type	Glass I	Glass II	Glass III	Glass II	Glass III	WR
N	12	21	20	15	17	1
SiO_2	53.77 ± 0.50	56.22 ± 1.06	59.33 ± 1.26	57.02 ± 0.74	60.27 ± 0.74	56.89
TiO_2	0.62 ± 0.02	0.56 ± 0.04	0.40 ± 0.08	0.58 ± 0.02	0.42 ± 0.03	0.53
Al_2O_2	17.55 ± 0.21	17.88 ± 0.23	17.79 ± 0.38	18.81 ± 0.20	18.11 ± 0.21	17.65
FeO_{total}	5.30 ± 0.15	4.58 ± 0.22	3.00 ± 0.46	4.73 ± 0.24	3.07 ± 0.31	4.12
MnO	0.13 ± 0.02	0.14 ± 0.02	0.14 ± 0.03	0.13 ± 0.03	0.13 ± 0.03	0.12
MgO	1.76 ± 0.08	1.20 ± 0.12	0.53 ± 0.16	1.27 ± 0.11	0.53 ± 0.13	1.15
CaO	4.95 ± 0.16	3.91 ± 0.21	2.34 ± 0.31	3,95 ± 0.21	2.30 ± 0.27	3.19
Na_2O	3.19 ± 0.16	3.60 ± 0.34	3.58 ± 0.71	3.45 ± 0.22	3.78 ± 0.70	2..78
K_2O	7.55 ± 0.13	7.94 ± 0.25	8.67 ± 0.57	7.95 ± 0.20	8.38 ± 0.44	7.48
LOI*	5.18 ± 0.40	3.97 ± 0.90	4.23 ± 0.89	2.83 ± 0.96	3.00 ± 1.11	5.43
Total	94.82 ± 0.40	96.03 ± 0.90	94.96 ± 1.50	97.17 ± 0.96	97.34 ± 0.68	99.58
K_2O/ Na_2O	2.37 ± 0.12	2.23 ± 0.21	2.38 ± 0.49	2.31 ± 0.13	2.15 ± 0.34	2.69

Tablica 1. Kvantitativni kemijski sastav (u mas.%) čestica stakla iz sloja tefre i leće tefre određen mikrosondom i kemijski sastav globalnoga uzorka sloja tefre. Čestice označene kao Glass I, Glass II *i* Glass III *predstavljaju redom stakla evoluirane, prijelazne i mafitne lave. Kemijski sastav globalnoga uzorka sloja tefre (WR) određen je metodom rendgenske fluorescentne analize (XRF) na taljenome uzorku.* LOI* *= gubitak mase žarenjem; u fragmentima stakla odgovara izračunatoj vrijednosti (100 mas.% – suma analize) koja nije uračunata u total. Srednje vrijednosti i standardne devijacije dane su na osnovi broja pojedinačnih analiza čestica stakla (N). U obzir su uzete samo pojedinačne analize koje zadovoljavaju kriterije svježega stakla prema odnosima vrijednosti (100 mas.% – suma analize) i SiO_2 (Clift & Dixon 1994). Kriterij najčešće ne zadovoljavaju čestice skupine* Glass III *(autor: B. Lugović, 2005).*

Table 1. Quantitative chemical composition (in wt.%) of glass particles from the tephra layer and tephra lens determined by micro-probe and chemical composition of a bulk tephra layer (WR). The particles designated as Glass I, Glass II *and* Glass III *respectively constitute evolved, intermediate and mafic lava, respectively. The chemical composition of the WR was determined by X-ray fluorescent analysis (XRF) on a fused sample.* LOI* *= loss on ignition; calculated values in glass fragments (100 wt.% – measured total) not shown in the total. Mean values and the standard deviation are given on the basis of the number of individual glass particle analyses (N). Only those individual analyses were taken into account which meet the criteria of fresh glass based on relations between values (100 wt.% – measured total) and SiO_2 (Clift & Dixon 1994). Particles of the* Glass III *group most often do not meet the criteria (author: B. Lugović, 2005).*

rock equivalent).[6] Potom je u Flegrejskim poljima, na pragu holocena, erupcijom napuljskoga žutog tufa (NYT) formirana kaldera površine 90 km^2, a procjenjuje se da količina izbačenoga piroklastičnog materijala iznosi 50 km^3.

Piroklastične naslage u Flegrejskim poljima i ekvivalentne distalne tefre koje se pripisuju erupciji NYT-a po sastavu su fonolit-trahit i latit-tefrifonolit (sl. 4) s karakterističnim visokim udjelom K_2O (sl. 5) i omjerom K_2O/Na_2O (≈ 2) te sadržajem CaO > 2 mas.% i FeO > 3 mas.% (Orsi *et al.* 1992; Scarpati *et al.* 1993). Za NYT tipična su polimodalna stakla

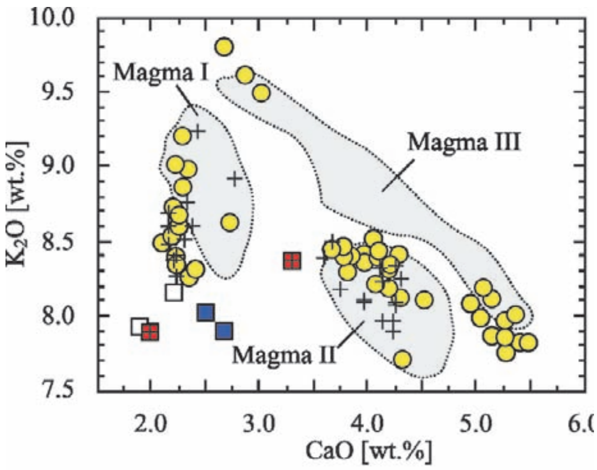
6 Kao zanimljivu podudarnost spominjemo da je i u najplićemu musterijenskom sloju Crvene stijene (Crna Gora) (sloj br. XI, ∇ 7,60 – 820) nađena naslaga vulkanskoga pepela debljine do 30 cm. U tom sloju gotovo nema ostataka života, a za malobrojne nalaze istraživač smatra da su "doklizali" iz sloja br. XII (Basler 1975: 33–34, 89–90; 1979: 21–25.). Sloj br. X pripisuje se orinjasijenu. Zasad nema nikakve potvrde da vulkanski pepeo iz sloja br. XI potječe iz Flegrejskih polja, ali radiokarbonska analiza uzorka iz sloja XII upućuje na datum 40.777 ± 900 godina BP, što odgovara datumu najveće erupcije kampanijskoga vulkana. Kataklizmička erupcija CI imala je značajan klimatski utjecaj na velik dio Sredozemlja na prijelazu iz srednje u mlađu paleolitičku fazu i moguće je da je pokrenula proces preobrazbe, odnosno promjenu neandertalaca u suvremene ljude (Fedele *et al.* 2002).

SOURCE OF TEPHRA

Judging by the size and morphology of the vitric particles and their high vesicularity, the analysed tephra deposits in Vela Spila are linked to a phreatoplinian eruption. At a time close to the radiocarbon age of the sediments beneath the tephra layer, the strongest relevant phreatoplinian eruptions occurred within the Campanian volcanic province in the Phlegraean Fields west of Naples.

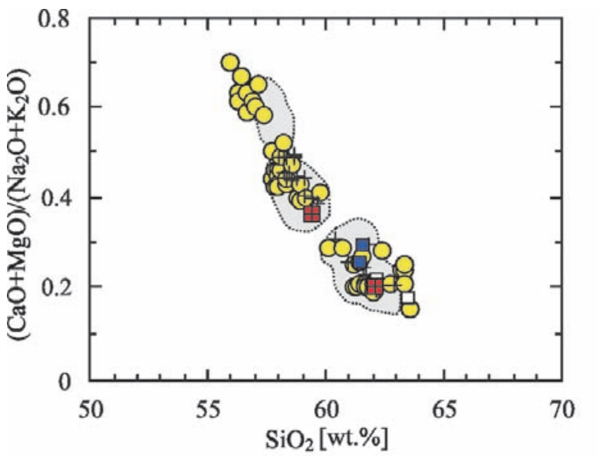
The volcanoes at Phlegraean Fields were active from 300,000 years ago (300 ka)[5] onward with two cataclysmic Plinian eruptions and several powerful intermediate eruptions during the Last Glacial which characterise bio-cultural and climatic change in the wider Mediterranean basin. The eruption of the Campanian Ignimbrite (CI) 39.28 ± 0.11 ka BP (De Vivo *et al.* 2001) is the strongest known eruption in the Mediterranean, with pyroclastic materials of trachyte-phonolite composition scattered over a surface of 30,000 km^2 in quantities comparable to a volume of 150 km^3 of magmatic rock (DRE

5 The symbol *ka* refers to the age expressed in thousands of years (*kiloanni*); *kyr* is the same.



Slika 6. K_2O – CaO dijagram vitričnih krhotina tefra iz Vele spile. Referentna polja konstruirana su prema kemijskome sastavu plovučaca NYT-a u domeni kaldere i predstavljaju tri različite magme u ognjištu neposredno prije erupcije (Orsi et al. *1992). Simboli su kao i na sl. 4 (autor: B. Lugović, 2005).*

Figure 6. K_2O – CaO diagram of vitric tephra fragments from Vela Špila (distal NYT). The reference fields were constructed according to the chemical composition of NYT pumice in the domain of the caldera (proximal NYT tephra) and they represent three different magmas in the chamber immediately prior to the eruption (Orsi et al. *1992). Symbols same are the same as in Fig. 4 (author: B. Lugović, 2005).*



Slika 7. (CaO + K_2O)/(Na_2O + K_2O) – SiO_2 dijagram vitričnih krhotina iz Vele spile. Čestice stakla iz sloja tefre razvrstavaju se u tri skupine, one iz leće tefre u dvije skupine. Referentna polja dana su za tefru C2 u sedimentima središnjega dijela Jadranskoga mora (Calanchi et al. *1998). Simboli su kao i na sl. 4 (autor: B. Lugović, 2005).*

Figure 7. (CaO + K_2O)/(Na_2O + K_2O) – SiO_2 diagram of vitric fragments from Vela Spila. The glass particles from the tephra layer are classified into three groups, and those from the tephra lens into two groups. The reference fields are given for the C2 tephra in the sediments of the central part of the Adriatic Sea (Calanchi et al. *1998). Symbols are the same as in Fig. 4 (author: B. Lugović, 2005).*

koja odražavaju tri geokemijski različita i odijeljena sloja magme u magmatskome ognjištu prije erupcije (Orsi *et al.* 1995). Vitrične krhotine triju različitih magma tijekom jedne kratkotrajne erupcije akumulirale su se u pojedinačnim jedinstvenim piroklastičnim ležištima kako u proksimalnim naslagama (sl. 6) tako i u distalnim slojevima i lećama piroklastike NYT-a (sl. 7).

Na temelju visokoga stupnja podudarnosti kemijskoga sastava fenokristala sanidina, flogopita i diopsida, kemijskoga sastava (tab. 1) i raspona sastava vitričnih krhotina (sl. 4 i sl. 5), a naročito po polimodalnome sastavu stakla (sl. 7) reprezentativnome za sve tri magme NYT-a (sl. 6), sloj tefre koji definira završetak paleolitičke kulture u Veloj spili identificiran je kao ležište distalne tefre NYT-a. Štoviše, analizirani sloj tefre u Veloj spili predstavlja najdeblju poznatu distalnu piroklastiku koja geokemijski najpotpunije odražava sastav proksimalnih piroklastičnih naslaga NYT-a, a svojom lokacijom potvrđuje mišljenje da je NYT najjače raspršen prema sjeveroistoku (Scarpati *et al.* 1993).

Između erupcije CI-a i NYT-a u Flegrejskim poljima i u Kampanijskoj nizini, unutar perioda od tri tisuće godina prije erupcije NYT-a (Girolamo *et al.* 1984), vulkanska aktivnost zabilježena je u rastućemu starosnom nizu (oko 15–18 tisuća godina BP) piroklastičnim naslagama *Tuffi Biancastri* (Pappalardo *et al.* 1999), *Lagno Amendolare* (Andronico 1997) i *Giuliano Incoherent Ignimbrite* (De Vivo *et*

= dry rock equivalent).[6] Subsequently, an eruption of Neapolitan Yellow Tuff (NYT) in the Phlegraean Fields at the beginning of the Holocene formed a 90 km^2 caldera, and an estimated 50 km^3 of pyroclastic materials were ejected.

The pyroclastic deposits in the Phlegraean Fields and the equivalent distal tephra attributed to the NYT eruption consist of phonolite-trachyte and latite-tephriphonolite (Fig. 4) with a characteristically high content of K_2O (Fig. 5), K_2O/Na_2O ratio around 2, and containing CaO > 2 wt.% and FeO > 3 wt.% (Orsi *et al.* 1992; Scarpati *et al.* 1993). For NYT, polymodal glass reflecting three geochemically different and separate layers in the magma chamber prior to the eruption is typical (Orsi *et al.* 1995).

6 As an interesting congruence, we note here that in the shallowest Mousterian layer at Crvena Stijena (Montenegro) (layer no. XI, ∇ 7.60 – 820), a volcanic ash deposit as thick as 30 cm was found. In this layer, there are almost no remains of life, and the few found are considered by the researcher to have "seeped down" from layer no. XII (Basler 1975: 33–34, 89–90; 1979: 21–25.). Layer no. X is attributed to the Aurignacian. So far there is no confirmation that the volcanic ash from layer no. XI comes from the Phlegraean Fields, but radiocarbon analysis of a sample from layer XII indicates a date of 40,777 ± 900 years BP, which corresponds to the date of the largest eruption of the Campanian Ignimbrite (CI). The cataclysmic CI eruption had a considerable climatic impact on most of the Mediterranean in the transition from the middle to late Palaeolithic phase and it is possible that it prompted a process of changes, i.e. the transformation of Neanderthals into contemporary humans (Fedele *et al.* 2002).

al. 2001). Prema raspoloživim podacima iz literature nijedna od erupcija koje neposredno prethode erupciji NYT-a ne sadrži bimodalnu piroklastiku prispodobivu fragmentima stakla iz leće tefre u Veloj spili (sl. 4–7). Dobra geokemijska podudarnost postoji između bimodalne populacije analiziranih stakala iz leće tefre (PRT) i heterogenoga sastava piroklastičnih naslaga na lokaciji Ponti Rossi.

Starost tefre

Za naslage koje blisko prethode taloženju sloja tefre u Veloj spili vezana su dva datuma ^{14}C (VERA – 2345 i VERA – 2346) određena na drvenome ugljenu i životinjskoj kosti. Oba su dala istovjetnu starost od 12.260 ± 40 BP, a nakon kalibriranja datum je određen u vrlo širokome rasponu od 13.500 do 11.900 kal. god. BC (za VERA 2346 od 13.500 do 12.600 god. BC s 46,1% vjerojatnosti, od 12.500 do 12.100 god. BC s 47,2% vjerojatnosti i od 12.000 do 11.900 god. BC s 2,1% vjerojatnosti).

Starost NYT-a na matičnome vulkanskom izvorištu određena je na uzorcima u domeni kratera odnosno kaldere *posredno*, datiranjem paleotala u neposrednoj podini i krovini piroklastičnih naslaga radiokarbonskom metodom ^{14}C AMS, i *izravno*, datiranjem vulkanskih minerala radioizotopnim metodama K-Ar i $^{40}Ar/^{39}Ar$. Rezultati dobiveni različitim postupcima u relativnome su neskladu pri čemu su starosti ^{14}C sistematski niže. Razlog neskladu na uzorcima starijima od 10 ka (Kitagawa & van der Plicht 1998) odnosno 15 ka (Wulf 2002) uzrokovan je naglim promjenama udjela ^{14}C u atmosferi povezanim s globalnom promjenom okoliša i različitim doprinosom iz svemira.

Najuže rasipanje izmjerenih rezultata ^{14}C za NYT dalo je srednju vrijednost od 12.300 ± 300 god. (Alessio *et al.* 1971; 1973), što odgovara starosti od 14.289 kal. god. BP (Stuiver *et al.* 1998) s rasponom 2σ kalibrirane starosti između 15.635 i 13.549 god. BP. Ranija datiranja metodom K-Ar na fenokristalima sanidina ukazala su na starost između 15,4 i 13,8 ka (Cassignol & Gillot 1982). Najnovija određivanja starosti vrlo preciznom metodom $^{40}Ar/^{39}Ar$ na fenokristalima sanidina pomiču starost erupcije NYT-a za više od tisuću godina unatrag u odnosu na rezultate ostvarene metodom ^{14}C. Vrijeme erupcije NYT-a, odnosno doba urušavanja kaldere u Flegrejskim poljima, izraženo kao 'najbolja' srednja vrijednost $^{40}Ar/^{39}Ar$, iznosi 14,9 ± 0,4 tis. god. BP (Deino *et al.* 2004). Neki uzorci, također pripisani NYT-u, odaju starost od 15.473 ± 0,292 tis. god. BP (Insinga *et al.* 2004), no vjerojatnije je da su produkt erupcija relativno slabijega intenziteta koje neposredno prethode erupciji NYT-a (Pappalardo *et al.* 1999).

Vitric fragments of these different magmas during a single short-time eruption were accumulated in the individual unique pyroclastic beds in both proximal sediments (Fig. 6) and in the distal layers and lenses of pyroclastics in Vela Spila (Fig. 7).

Based on the high degree of similarity between the chemical composition of the phenocrystic sanidine, phlogopite and diopside, on the chemical composition on vitric fragments (Tab. 1) and the range of their composition (Fig. 4 and Fig. 5), and particularly in terms of the polymodal glass composition (Fig. 7) which is typical of all three NYT magmas (Fig. 6), the tephra layer that defines the end of the Palaeolithic culture in Vela Spila has been identified as a distal NYT tephra. The analysed tephra in Vela Spila is the thickest known distal tephra layer which geochemically to the fullest reflects the composition of proximal NYT deposits and its location confirms that NYT was mostly dispersed to north-east (Scarpati *et al.* 1993).

Between the CI and NYT eruptions in the Phlegraean Fields and in the Campanian Plain, within a period of three thousand years before the NYT eruption, approximately between 18,000 and 15,000-year BP (Girolamo *et al.* 1984), volcanic activity was successively recorded by the *Giuliano Incoherent Ignimbrite* (De Vivo *et al.* 2001) pyroclastic sediments, *Lagno Amendolare* (Andronico 1997) and by the *Tuffi Biancastri* (Pappalardo *et al.* 1999). According to data available from the literature, none of the eruptions immediately preceding the NYT eruption contains bimodal vitric particles comparable to the glass fragments from the tephra lens in Vela Spila (Figs. 4–7). A strong geochemical similarity exists between the bimodal glass population from the tephra lens (PRT) and the heterogeneous composition of pyroclastic sediments at the Ponti Rossi site.

Age of tephra

Two ^{14}C dates (VERA – 2345 and VERA – 2346) determined on charcoal and animal bone are associated with the deposits that closely precede the deposition of the tephra layer in Vela Spila. Both have provided identical measured ages of 12,260 ± 40 BP. After calibration the date split in a very wide range from 13,500 to 11,900 calibrated years BC (for VERA 2346: from 13,500 to 12,600 years BC with 46.1% probability; from 12,500 to 12,100 years BC with 47.2% probability; and from 12,000 to 11,900 years BC with 2.1% probability).

The age of the NYT from the crater zone of caldera was determined *indirectly* by radiocarbon ^{14}C AMS

Starost taloženja tefre NYT-a određena je metodom ^{14}C AMS i stratigrafskim metodama visoke rezolucije u jezeru Lago di Monticchio (LGM na karti 1) na 14.110 – 14.120 kal. god. BP na sloju debelom 2,2 cm koji sadrži bimodalno staklo sastava trahita do tefrifonolita-latita (Wulf 2002). Taj raspon uzima se u zadnje vrijeme kao referentna ^{14}C starost tefra NYT-a za biostratigrafsku i paleoklimatsku korelaciju (Schmidt *et al.* 2002).

Leća tefre (PRT) u Veloj spili nalazi se 45 cm pod slojem NYT-a u 160 cm debelim, sedimentološki vrlo ujednačenim naslagama, što upućuje na dobro uhodani život u špilji tijekom zadnjih 3889 (3880) godina paleolitika izračunatih iz razlike kal. starosti VERA – 2338 i VERA – 2346 (Čečuk & Radić 2005: 32). Pretpostavi li se da je u tome vremenu ispuna bila jednolična, za taloženje 45 centimetara naslaga trebalo je približno 1100 godina. Uzimajući u obzir starost ^{40}Ar/^{39}Ar erupcije NYT-a od 14,9 ka kao vremenski reper, erupcija za koju se veže leća tefre u Veloj spili odigrala se prije približno 16 tisuća godina. Ta se starost savršeno podudara s vremenom erupcije piroklastike na lokalitetu Ponti Rossi datirane na fenokristalima sanidina metodom ^{40}Ar/^{39}Ar između 15,9 i 16,1 tis. god. BP (Pappalardo *et al.* 1999). Budući da je navedena erupcija dala bimodalnu piroklastiku prispodobivu fragmentima stakla iz leće tefre u Veloj spili (sl. 4–7), postoje dobri razlozi da se potonja smatra ekvivalentom piroklastičnih naslaga koje izdanjuju na lokaciji Ponti Rossi.

Klima, paleookoliš i način življenja

Krajem pleistocena, odnosno na vrhuncu zadnjega glacijalnog maksimuma (LGM), okoliš se znatno razlikovao od današnjega prvenstveno zbog drukčijih klimatskih obilježja i niže razine mora (Bailey 2000: 15–23). Pleistocenskim okolišem od 18,5 do 16 ^{14}C kal. ka[7] dominiraju travnate ravnice prekrivene oskudnom vegetacijom. Od biljaka ističu se pelin (*artemisia*) i kosternica (*ephedra*), ali prisutne su i druge biljke poput raznih trava (*poaceae*), loboda (*chenopodiacae*) i glavočika (*asteraceae*) (Combourieu-Nebout *et al.* 1998: 305–307). Crnogorična stabla (jela i smreka) češća su od onih listopadnih zastupljenih hrastom i grabom te lijeskom, brijestom, jasenom i lipom. Veći dio dna današnjega Jadrana u to je vrijeme bio polupustinja, odnosno aridna stepa bez šume. Podaci o biljnome svijetu iz narednoga

[7] Različiti autori navode različite datume za pojedine epohe, a razlike se uočavaju i između starije i novije literature, što ponekad dovodi do konfuzije.

method of dating on the palaeosol beneath and above the pyroclastic sediments, and *directly*, by dating the volcanic minerals using the radioisotope K-Ar and ^{40}Ar/^{39}Ar methods of dating. The results obtained by the different procedures are relatively discrepant; wherein the radiocarbon ^{14}C ages are systematically lower. The reason for the discrepancy of the ages obtained in samples older than 10 ka (Kitagawa & van der Plicht 1998) and 15 ka (Wulf 2002) is due to sudden changes in the ^{14}C content in the atmosphere related to global environmental change and differing contributions from the space.

The narrowest dispersion of ^{14}C data measured for the NYT yielded a median value of 12,300 ± 300 years (Alessio *et al.* 1971; 1973), which corresponds to an age of 14,289 calibrated years BP (Stuiver *et al.* 1998) with a 2σ range of calibrated age between 15,635 and 13,549 years BP. Previous K-Ar dating on phenocrystic sanidines gave an age between 15.4 and 13.8 ka (Cassignol & Gillot 1982). The most recent determination of age using the very precise ^{40}Ar/^{39}Ar method on sanidine phenocrysts moves the age of the NYT eruption by over a thousand years back in the past concerning the ages obtained by the ^{14}C method. The age of NYT eruption, i.e. the time of the caldera collapse in the Phlegraean Fields, expressed as the 'best' ^{40}Ar/^{39}Ar median value, is 14.9 ± 0.4 thousand years BP (Deino *et al.* 2004). Some samples, also attributed to the NYT, give an age of 15,473 ± 0.292 thousand years BP (Insinga *et al.* 2004), but it is likely that they are the product of relatively weaker eruption(s) which immediately preceded the NYT eruption (Pappalardo *et al.* 1999).

The age of deposition of the NYT tephra was inferred by the ^{14}C AMS method and high resolution stratigraphic methods in Lago di Monticchio (LGM on the map 1) to 14,110-14,120 calibrated years BP Wulf 2002). The age determination was performed by the ^{14}C AMS method and high-resolution stratigraphic methods on a 2.2 cm thick layer which contains a bimodal glass composition of trachyte to tephriphonolite-latite. This range has recently been used as the reference ^{14}C age of the NYT tephra for biostratigraphic and palaeoclimatic correlation (Schmidt *et al.* 2002).

The tephra lens (PRT) in Vela Spila is located 45 cm below the NYT layer within 160 cm thick and texturally very uniform sediments. This indicates a well-developed life in the cave during the last 3,889 (3,880) years of the Palaeolithic, calculated from the ^{14}C calibrated age differences of VERA – 2338 and VERA – 2346 (Čečuk & Radić 2005: 32). Assuming that the cave infilling at that time was uniform, approximately 1,100 years would be required for 45 cm razdoblja, od 16 do 14,4 ^{14}C kal. ka, vrlo su oskudni (Combourieu-Nebout *et al.* 1998: 309), što autori objašnjavaju povećanom aridnošću i posljedičnom slabom vegetacijom. Slično stanje vlada u razdoblju između 14,4 i 12,7 ka (stariji *Dryas*): na temelju porasta količine peluda loboda, glavočika i nižega grmlja u odnosu na pelud stabala procjenjuje se da je u tome razdoblju polupustinjsko područje bilo najrasprostranjenije. Šumske zajednice očuvale su se samo na okolnim, povišenim, redovito zaklonjenim predjelima. Sve ukazuje na vrlo hladnu i suhu klimu, uz izražene sezonske i dnevne oscilacije, dok je nešto više vlage bilo jedino u povišenim predjelima obraslima crnogoričnom šumom. U to je vrijeme morska razina preko 130 m niža od današnje (Shackleton *et al.* 1984, Lambeck *et al.* 2004), razmjerno je stabilna, bez nagloga uzdizanja i znatnijega utjecaja na okoliš.

Vela spila ima vrlo povoljnu lokaciju s istaknutim položajem na južnim padinama brda koje dominira nad dvadesetak kilometara dugom dolinom, današnjim zaljevom Vele Luke. Zbog zaklonjenoga položaja, vjerojatne pošumljenosti i postojanja vodotoka takav okoliš omogućavao je bolje životne uvjete od širega i otvorenijega prostora. Stoga je taj prostor bio pogodan za život ljudi i većega broja krupnih životinja čiji su mnogobrojni ostaci pronađeni u svim istraživanim kvadrantima (tab. 2). Osnova strategije preživljavanja ljudske zajednice tijekom zadnjega glacijalnog maksimuma bio je lov životinja zbog mesa, kože i kostiju. Bez obzira na surove životne uvjete tijekom nekoliko milenija razmjerna postojanost prirodnih uvjeta osigurava stabilnu gospodarsku osnovu. Sve se to odražava i na materijalnu kulturu u kojoj se uočavaju ujednačene karakteristike (Čečuk & Radić 2005: 25 i dalje).

Slika dobivena iščitavanjem stratigrafske situacije kulturnih slojeva u Veloj spili vrlo je jednostavna i jasna. Za kasnopleistocenske naslage karakteristični su iznimno brojni ostaci koji svjedoče o životu paleolitičkih lovaca na krupnu divljač (tab. 2), a analiza kremenih artefakata i ostataka lovačkoga plijena omogućuje da ih kulturno vežemo za epigravetijen (Čečuk & Radić 2005: 21–48).

Promjene započinju prije 15,7 – 15,4 ^{14}C kal. ka kao odraz promjene klime i porasta razine mora u Sredozemlju, što ujedno koincidira s porastom razine mora na umjerenim geografskim širinama u Atlantskom oceanu (Siani *et al.* 2001). Dubina mora u širemu okružju današnje Korčule (od Neretve do Lastova i od Mljeta do Visa) ne prelazi 100 m. Dalje na zapadu i jugu dubina naglo raste na preko 130 metara. Podizanje razine mora nakon würmskoga glacijacijskog maksimuma, kad je razina Jadranskog mora bila preko 130 m niža od današnje, nije bitno utjecalo na

of sediments. Taking into account the ^{40}Ar/^{39}Ar age of the NYT eruption of 14.9 ka as the chronological indicator, the related edifice of the tephra lens in Vela Spila must have errupted around 16,000 years ago. This age corresponds perfectly to the time of the eruption of pyroclastics at the Ponti Rossi site dated on sanidine phenocrysts by the ^{40}Ar/^{39}Ar method to between 15.9 and 16.1 thousand years BP (Pappalardo *et al.* 1999). Since the Ponti Rossi eruption produces bimodal pyroclasts comparable to the glass fragments from the tephra lens in Vela Spila (Figs. 4–7), it appears reasonable to consider both tephras as the products of the same eruption.

Climate, palaeo-environment and lifestyle

At the end of the Pleistocene, i.e. at the peak of the last glacial maximum (LGM), the environment was considerably different than today's, primarily due to the different climatic features and lower sea levels (Bailey 2000: 15–23). The Pleistocene environment from 18.5 to 16 ^{14}C calibrated ka.[7] was dominated by grass-covered plains covered by meagre vegetation. The plants were dominated by wormwood (*Artemisia*) and jointfir (*Ephedra*), although other plants were present, such as various grasses (*Poaceae*), goosefoot (*Chenopodiacae*) and daisies (*Asteraceae*) (Combourieu-Nebout *et al.* 1998: 305–307). Conifers (fir and spruce) were more common than deciduous trees, mainly oak and hornbeam, followed by hazel, elm, ash and linden trees. Most of today's Adriatic was at that time a semi-desert, an arid steppe without forests. Data on the plant life of the subsequent period, from 16 do 14.4 ^{14}C calibrated ka are very meagre (Combourieu-Nebout *et al.* 1998: 309), which is explained by scholars in terms of the greater aridity and consequently sparse vegetation. A similar situation held during the period between 14.4 and 12.7 ka (older *Dryas*): based on growth in the pollen quantities of goosefoot, daisies and low shrubs in comparison to tree pollen it is estimated that the semi-arid zone was the most extensive during this period. Forest associations were preserved only in neighbouring, elevated and regularly sheltered tracts. All of this indicates a very cold and dry climate, with drastic seasonal and daily oscillations, while only the somewhat higher tracts covered with coniferous forests had more moisture. At that time, the sea level was over 130 m less than today's (Shackleton *et al.* 1984, Lambeck *et al.* 2004),

[7] Various authors cite different dates for individual epochs, and differences are notable between the older and more recent literature, which sometimes lead to confusion.

	gornji paleolitik / upper Palaeolithic	sloj iznad tefre / layer above the Tephra	mezolitik / mesolithic
Kremene alatke (kom.) / Flint tools (pcs.)	1.060	2	7
Cervus elaphus	326	3	1
Equus sp.	116	0	0
Bos sp.	23	0	0
Sitne zvijeri *(vulpes sp...)* / Small carnivore	1	3	27
Pisces	0	3	38
Školjke i puževi (kom.) / Shellfish and snails (pcs.)	26	248	10.994

Tablica 2. Učestalost nalaza alatka i ostataka prehrane u slojevima koji prethode taloženju NYT-a, u sloju neposredno iznad NYT-a i u slojevima mlađega mezolitika (prema stanju u kvadrantima f-g x 5'-7') (autor: D. Radić, 2004 prema Paunović et al. *2002).*

Table 2. Frequency of discovery of tools and food remains in the layers preceding the NYT deposition, in the layer immediately above the NYT and in the layers of the earlier Mesolithic (based on the status in quadrants f-g x 5'-7') (author: D. Radić, 2004 based on Paunović et al. *2002).*

izgled bližega okoliša. Tek u razdoblju mlađemu od oko 16 ^{14}C kal. ka more se izdiglo iznad izobate -100 m (Lambeck *et al*. 2004) i preplavilo ondašnje doline (krška polja) između današnjih otoka. Ušća Neretve i Cetine, koja su se nalazila negdje između Visa i Sušca, počela su se povlačiti prema sjeveru.

Spomenuta događanja, zbog kojih nestaje ili se znatno mijenja dotadašnji okoliš, vremenski se podudaraju s erupcijom piroklastike na lokalitetu Ponti Rossi (^{40}Ar/^{39}Ar starost 16 ka, ^{14}C starost 15,4 ka) i erupcijom NYT-a koje se u naslagama Vele spile prepoznaju kao tanka leća, odnosno debeli sloj tefre. Jesu li snažni potresi koji prate kataklizmičke vulkanske erupcije imali dodatna utjecaja na svojstva i promjenu života ljudi u Veloj spili, utvrdit će se budućim preciznim stratigrafskim istraživanjima. Važno je napomenuti da takva mogućnost nije isključena ako je suditi po kamenim gromadama teškim do nekoliko stotina kilograma neposredno nad slojem NYT-a.

Vrijeme erupcije NYT-a, koja se dogodila prije oko 14.9 ka, odnosno prema metodi ^{14}C prije oko 14,1 ka, obilježeno je temperaturama koje spadaju u red najnižih u zadnjih 20000 godina. Porast temperature bilježi se nešto kasnije (*Bölling/Allröd*) i nastavlja se u narednim razdobljima (mlađi *Dryas*). Klimatske promjene, bez obzira na osciliranja, kreću se prema općemu zatopljenju uz veće količine oborina, što globalno dovodi do podizanje razine mora za više desetaka metara. Taj proces popraćen je pro-

and it was relatively stable, without sudden rises or significant impact on the environment.

Vela Spila has a very favourable location with a distinguished position on the southern slopes of a hill that dominates a roughly twenty-kilometre long valley, today's Vela Luka Bay. Thanks to its sheltered position, probable forested environs and the existence of running water, this environment provided better living conditions than wider and more open areas. This area was thus suitable for human life and a higher number of large animals, whose numerous remains were found in all examined quadrants (Tab. 2). The basic survival strategy of the human community during the last glacial maximum was to hunt animals for meat, leather and bones. Regardless of the harsh living conditions, over several millennia the relative stability of natural conditions ensured a stable economic foundation. All of this was also reflected in the material culture which exhibited uniform characteristics (Čečuk & Radić 2005: 25 and *passim*).

The picture obtained by interpretation of the stratigraphic situation of the cultural layers in Vela Spila is very simple and clear. The late Pleistocene sediments are characterised by exceptionally numerous remains that testify to the existence of Palaeolithic big game hunters (Tab. 2), while analysis of flint artefacts and the remains of hunted game makes it possible to link this culture to the Epigravettien (Čečuk & Radić 2005: 21–48).

[8] Nalazi školjaka iz gornjopaleolitičkih naslaga uglavnom se odnose na školjke *Chamelea galina*, *Glycymeris violacascens* i sl., prilagođene uvjetima kakvi su krajem pleistocena vladali u širemu okolišu Vele spile (pješčani nanosi blizu ondašnjega ušća Neretve).

[8] The shellfish from the Upper Palaeolithic sediments are generally *Chamelea galina*, *Glycymeris violacascens*, etc., adapted to the conditions that held at the end of the Pleistocene in the wider environs of Vela Spila (sandy deposits near that era's mouth of the Neretva River).

mjenama u reljefu, biljnome i životinjskome svijetu, što u konačnici rezultira mediteranizacijom krajolika, tj. smanjenjem i nestankom prirodnoga okoliša (travnatih ravnica, šuma na padinama, vodotoka) pogodnoga za život krupnih životinja i oblikovanjem reljefa sličnoga ili identičnoga današnjemu. U kolikoj mjeri lokalna događanja (erupcija NYT-a i potresi) utječu na promjene na jadranskome prostoru ili ih podupiru, radi li se o segmentima istoga procesa ili je riječ samo o podudarnosti – zasad je teško kategorički tvrditi i istraživanja će se u svakom slučaju nastaviti.

Ostaci prehrane, nađeni alati i oružja ukazuju na to da je dotadašnja, tisućama godina uspješna, strategija pribavljanja hrane morala biti napuštena, potpuno izmijenjena i prilagođena novim okolnostima (tab. 2). Kraj pleistocena i na širemu je prostoru popraćen krizama, smanjenjem intenziteta ili mjestimično i prestankom života, a u Veloj spili obilježava ga lokalna specifičnost, odnosno prijelaz s iskorištavanja polupustinjske stepe, ušća rijeka i pošumljenih padina na eksploatiranje razmjerno siromašnih i ondašnjim ljudima teško dostupnih morskih resursa. Uzme li se sve to u obzir, ne začuđuje siromaštvo sloja nataloženoga neposredno iznad tefre (tab. 2) nastaloga u vremenu obilježenome razvijanjem nove strategije pribavljanja hrane, nalaženjem novih ležišta sirovine za izradu kamenih oruđa i novih prometnica, pravaca sezonskih migracija itd.

Osim strukturom namirnica i načinom njihova pribavljanja sveobuhvatnost promjena najizrazitije je naznačena tipovima korištenih alatka i posebno repertoarom pojedinih inačica (vidi Čečuk & Radić 2005: 21–68). Usporede li se dvije epohe, vidi se da je oruđe različito zastupljeno, a posebno je nesrazmjeran kvantitativan odnos nađenih artefakata (vidi tab. 2). U sferi društvenih odnosa uočava se korištenje drukčijega nakita. Nestaju školjke česte tijekom paleolitika – privjesci *Chamele galinae* i slične krupnije *veneridae*; isto je s pužićima iz obitelji *littorinidae*, vjerojatno tupastim obalnim pužićima (*Littorina obtusata*), također probušenima radi nizanja u ogrlicu. Nestaju i dotada relativno brojni jelenji kanini (ponekad probušeni, ukrašeni nizom ureza itd.).

Zaključak

Geokemijska i morfološka obilježja te kvantitativni kemijski sastav vulkanskih čestica iz sloja, odnosno leće pepela, iskopanih u Veloj spili na dubini od 5,80 i 6,25 m, ukazuju na to da potječu iz iste vulkanske mikroprovincije. Kvantitativnom analizom kemijskoga sastava čestica stakla i minerala metodom

The changes began prior to 15.7-15.4 ^{14}C calibrated ka as a reflection of climate change and rising sea levels in the Mediterranean, which also coincided with growth in sea levels at the temperate latitudes in the Atlantic Ocean (Siani *et al.* 2001). The depth of the sea in the wider surroundings of today's Korčula (from the Neretva River to the island of Lastovo and from the island of Mljet to Vis) did not exceed 100 m. Further west and south, this depth increased drastically to over 130 meters. Rising sea levels after the Würm glacial maximum, when the level of the Adriatic Sea had to have been 130 m lower than today, did not greatly influence the appearance of the near environment. Only during the period younger than approximately 16 ^{14}C calibrated ka did the sea rise above the -100 m isobaths (Lambeck *et al.* 2004) and flood the valley (karst field) of the time between the present-day islands. The mouths of the Neretva and Cetina Rivers, which were located somewhere between Vis and Sušac, began to recede northward.

These events, which led to a disappearance or considerable changes of the environment of the time, corresponded chronologically to the eruption of pyroclastics at Ponti Rossi (^{40}Ar/^{39}Ar age 16 ka, ^{14}C age 15.4 ka) and the NYT eruption which is recognised in the sediments of Vela Spila as a thin tephra lens and a thick tephra layer respectively. Whether or not the powerful earthquakes that accompany cataclysmic volcanic eruptions exerted an added impact on the quality of and changes in the lives of the people in Vela Spila will be determined by more precise stratigraphic research in the future. It is important to note that such a possibility cannot be discounted given the stone blocks weighing up to several hundred kilograms just above the NYT layer.

The time of the NYT eruption, which occurred about 14.9 ka ago, or roughly 14.1 ka using the ^{14}C method, was marked by temperatures that count among the lowest in the last 20,000 years. Rising temperatures were recorded somewhat later (*Bölling/Allröd*) and they continued into the subsequent periods (earlier *Dryas*). Climate change, regardless of oscillations, went in the direction of general warming with larger quantities of precipitation, which led to rising sea levels by several dozen meters on a global scale. This process was accompanied by changes in the relief and in the plant and animal life, which ultimately led to the Mediterraneanisation of the landscape, i.e. a reduction and disappearance of the natural environment (grass-covered plains, forests on slopes, waterways) suited to large animals and the formation of a relief similar or identical to that of today. The extent to which local events (the NYT eruption and earthquakes) influenced changes in the Adriatic elektronske mikroanalize (mikrosondom) utvrđena je velika, nedvojbena podudarnost s piroklastičnim produktima raspršenima širom Sredozemlja koji su vezani za silovitu erupciju napuljskoga žutog tufa, odnosno piroklastike koja izdanjuje na lokaciji Ponti Rossi u Flegrejskim poljima (Campi Flegrei) u blizini Napulja.

Starost erupcije NYT-a na vulkanskome izvorištu određena je metodom $^{40}Ar/^{39}Ar$ na 14,9 ± 0,4 ka, a starost taloženja tefre metodom ^{14}C AMS na 14.110 – 14.120 ka. Nadnevci dobiveni metodom ^{14}C na ugljenu i kosti iz Vele spile uzetima iz sloja neposredno ispod tefre NYT-a odgovaraju navedenim podacima. Prema analizi izvorišnoga piroklastičnog materijala na lokaciji Ponti Rossi određeno je vrijeme kad se istaložila leća tefre: bilo je to u razdoblju od prije 16 ka, odnosno 15,4 ^{14}C kal. ka.

Prije 14,3 ^{14}C kal. ka[9] (Sangiorgi *et al.* 2002: 209), približno istovremeno s erupcijom NYT-a, proces otapanja ledenjaka rezultirao je uzdizanjem mora i potapanjem dijela ondašnjega šireg okoliša Vele spile. Postupno zatopljenje preoblikuje krajolik i dovodi do promjena i nestanka dotadašnjega biljnog i životinjskog svijeta. Život na samome kraju pleistocena još uvijek predstavlja nepoznanicu, a na to razdoblje bit će usmjerena pažnja tijekom narednih istraživanja. Sloj tefre stratigrafski oštro razdvaja bogate pleistocenske naslage od mlađih, a u kulturnome smislu te promjene prepoznajemo kao kraj paleolitika. Život na lokalitetu obnovio se nakon dužega kriznog razdoblja, tek tijekom holocena, za vrijeme mezolitika.

[9] Zapravo nakon starijega *Dryasa*; u literaturi se spominju razni datumi.

zone or abetted them, whether these were components of the same process or simply coincidences – cannot be categorically asserted with any certainty at present, and research shall continue in any case.

The discovered remains of food, tools and weapons indicate that the food acquisition strategy so successful until that time had to be abandoned, entirely altered and adapted to new circumstances (Tab. 2). The end of the Pleistocene was accompanied by crises, reduced intensity or even local disappearance of human life in the wider region, and at Vela Spila it was marked by a locally specific phenomenon, i.e. the transition from exploitation of the semi-arid steppe, the mouths of rivers and forested slopes to exploitation of the relatively meagre and rather difficult to access (for the people of that era) marine resources. Taking all of these factors into account, one cannot be surprised by the poverty of the layer collected immediately above the tephra (Tab. 2) that emerged at a time marked by the development of new food acquisition strategies, the discovery of new raw material deposits to make tool implements and new routes and directions for seasonal migrations, etc.

Besides the structure of provisions and the methods to obtain them, the comprehensive nature of change is most apparent in the indicated types of tools and particularly the repertoire of individual variants (see Čečuk & Radić 2005: 21-68). If these two epochs are compared, one can see that the implements are differently present, and there is a particular imbalance in the quantitative ratio between discovered artefacts (see Tab. 2). In the sphere of social relations, use of different jewellery is notable. The shells so frequent in the Palaeolithic began to disappear: *Chamelea galina* pendants and similar, larger ones from the *Veneridae* family; the same holds for the small snails of the *Littorinidae* family, probably rounded coastal snails (*Littorina obtusata*), also pierced for placement on necklaces. The until-then relatively numerous deer canines (sometimes pierced, decorated by rows of incisions, etc.) also disappeared.

Conclusion

The geochemical and morphological features and quantitative chemical composition of the volcanic particles from the *tephra layer* and *tephra lens* excavated in Vela Spila Cave at depths of 5.8 to 6.25 m indicate that they derived from the same volcanic micro-province. Quantitative analysis of the chemical composition of glass and mineral particles obtained by electron micro-analysis (microprobe) ascertained the identical geochemical signatures with the pyroclastic products scattered over the wider Mediterranean basin which are attributed respectively to the cataclysmic eruption of the Neapolitan Yellow Tuff and to an edifice produced pyroclastic deposits at the Ponti Rossi site in the Phlegraean Fields (Campi Flegrei) near Naples.

The age of the NYT eruption was determined by the $^{40}Ar/^{39}Ar$ method to 14.9 ± 0.4 ka, while the age of tephra deposition was determined by the ^{14}C AMS method to 14,11-14,12 ka. The dates obtained by the ^{14}C method on the coal and bones from Vela Spila taken from the layer immediately beneath the NYT tephra correspond to these data. Based on the geochemical similarity to the pyroclastics at Ponti Rossi, the time of deposition of the tephra lens was determined to 16 ka or to 15.4 ^{14}C calibrated ka.

Prior to 14.3 ^{14}C calibrated ka[9] (Sangiorgi *et al.* 2002: 209), roughly at the same time as the NYT eruption, glacial melting resulted in rising sea levels and flooding of a large part of the wider environs of Vela Spila at that time. Gradual warming transformed the landscape and led to changes and the disappearance of much of the previous plant and animal life. Life at the very end of the Pleistocene is still something of an unknown, and attention shall be accorded to this period during subsequent research. The tephra layer creates a stratigraphically sharp division between the rich Pleistocene sediments and the more recent sediments, and in the cultural sense these changes are recognised as the end of the Palaeolithic. Life at this site was restored after a longer crisis, but only during the Holocene, in the Mesolithic period.

[9] Actually after the earlier *Dryasa*; various dates are cited in the literature.

LITERATURA / BIBLIOGRAPHY

Alessio *et al.* 1971 — M. Alessio, F. Bella, S. Improta, G. Belluomini, C. Cortesi & B. Turi: "University of Rome Carbon – 14 dates IX", *Radiocarbon* 13, Tucson, 1971, 395–411.

Alessio *et al.* 1973 — M. Alessio, F. Bella, S. Improta, G. Belluomini, C. Cortesi & B. Turi: "University of Rome Carbon –14 dates X", *Radiocarbon* 15, Tucson, 1973, 165–178.

Andronico 1997 — D. Andronico: "La stratigrafia dei prodotti dell'eruzione di Lagno Amendolare (Campi Flegrei, Napoli)", *Atti Società Toscana di Scienze naturali Memorie* A 104, Pisa, 1997, 165–178.

Bailey 2000 — D. W. Bailey: *Balkan Prehistory*, London, 2000.

Basler 1975 — Đ. Basler: "Stariji litički periodi u Crvenoj stijeni", in *Zbornik radova Crvena stijena*, Nikšić, 1975, 11–120.

Basler 1979 — Đ. Basler: "Tragovi vulkanske djelatnosti u dolini Trebišnjice", *Naš krš* 7, Sarajevo, 1979, 21–25.

Calanchi *et al.* 1998 — N. Calanchi, A. Cattaneo, E. Dinelle, G. Gasparotto & F. Lucchini: "Tephra layers in Late Quaternary sediments of the central Adriatic Sea", *Marine Geology* 149, 1998, 191–209.

Cassignol & Gillot 1982 — C. Cassignol & P. Y. Gillot: "Range and effectiveness of unspiked potassium-argon dating: experimental ground work and application", in G. S. Odin (ed.), *Numerical Dating in Stratigraphy*, New York, 1982, 160.

Clift & Dixon 1994 — P. D. Clift & J. E. Dixon: "Variation in arc volcanism and sedimentation related to rifting of the Lau Basin, southwest Pacific", in J. W. Hawkins *et al.* (eds.): "Proceedings Ocean Drilling Program", *Scientific Research* 135, College Station TX, 1994, 23–57.

Combourieu-Nebout *et al.* 1998 — N. Combourieu-Nebout, M. Paterne, J-L. Turon & G. Siani: "A high-resolution record of the last deglaciation in the central Mediterranean sea: palaeovegetation and palaeohydrological evolution", *Quaternary Science Review* 17, 1998, 303–317.

Čečuk & Radić 2005 — B. Čečuk & D. Radić: *Vela spila, Višeslojno pretpovijesno nalazište – Vela Luka, otok Korčula* (*Centar za kulturu, Monografije* 1), Vela Luka, 2005.

Davies *et al.* 2002 — S. M. Davies, N. P. Branch, J. J. Lowe. & C. S. M. Turney: "Towards a European tephrochronological framework for Termination 1 and the Early Holocene", *Philosophical Transactions of the Royal Society London* A 360, London, 2002, 767–802.

Deino *et al.* 2004 — A. L. Deino, G. Orsi, S. de Vita & M. Piochi: "The age of the Neapolitan Yellow Tuff caldera-forming eruption (Campi Flegrei caldera – Italy) assessed by 40Ar/39Ar dating method", *Journal of Volcanology and Geothermal Research* 133, 2004, 157–170.

De Vivo *et al.* 2001 — B. De Vivo, G. Rolandi, P. B. Gans, A. Calvert, W. A. Bohrson, F. J. Spera & H. E. Belkin: "New constrains on the pyroclastic eruptive history of the Campanian volcanic Plain (Italy)", *Mineralogy and Petrology* 73, 2001, 47–65.

Girolamo *et al.* 1984 — P. Di Girolamo, M. R. Ghiara, L. Lirer, R. Munno, G. Rolandi & D. Stanzione: "Vulcanologia e petrologia dei Campi Flegrei", *Bolletino della Società Geologica Italiana* 103, 1984, 349–413.

Fedele *et al.* 2002 — F. G. Fedele, B. Giaccio, R. Isaia & G. Orsi: "Ecosystem impact of the Campanian Ignimbrite eruption in Late Pleistocene Europe", *Quaternary Research* 57, 2002, 420–424.

Insinga *et al.* 2004 — D. Insinga, A. Calvert, B. D'Argenio, L. Fedele, M. Lanphere, V. Morra, A. Perrotta, M. Sacchi, & C. Scarpati: "40Ar/39Ar dating of the Neapolitan Yellow Tuff eruption (Campi Flegrei, southern Italy): volcanological and chronostratigraphic implications", *Geophysical Research Abstracts* 6, 2004, 10–12.

Kitagawa & van der Plicht 1998 H. Kitagawa & J. van der Plicht: "Atmospheric radiocarbon calibration to 45,000 yr B.P.: Late Glacial fluctuations and cosmogenic isotope production", *Science* 279, 1998, 1187–1190.

Lambeck *et al.* 2004 K. Lambeck, F. Antonioli, A. Purcell & S. Silenzi: "Sea-level change along the Italian coast for the past 10,000 yr", *Quaternary Science Reviews* 23, 2004, 1567–1598.

Le Bas *et al.* 1986 M. J. Le Bas, R. W. Le Maitre, A. Streckeisen & B. Zanettin: "A chemical classification of volcanic rocks based on the total alkali-silica diagram", *Journal of Petrology* 27, 1986, 745–750.

Miculinić 2006 K. Miculinić: Morfologija i morfometrija zubi vrste Equus hydruntinus REGALIA 1904 (Mammalia, Perissodactyla) iz Vele spile na otoku Korčuli (neobjavljen magistarski rad / unpublished M.A. thesis, Prirodoslovno-matematički fakultet, Sveučilište u Zagrebu), Zagreb, 2006.

Miracle *et al.* 2000 P. Miracle, N. Galanidou & S. Forenbaher: "Pioneers in the Hills: Early Mesolithic Foragers at Šebrn Abri (Istra, Croatia)", *European Journal of Archaeology* 3/3, 2000, 293–329.

Orsi *et al.* 1992 G. Orsi, M. D'Antonio, S. de Vita & G. Gallo: "The Neapolitan Yellow Tuff, a large-magnitude trachytic phreatoplinian eruption: eruptive dynamics, magma withdrawal and caldera collapse", *Journal of Volcanology and Geothermal Research* 53, 1992, 275–287.

Orsi *et al.* 1995 G. Orsi, L. Civetta, M. D'Antonio, P. Di Girolamo & M. Piochi: "Step-filling and development of three-layer magma chamber: the Neapolitan Yellow Tuff case history", *Journal of Volcanology and Geothermal Research* 67, 1995, 91–312.

Pappalardo *et al.* 1999 L. Pappalardo, L. Civetta, M. D' Antonio, A. Deino, M. Di Vito, G. Orsi, A. Carandente, S. de Vita, R. Isaia, & M. Piochi: "Chemical and Sr-isotopical evolution of the Phlegrean magmatic system before the Campanian Ignimbrite and the Neapolitan Yellow Tuff eruptions", *Journal of Volcanology and Geothermal Research* 91, 1999, 141–166.

Paterne *et al.* 1988 M. Paterne, F. Guichard & J. Labeyrie: "Explosive activity of the south Italian volcanoes during the past 80,000 years as determined by marine tephrochronology", *Journal of Volcanology and Geothermal Research* 34, 1988, 153–172.

Paunović *et al.* 2002 M. Paunović, V. Malez, J. Mauch Lenardić, G. Jambrešić, D. Brajković i K. Miculinić: *Vela spila – Preliminarna odredba kvartarne faune vertebrata iz Vele spile na otoku Korčuli* (Elaborat Zavoda za paleontologiju i geologiju kvaltara Hrvatske akademije znanosti i umjetnosti), Zagreb, 2002.

Peccerillo & Taylor 1976 A. Peccerillo & S. R. Taylor: "Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastamou area, Northern Turkey", *Contribution to Mineralogy and Petrology* 58, 1976, 63–81.

Radić 2005 D. Radić: "Vela spila: preliminarna analiza starijeneolitičkih i mezolitičkih naslaga iz sonde istražene 2004. godine", *Opuscula archaeologica* 29, Zagreb, 2005, 307–348.

Radić & Lugović 2004 D. Radić & B Lugović: "Petrografska i geokemijska korelacija artefakta iz mezolitičkih naslaga Vele spile i magmatskih stijena Srednjodalmatinskog otočja", *Opuscula archaeologica* 28, Zagreb, 2004, 7–18.

Sangiorgi *et al.* 2002 F. Sangiorgi, L. Capotondi & H. Brinkhuis: "A centennial scale organic-walled dinoflagellate cyst record of the last deglaciation in the South Adriatic Sea (Central Mediterranean)", *Palaeogeography, Palaeoclimatology, Palaeoecology* 186, 2002, 199–216.

Scarpati *et al.* 1993 C. Scarpati, P. Cole, & A. Perrotta: "The Neapolitan Yellow Tuff – a large volume multiphase eruption from Campi Flegrei, Southern Italy", *Bulletin of Volcanology* 55, 1993, 343–356.

Schmidt *et al.* 2002 — R. Schmidt, C. van den Bogaard, J. Merkt, & J. Müller: "A new Lateglacial chronostratigraphic tephra marker for the south-eastern Alps: The Neapolitan Yellow Tuff (NYT) in Längsee (Austria) in the context of a regional biostratigraphy and palaeoclimate", *Quaternary International* 88, 2002, 45–56.

Shackleton *et al.* 1984 — J. C. Shackleton, T. H. van Andel & C. N. Runnels: "Coastal paleogeography of the Central and Western Mediterranean during the last 125,000 years and its archaeological implication", *Journal of Field Archaeology* 11, 1984, 307–315.

Siani *et al.* 2001 — G. Siani, M. Paterne, E. Michel, R. Sulpizio, A. Sbrana, M. Arnold G. & Haddad: "Mediterranean Sea surface radiocarbon reservoir age changes since the Last Glacial maximum", *Science* 294, 2001, 1917–1920.

Stuiver *et al.* 1998 — M. Stuiver, P. J. Reimer, E. Bard, J. W. Beck, G. S. Burr, K. A. Hughen, B. Kromer, F. G. McCormac, J. van den Plicht & M. Spurk: "INTCAL98 radiocarbon age calibration, 24,000-0 cal BP", *Radiocarbon* 40, Tucson, 1998, 1041–1083.

Wulf 2000 — S. Wulf: *Das tephrochronologische Referenzprofil des Lago Grande di Monticchio. Eine detaillierte Stratigraphie des süditalienischen explosiven Vulkanismus der letzten 100.000 Jahre* (Universität Potsdam, Dissertation), 2000.