45.000 let stare fosilne dlake jamskega medveda iz najdišča Divje babe I v Sloveniji

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Izvleček

V paleolitskem najdišču in fosilnem brlogu jamskega medveda Divje babe I so bili najdeni poleg številnih kosti in zob tudi odtisi dlak in njihovi fosilni ostanki, stari 45.000 let. Fosilizirane dlake iz Divjih bab I so zaenkrat edinstven primer v jamskem sedimentacijskem okolju.

Abstract

Imprints and fossilised remains of cave bear hair were found in a fossil den at the Palaeolithic site of Divje babe-I, in addition to a plethora of bones and teeth. The hairs from Divje babe-I are currently the only example of their kind found in cave deposits.

UVOD

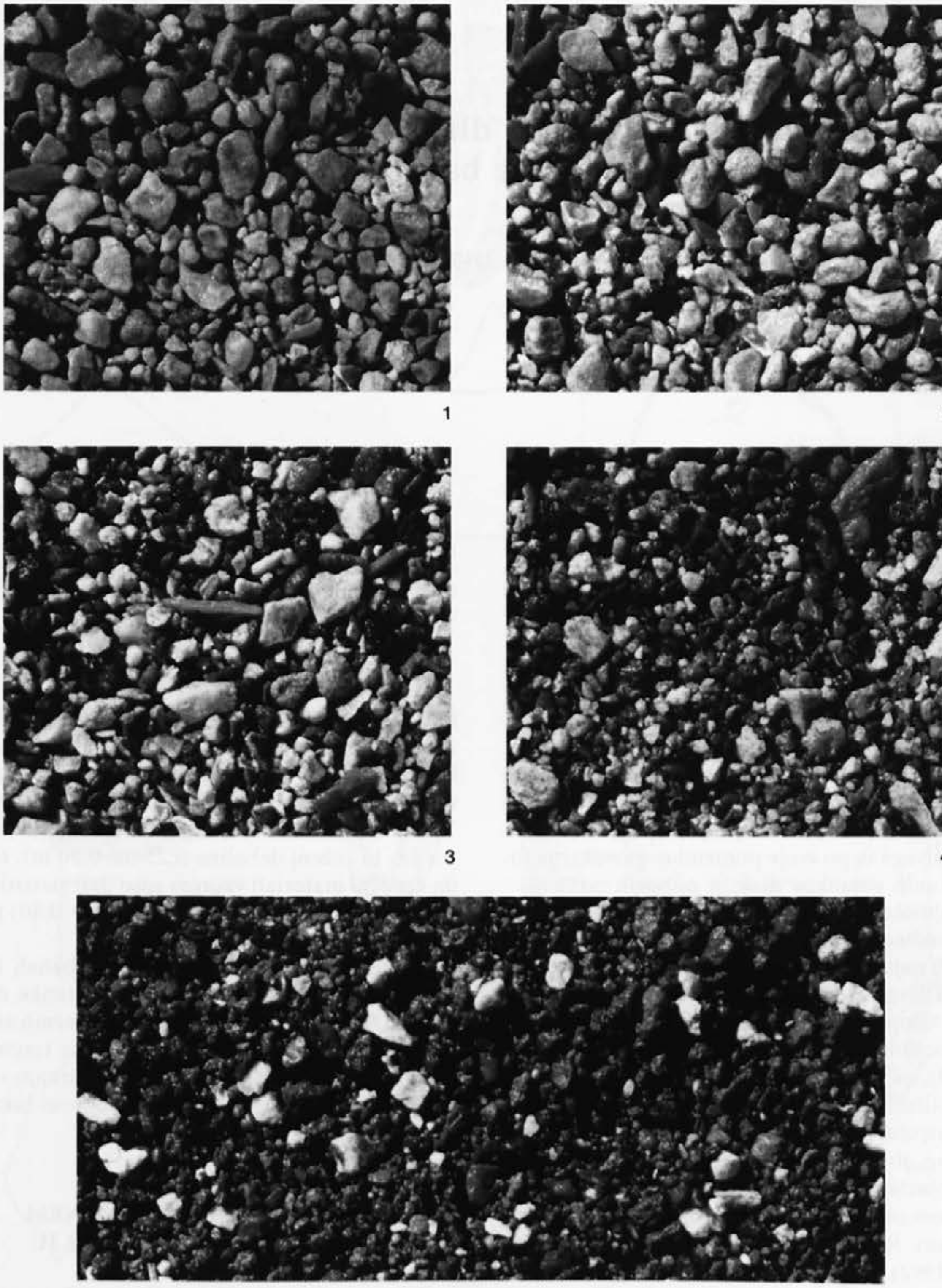
Dolgoletne raziskave v novejšem večplastnem paleolitskem najdišču Divje babe I v dolini Idrijce v severozahodni Sloveniji so pripeljale tudi do zanimivega in po svoje pomembnega odkritja fosiliziranih ostankov dlak in njihovih odtisov.

Najdišče Divje babe I je v slovenskem prostoru pomembno predvsem zaradi nove skupine paleolitskih najdb in trenutno najbolj bogatih paleontoloških in paleobotaničnih ostankov v arheološkem sklopu. Paleolitske najdbe pripadajo posebni različici mlajšega moustériena (5 horizontov, plasti 3 - 14), za katero je značilen velik delež mlajšepaleolitskih orodij, in zgodnjemu aurignacienu (1 horizont, plast 2) (neobjavljeno). Paleontološke najdbe obsegajo več kot 50 različnih taksonov (neobjavljeno), med katerimi je z izredno velikim številom ostankov zastopan jamski medved (*Ursus spelaeus* Rosenmüller in Heinroth 1794) (Turk *et al.* 1992). Paleobotanični ostanki so predstavljeni z najdbami peloda in lesnega oglja (Turk *et al.* 1988-1989; Šercelj, Culiberg 1985; 1991). Najdišče je na podlagi značilnih paleolitskih najdb in neobjavljenih radiokarbonskih AMS datacij dobro kronostratigrafsko opredeljeno. Pripada interpleniglacialu zadnjega glaciala (würm) in je, vsaj kar zadeva plasti 2 - 13, staro od 35.300 do 50.800 let (RIDDL 734, 746, 759; Turk *et al.* 1989). Najbolj zanesljive datacije plasti z moustérienskimi najdbami so bile pridobljene na podlagi vzajemnih vzorcev lesnega oglja in kostnega kolagena (RIDDL 739+745 in 746+759) iz zaključenih celot (kvadrat 1 x 1m in reženj debeline 0,25 oz. 0,30 m), tako da različni materiali vzorcev niso dali statistično različne radiokarbonske starosti (P > 0,80) (*cfr.* Taylor 1987, 125).

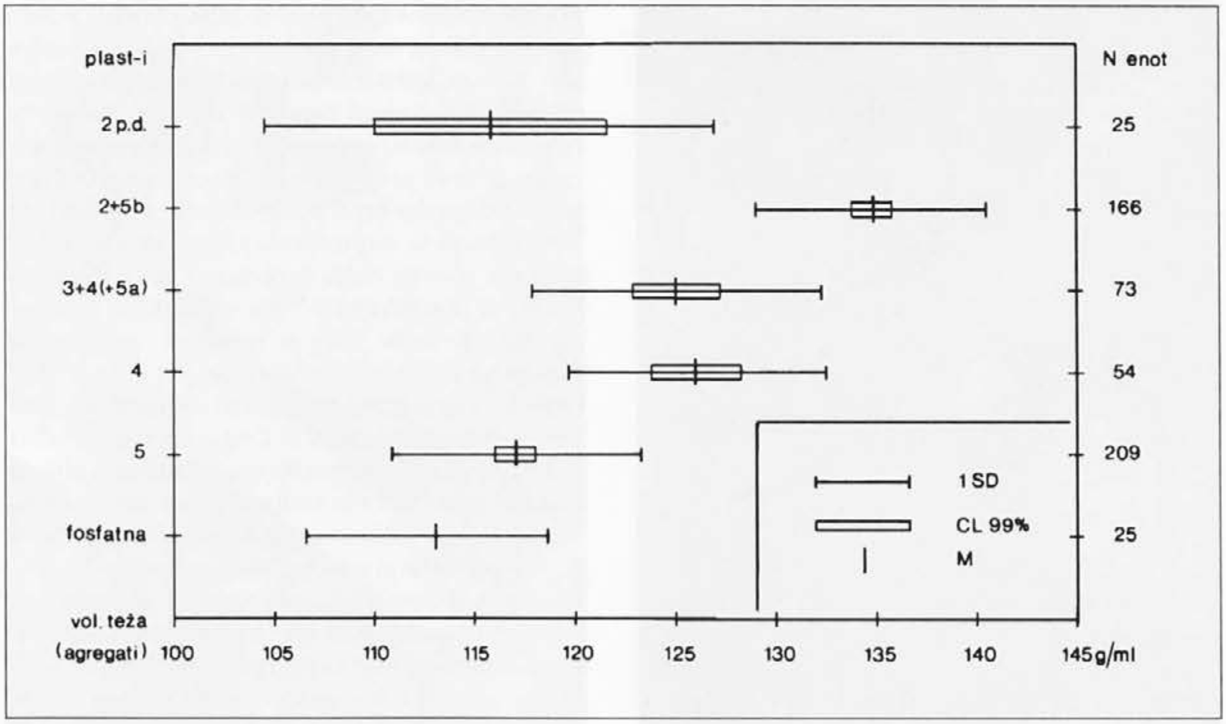
Sistematska izkopavanja v Divjih babah I so se začela leta 1980 in še trajajo. Ostanke dlak smo odkrili leta 1994. To je plod obsežnih sedimentoloških raziskav in zelo natančne terenske metode, ki od leta 1990 temelji na spiranju vseh odkopanih usedlin na sitih s premerom luknjic 10, 3 in 0,5 mm.

NAJDBE V SVOJEM NARAVNEM SEDIMENTACIJSKEM OKOLJU

Za vse usedline Divjih bab I so značilni sprimki in kosi matične dolomitne kamnine, v kateri se je v pleistocenu izoblikovala jama. Kosi dolomita so vseh velikosti, od melja do blokov, sprimki pa samo manjši od ok. 10 mm. Njihovo število narašča eksponencialno obratno sorazmerno z velikostjo frakcij. Plasti, 26 po številu, se med



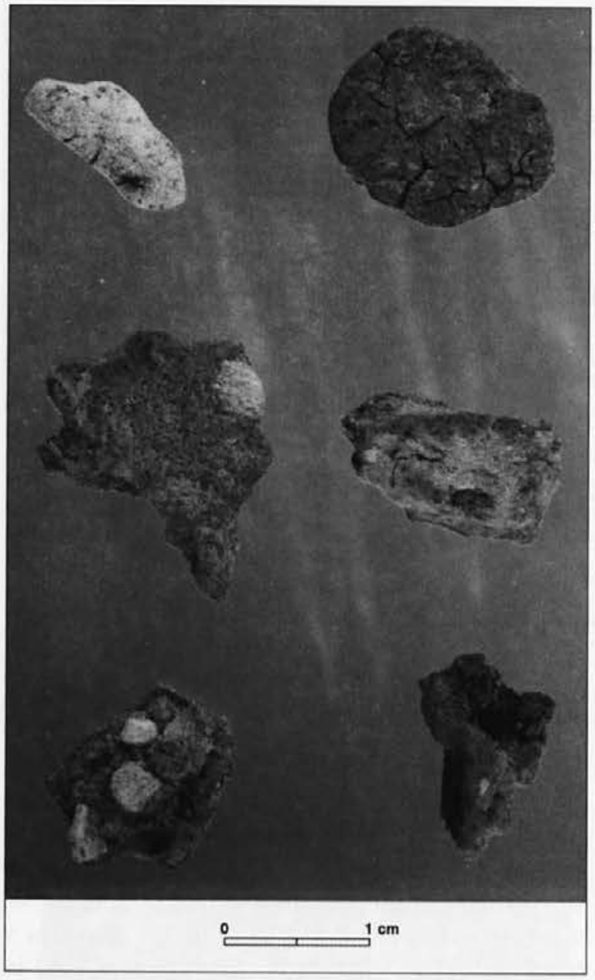
Sl. 1:. Fosfatni sprimki v frakcijah 0,5 - 3,0 mm iz različnih plasti.
Fig. 1: Phosphate aggregates, 0.5 mm to 3.0 mm fraction, from various layers.



Sl. 2: Standardne statistike volumenskih tež po plasteh.
Fig. 2: Standard statistics of aggregate density by layers.

seboj razlikujejo predvsem po gostoti sprimkov (*sl. 1*), ki jo lahko enostavno merimo s prostorninskimi težami (*sl. 2*). Sprimki so krhki, bolj ali manj zaobljeni in pogosto razpokani (*sl. 3*). Razpoke so stare, saj so v njih madeži vivianita in dendriti. Oboje dobimo tudi na površinah sprimkov, dolomitnih kosov in fosilnih kosti. Razpoke dokazujejo, da je bila snov, iz katere so sprimki, nekoč plastična, in da je razpokala pri strjevanju. Kemijska analiza (P in K) sprimkov je pokazala močno povečano vsebnost fosforja (10 - 23 % namesto 0,02 - 0,87 %, kot je običajno za neposeljene jame in tla v bližnji okolici) in normalno vsebnost kalija. Zato smo jih imenovali fosfatni sprimki. Plasti, ki vsebujejo v drobnih frakcijah skoraj same fosfatne sprimke in imajo najvišjo vsebnost fosforja, pa smo imenovali fosfatne plasti. Kemijska analiza frakcije usedlin, manjše od 1 mm, je potrdila iz pedološke prakse znano pozitivno korelacijo med obema elementoma ($r = 0.443$, $P < 0.01$, $n = 48$), čeprav v najdišču ni nobenih ilovnatih usedlin, za katere je značilna povečana vsebnost kalija (Limbrey 1975, 74). Vrednosti kalija se spreminjajo v razponu, ki je običajen za karbonatna tla. Ker so nekatere fosfatne spojine v tleh relativno najbolj obstojne, kar še posebej velja za naša karbonatna (bazična) jamska tla, smo vrednosti fosforja podrobneje analizirali. Izsledki so zanimivi in potrjujejo našo staro domnevo (Turk *et al.* 1989). Sprimki, izraženi s prostorninskimi težami frakcij 0,5 - 3,0 mm, so v negativni korelaciji z vsebnostjo fosforja v usedlinah ($r = -0.497$, $P < 0.001$, $n = 176$) in z maso fosilnih ostankov ($r = -0.300$, $P < 0.001$, $n = 492$). Slednji 99,9 % pripadajo jamskemu medvedu. Vsebnost fosforja v usedlinah je v pozitivni korelaciji z maso fosilnih ostankov ($r = 0.378$, $P < 0.001$, $n = 176$). Vendar te zakonitosti ne veljajo za t. im. fosfatne plasti, ki vsebujejo skoraj same sprimke in fosilne ostanke. Iz tega sledi, da je bil nastanek sprimkov z močno povečano vsebnostjo fosforja (*sl. 10*) pogojen predvsem s prisotnostjo jamskega medveda v najdišču (Schmid 1958; 1961; Turk et al. 1989; Kunst 1992). Najdišča brez jamskega medveda takih sprimkov nimajo, drugi agregati pa ne nastopajo v tako velikem številu in v tako različnih velikostih. V najdiščih z množičnimi ostanki jamskega medveda lahko torej, namesto običajnega razvoja usedlin, pričakujemo posebno fosfatogenezo. S tem pa dobimo tudi nov model za razlago nekaterih jamskih usedlin pri nas in drugod. Model lahko izpopolni danes že zastarel, a še vedno upoštevan Laisov model (1941; Schmid 1958; Laville 1975).

Od gostote sprimkov, njihove barve in inkrustacij na dolomitnih frakcijah so odvisne barve sedimentov. Te so nam bile pomemben stratigrafski kazalec. Za barvo so odločilni naravni pigmenti,

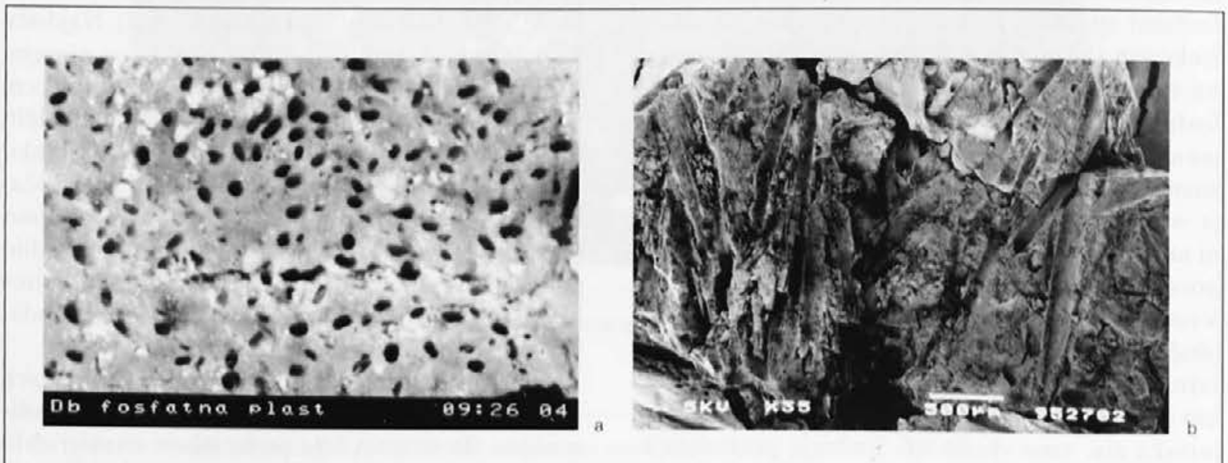


Sl. 3: Večji fosfatni sprimki.
Fig. 3: Larger phosphate aggregates.

predvsem železovi oksidi. Iz drugih najdišč vemo, da so jih v paleolitiku pogosto uporabljali v kozmetične in higienske namene (Pilz *s. a.*). Relativno majhne količine teh barvil so lahko različno obarvale cele plasti (beri paleolitske horizonte), odvisno od tega, koliko so paleolitski prebivalci jamo onesnažili s svojimi barvili in od tega, kakšno je bilo vsakokratno sedimentacijsko okolje: redukcijsko (z vodo prepojene, drobnozrnate usedline) ali oksidacijsko (zračne, grobozrnate usedline). Tako lahko s še nepreizkušenim modelom antropogenih vplivov bolje razumemo celo paleto ciklično se ponavljajočih barv v stratigrafskem nizu. Taka pestrost barv je značilna predvsem za mnoga paleolitska najdišča (cfr. Turk *et al.* 1989, tabla 2) in si jo težko razlagamo izključno z naravnimi sedimentacijskimi in diagenetskimi procesi.

Fosfatni sprimki vsebujejo različno količino dolomitnega peska in melja, zlepljenega s kalcijevim fosfatom. Zelo homogeni sprimki so zgrajeni iz strjene želatinaste snovi z redkimi vključki, predvsem dolomitnih zrnc. Če take sprimke prelomimo, ugotovimo, da so v notranjosti prepreženi s številnimi mikroskopskimi kanalčki (*sl. 4 a*). Prečni preseki teh kanalčkov so okrogli in ovalni, redkeje ledvičasti, premeri pa različnih dimenzij. Tanjši kanalčki imajo premere velikosti 0,05 - 0,09 mm (poprečje 0,067 mm), debelejši pa 0,11 - 0,22 mm (poprečje 0,135 mm). Meritve smo naredili z mikroskopskim merilcem. Podolžni preseki so ravni žlebiči z bolj ali manj gladkimi površinami brez posebne zgradbe. Samo izjemoma so na površini žlebičev vidni odtisi vlaken. Preplet žlebičev in mineralizirana vlakna v kanalčkih smo v enem primeru odkrili tudi na razpokani površini fosfatnega sprimka (*sl. 4 b*). Da gre za staro površino, na katero se je nekaj odtisnilo, dokazuje značilna patina, ki je sveži prelomi sprimkov nimajo, in zaobljenost vseh površinskih robov.

Sl. 4: Fosfatni sprimek z luknjicami (odtisi dlak) v prelomu (*a*). Žlebiči (odtisi dlak) na površini fosfatnega sprimka (*b*).
Fig. 4: Phosphate aggregate with holes (imprints of hairs) along the fracture line (*a*). Grooves (imprints of hairs) on surface of phosphate grain (*b*).



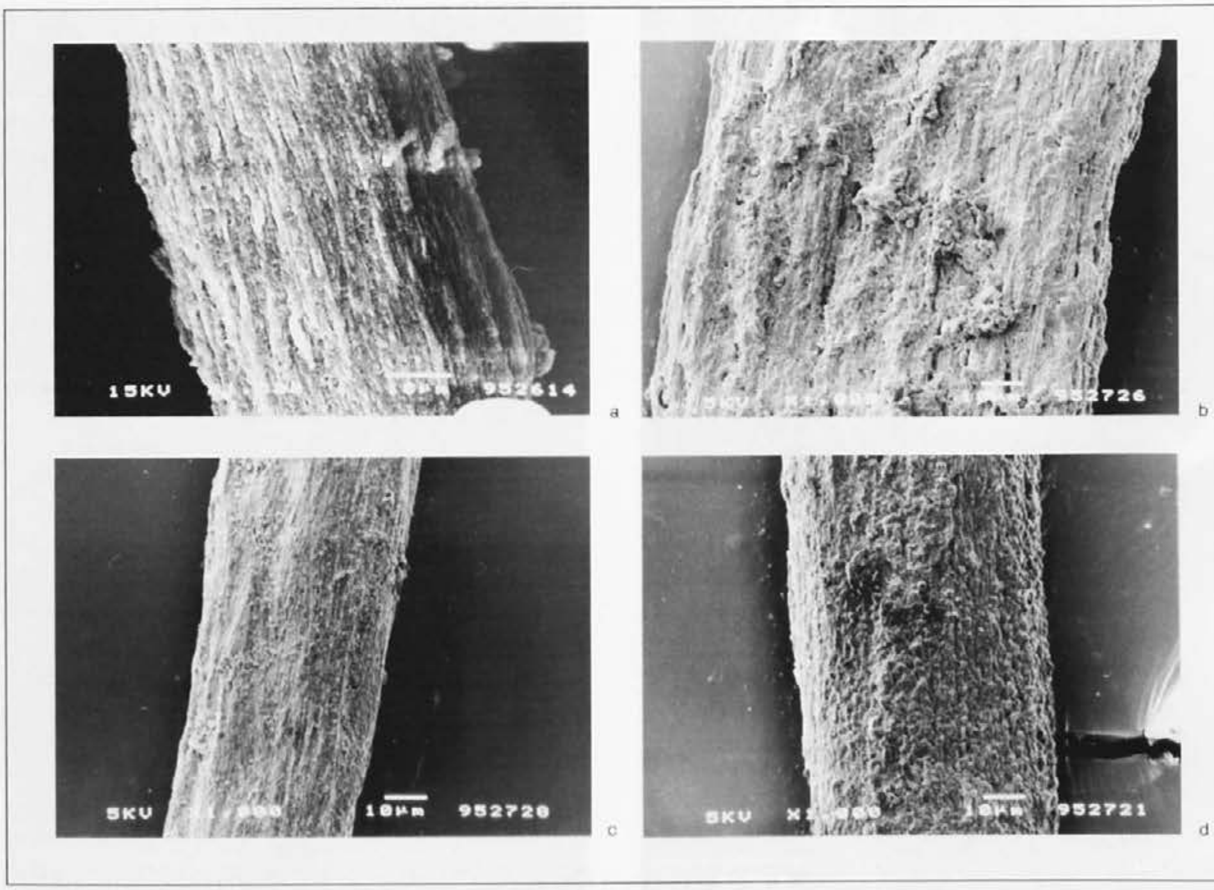
Sl. 5: Vlakno (fosilna dlaka) v kanalčku v fosfatnem sprimku.
Fig. 5: Fibre (fossil hair) in channel of phosphate grain.

V posameznih kanalčkih tičijo daljša vlakna okroglega preseka, ki so praviloma precej tanjša kot odprtina kanalčka (*sl. 5*). Tako kanalčki kot vlakna so zelo pogosti zlasti v sprimkih t. im. fosfatnih plasti, ki vsebujejo tudi precej fosilnih kosti in zob jamskega medveda. Pod elektronskim mikroskopom smo pregledali 17 vlaken. Od teh smo jih 12 izolirali. Površina vlaken je sestavljena iz različno debelih vzdolžnih niti, ki so vidne tudi pri zelo veliki povečavi (*sl. 6 a-d*). V enem primeru je površina obročasto nabrana (*sl. 7 a2*). Vlakna so, podobno kot kanalčki, različnih debelin (0,035 - 0,115 mm, poprečje 16 vlaken je 0,054 mm). Vlakna se lahko proti enemu koncu tanjšajo, proti drugemu pa debelijo (*sl. 7 b2*). Pregledani prečni preseki so bili vsi bolj ali manj okrogli. Za nekatere je značilno, da so sestavljeni iz nekakšne ovojnice in jedra (*sl. 7 a2*), za druge zopet, da imajo v sredini luknjico (*sl. 7 c2*).

Prva misel, ki se nam je utrnila pri naključnem odkritju opisanih oblik, predvsem kanalčkov in žlebičkov - fosilizirana vlakna smo dokončno odkrili šele pod elektronskim mikroskopom - je bila, da gre za odtise medvedjih dlak. Na to ne bi pomislili, če ne bi imeli v stanovanju psa, ki pušča za sabo polno dlak. Koliko dlak so morali v Divjih babah I natrositi šele vsi tisoči in tisoči velikanskih jamskih medvedov, ki so se poleti hladili in pozimi prezimovali v njej! Od teh so poprečno najmanj trije, stari nad eno leto, poginili in strohneli v 1 m^3 usedlin plasti 2 - 5 v 10.000 letih ! V plasteh 10 - 14 se je število poginulih na 1 m^3 usedlin skoraj podeseterilo. Od vseh teh milijard dlak se jih je lahko v takšni ali drugačni obliki vsaj nekaj tisoč ohranilo do danes.

ODTISNJENE IN FOSILIZIRANE MEDVEDJE DLAKE, DA ALI NE ?

Divje babe I so značilen brlog jamskega medveda. Podobni brlogi so bili že bolj ali manj natančno raziskani v Sloveniji in bližnji okolici (Brodar M. 1959; Rakovec 1967; Brodar in Brodar 1983; Broglio 1964; Malez 1986). Zanje je značilno veliko število fosilnih ostankov. Ti so neenakomerno razporejeni po plasteh, tako vertikalno kot lateralno (*sl. 8*). Druge najdbe so veliko bolj omejene in redke. Ostanki zob in kosti pripadajo predvsem zelo mladim medvedkom, ki so poginili v času menjave zobovja. Teh je v Divjih babah I kar 40 - 86 %. Njihov delež se od plasti do plasti spreminja. Izolirani mlečni zobje in izolirani stalni zobje v fazi erupcije so po plasteh v močni pozitivni korelaciji ($r = 0.359 - 0.567$, $P < 0,01$ in $< 0,001$, $n = 54 - 166$) To pomeni, da pripadajo enim in istim osebkom, ki so poginili med prvim zimovanjem sami ali skupaj z materjo. Spolna sestava fosilne populacije, ugotovljena na podlagi dimorfizma stalnih zob, se spreminja skupaj s starostno strukturo (Turk *et al.* 1992). To pomeni, da so enoletni in dvoletni mladiči prezimovali skupaj z materami in skupaj z njimi tudi poginili. Veliko peloda žužkocvetk v sedimetih Divjih bab I, katerega količina se spreminja skupaj s količino fosilnih ostankov jamskega medveda, dokazuje, da so se medvedi zadrževali v jami tudi poleti, saj so nekatere žužkocvetke še vedno na jedilniku rjavega medveda. Jamski medved je bil torej nedvomno edini stalni uporabnik jame. Poleg človeka je bil hkrati glavni naravni onesnaževalec. Zato lahko upravičeno domnevamo, da odtisnjena in fosilizirana vlakna, ki se pojavljajo množično, predstavljajo dlake jamskega medveda. Da gre za človeške lase, ki so po obliki in merah zelo podobni medvedjim dlakam, je glede na število paleolitskih ostankov in glede na popolno odsotnost



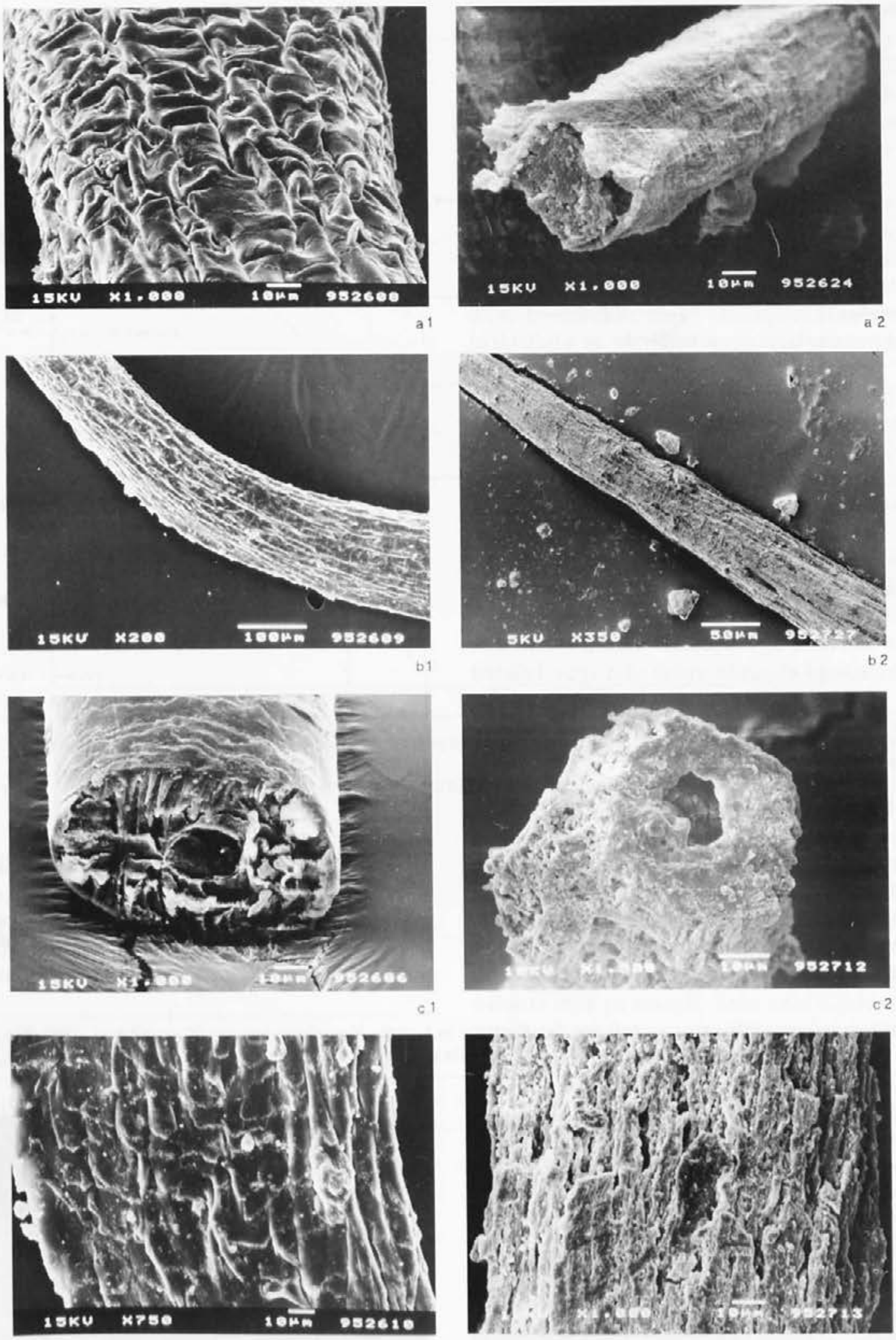
Sl. 6 a-d: Površine izoliranih vlaken (fosilnih dlak).
Figs 6 a-d: Surfaces of isolated fibres (fossil hairs).

skeletnih najdb, malo verjetno, ne pa izključeno. Dlake ostalih naših večjih seslacev, po obliki prerezov in razponu velikosti prerezov, kanalčkom v fosilnih sprimkih ne ustrezajo.

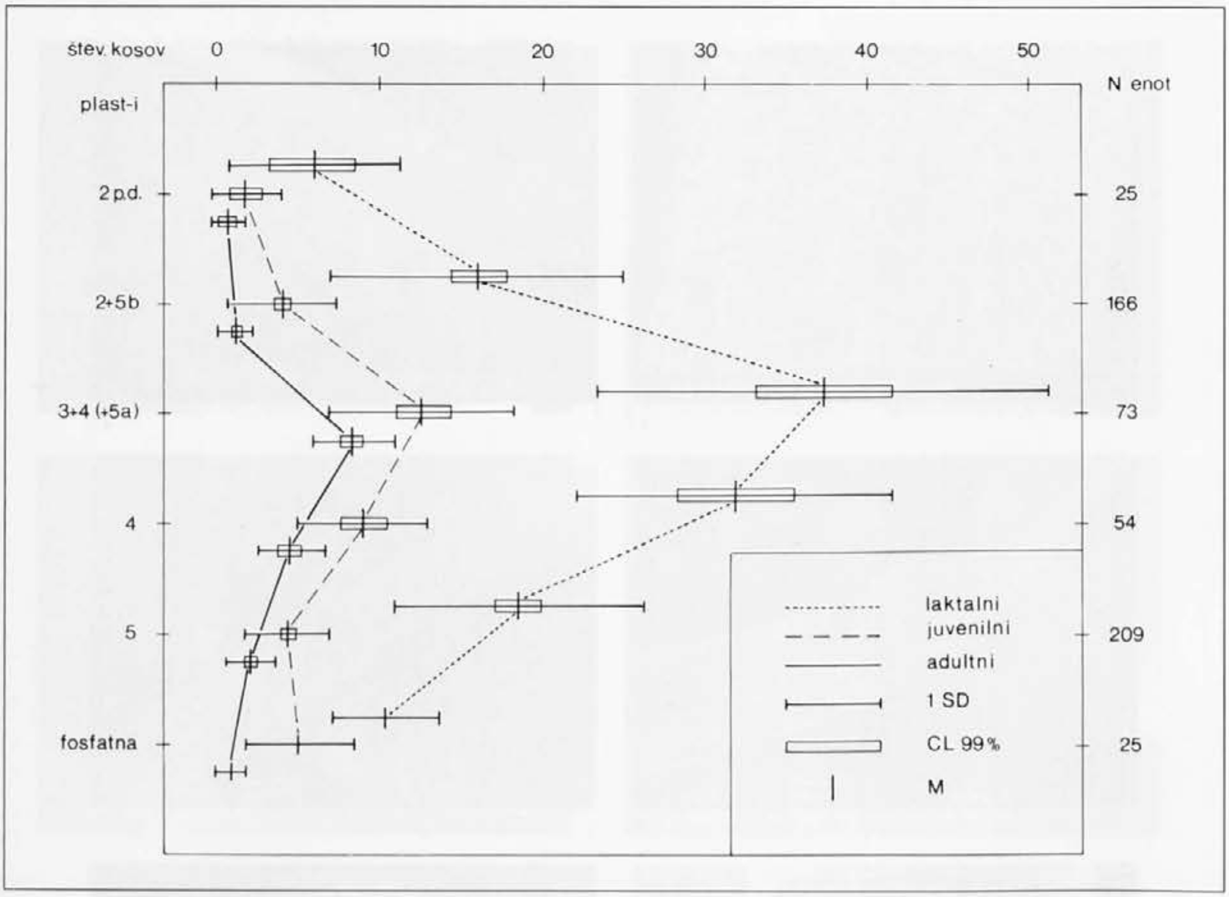
Rezultat več kot sto let trajajočih raziskav najdišč in fosilnih ostankov jamskega medveda je zelo podrobno poznavanje te izumrle živalske vrste (Kurtén 1976). Kljub temu nam ni znano, da bi kdaj našli tudi fosilne dlake. Zagotovo pa taka najdba, tudi če se kje omenja, ni bila ustrezno dokumentirana. Znana nam je navedba odtisov dlak jamskega medveda iz jame Fauzan v francoski pokrajini Hérault (Gillet 1963-1965, 138). Odtisi so bili najdeni v fosilnem medvedjem ležišču ("gnezdu"), izkopanem v ilovico. Taka ležišča so precejšnja redkost. V Divjih babah I se niso ohranila. Kjer so bila še najdena, se odtisi dlak ne omenjajo (Barthe 1984; Malez 1988). V Divjih babah I imamo poleg odtisov očitno ohranjene tudi fosilizirane dlake. Zato smo se odločili za podrobno primerjavo z dlakami rjavega medveda, ki je najbližji živeči sorodnik izumrlega jamskega medveda.

Dlaka sesalcev je v pretežni meri sestavljena iz drobnih nitk (mikrofilomentov) keratina, izjemno trdnega, prožnega in odpornega proteina. Zunanja zelo tenka plast - povrhnjica ali opna (kutikula) dlake je iz številnih poroženelih luskastih celic (*sl. 9 a*). Pod povrhnjico je skorja (korteks). Sestavljajo jo celice, ki so pri človeku značilne vretenaste oblike, in so vtkane v mrežo vlaknastih keratinskih omotov (*sl. 9 b*) (Corcuff *et al.* 1993). Sredica (medula) dlake je iz mrtvih celic, ki so različno vidne, in predstavljajo prehrambeni kanal napolnjen z zrakom ali organsko tekočino s pigmenti (*sl. 7 c1*). Zgradba dlake se v podrobnostih razlikuje od ene seslaske vrste do druge in se ne spremeni niti pri prebavljanju, kar s pridom uporabljamo pri analizi prehrane plenilcev (Day 1966).

Kožuh današnjega rjavega medveda (*Ursus arctos* Linnaeus, 1758) je podobno kot kožuh ostalih naših večjih sesalcev sestavljen iz več vrst dlak. Osnovni sta daljša, krovna nadlanka in gostejša, volnata podlanka. Obe se po obliki in zgradbi močno razlikujeta. Vrstno in rodovno bolj značilne so dlake nadlanke. Dlake iz različnih delov kožuha so si zelo podobne razen kratkih dlak šap in smrčka (Debrot *et al.* 1982; Teerink 1991). Pri zvereh (carnivora) ni bistvene razlike med zimsko in letno dlako, kot je to očitno pri prežvekovalcih (Debrot



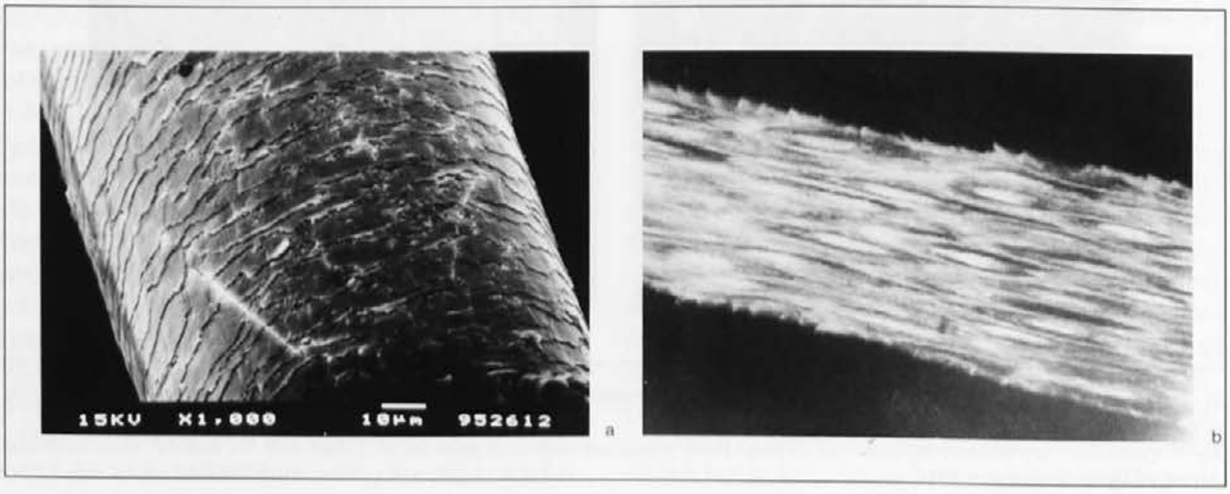
Sl. 7: Recentne dlake rjavega medveda (*a1-d1*) in domnevne fosilne dlake jamskega medveda (*a2-d2*). Na slikah *7a1, 7b1* in *7d1* je kutikula poškodovana z vodikovim peroksidom.
Fig. 7: Contemporary brown bear hairs (*a1-d1*) and likely fossilised cave bear hairs (*a2-d2*). *Figs 7a1, 7b1* and *7d1* show cuticulas damaged by hydrogen peroxide.

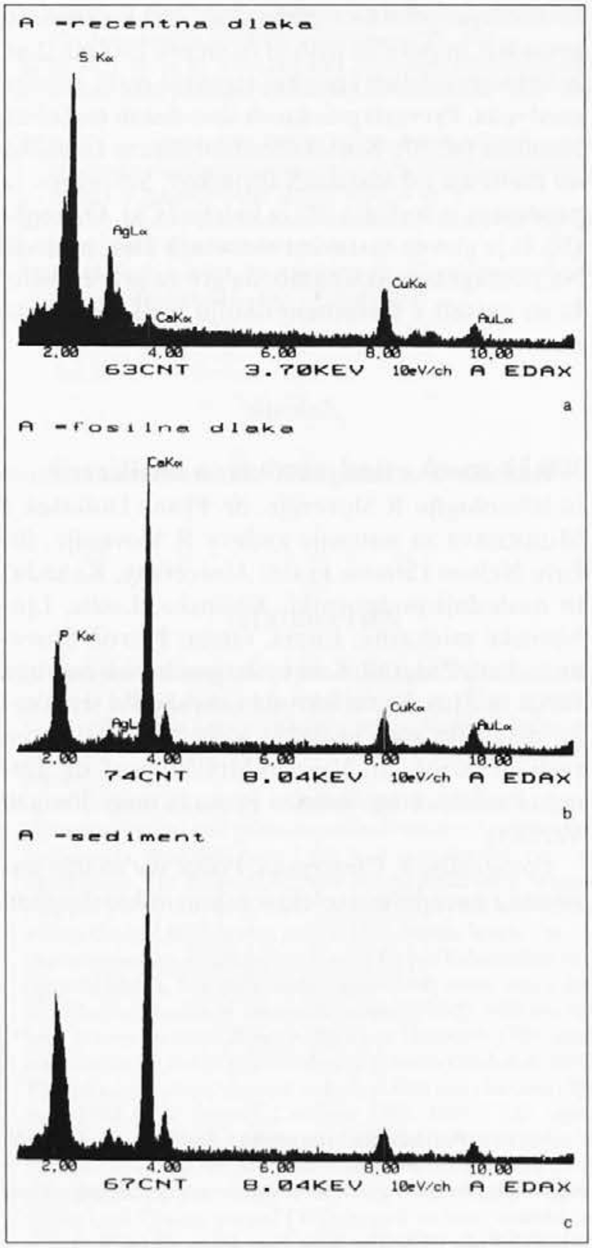


Sl. 8: Standardne statistike za pogostnost izoliranih zob jamskega medveda v delu stratigrafskega niza na enoto (1 m^2 in rezenj debeline 0,12 m).
Fig. 8: Standard statistics for determining frequency of isolated cave bear teeth in stratigraphic series per unit (1 square metre, 0.12 m deep).

et al. 1982). Za določevanje živalske vrste si pomagamo z več značilnostmi dlake. Velikost, oblika in vzorec lusk kutikule se spreminja glede na lego na dlaki. Pri rjavem medvedu je vzorec povrhnjice transversalen, nepravilno valovit in pri korenu dlake prehaja v mozaičen vzorec (Dziurdzik 1973; Debrot *et al.* 1982). Vrstno značilni sta tudi debelina korteksa glede na premer dlake in zgradba medule. Morfološko kaže sredica mnogo različnih vzorcev, vidnost teh pa se lahko pri prebavljanju

Sl. 9: Kutikula recentne dlake rjavega medveda (*a*). Kutikula in korteks človeškega lasu (*b*) (Corcuff *et al.* 1993, Fig. 12).
Fig. 9: Cuticula of contemporary brown bear hair (*a*). Cuticula and cortex of human hair (*b*)(Corcuff *et al.* 1993, Fig. 12).





Sl. 10: Energijsko disperzijska X-žarkovna analiza (EDAX) recentne dlake rjavega medveda (*a*), fosilne dlake (*b*) in sprimka (*c*).
Fig. 10: Results of Energy Dispersion X-ray Analysis (EDAX) of contemporary brown bear hair (*a*), fossilised hair (*b*), and aggregate(*c*).

spremeni, kot se to utegne zgoditi tudi pri fosilizaciji. Rjavi medved ima mnogoceličen (multiceluraren) mrežasti vzorec sredice (Debrot *et al.* 1982).

Dlake nadlanke imajo v prečnem prerezu različno obliko, od okrogle do bolj zapletenih vzorcev. Oblika in premer prečnih rezov se pri dlakah nadlanke vzdolž dlake bistveno spreminja, saj se dlake od korena proti vrhu širijo in na konici zopet stanjšajo. Na najširšem delu so dlake običajno sploščene. Pri rjavem medvedu so dlake podlanke praviloma okrogle do rahlo ledvičastega preseka in premera 0,05 - 0,09 mm. Dlake nadlanke imajo obliko prečnega prereza od najpogostejše okrogle (Dziurdzik 1973) do eliptične in redkeje ledvičaste oz. vbočeno-izbočene. Premer dlake nadlanke se giblje od 0,11 do 0,20 mm. Najdebelejše dlake so v prerezu okrogle.

Na podlagi zbranih analitskih podatkov lahko naredimo primerjavo med fosilnimi domnevnimi dlakami jamskega medveda in recentnimi dlakami rjavega medveda. Primerjavo otežujeta dejstvi, da so fosilizirane dlake ohranjene fragmentarno in da dlake ne variirajo samo med vrstami temveč tudi znotraj iste vrste.

Kutikula se v večini primerov ni fosilizirala. Tam, kjer se je izjemoma ohranila, pa je močno spremenjena (*sl. 7 a2, d2*). Domnevamo, da so različne kisline in baze med *fosfatogenezo* lahko poškodovale povrhnjico dlak pred fosilizacijo. Zato smo nekaj recentnih dlak, prikazanih na *sl. 7*, namočili v vodikov peroksid. Dobili smo podobne površinske vzorce kutikule, kot jih imajo domnevne kutikule fosilnih dlak. V podobnem sedimentacijskem okolju, kot ga poznamo v Divjih babah I, se je zelo dobro ohranila kutikula človeških las, starih 10.000 let (Morell 1994).

Korteks domnevnih fosilnih dlak je na splošno bolje ohranjen kot kutikula (*sl. 6*). Kortikalna zgradba je bila med fosilizacijo večinoma spremenjena. Vendar so se izjemoma lahko ohranili celo vlaknasti keratinski omoti okoli kortikalnih celic (*cfr. sl. 6 a* in *9 b*). Spremenjen je očitno tudi odnos med debelino korteksa in premerom fosilnih dlak. V plastičnih fosfatnih sprimkih so se lahko dlake pred fosilizacijo pod vplivom kislin in baz deformirale, tako da so odtisi večji, fosilizirani ostanki dlak pa manjši. Zato nam ti podatki niso v pomoč pri determinaciji na ravni vrste.

Medulo domnevnih fosilnih dlak smo odkrili v dveh primerih (*sl. 7 c2*). Je brez vzorca in za določanje vrste ne pride v poštev. Velikost premera sredice fosilizirane dlake se dobro ujema s premerom kanala recentne dlake rjavega medveda.

Debeline in oblike presekov domnevnih fosilnih dlak so najbolj verodostojno ohranjene v odtisih na površini in znotraj fosfatnih sprimkov. Oblika in velikost manjših luknjic ustrezata dlaki podlanki rjavega medveda. Prav tako premeri večine fosiliziranih dlak. Večje luknjice v sprimkih so po obliki in velikosti bolj variabilne ter se povsem ujemajo z razponom velikosti in obliko prečnih presekov dlak nadlanke rjavega medveda. Zanimivo je, da niso večje od debelin recentnih dlak rjavega medveda. Na domnevnih fosilnih dlakah opažamo tudi za recentne dlake značilno tanjšanje oz. debeljenje v vzdolžni smeri (*sl. 7 b2*). Dlake ostalih naših večjih sesalcev po obliki prerezov in razponu premerov ne ustrezajo luknjicam v fosilnih sprimkih.

SKLEP

Fosilne odtise in fosilizirana vlakna v fosfatnih sprimkih iz najdišča Divje babe I lahko z veliko verjetnostjo opredelimo kot ostanke dlak jamskega medveda. To so tako prve dokumentirane najdbe fosilnih dlak te izumrle živalske vrste nasploh. Najdbe so radiokarbonsko zanesljivo datirane z AMS postopkom na podlagi vzajemnih vzorcev lesnega oglja in kostnega kolagena jamskega medveda (RIDDL, neobjavljeno). Njihova povprečna radiokarbonska starost znaša 45.450 let. Z njimi se odpira nova mikropaleontološka smer v raziskavah pleistocenske sesalske favne in ostankov njenih tkiv, ki so se ohranili v povsem običajnih sedimentacijskih okoljih in pogojih fosilizacije za razliko od nekaterih izjemnih podobnih mlajšepleistocenskih najdb drugih velikih sesalcev v posebnih okoljih (*cfr.* Kurtén 1968, 137s, 143).

DODATEK

Z energijsko disperzijsko X-žarkovno analizo (EDAX) smo obdelali več točk na svežem prelomu fosfatnega sprimka z odtisi dlak, več kortikalnih presekov in površin istih in različnih fosilnih dlak in kutikulo z delom korteksa recentne dlake rjavega medveda. Pri vseh poizkusih smo dobili podobne rezultate (*sl. 10*). Korteks fosilnih dlak se kemijsko ne razlikuje od fosfatnih sprimkov. Sestavljen je predvsem iz fosforja (P) in kalcija (Ca). O žveplu (S), ki je glavna sestavina recentnih dlak, ni sledi. Na podlagi tega sklepamo, da gre za prave fosile, ki so nastali v fosfatnem okolju med fosfatogenezo.

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Fotografije F. Cimerman. Povečave so bile narejene z navadnim in elektronskim mikroskopom.

BARTHE, J.-M. 1984, L' Ours des cavernes. Ce familier méconnu. - *Spelunca* 16, 25 ss.

BRODAR, M. 1959, Mokriška jama, nova visokoalpska aurignaška postaja v Jugoslaviji. - *Razpr. 4. razr. SAZU* 5, 417 ss.

BRODAR, S. in M. BRODAR 1983, *Potočka zijalka. Visokoalpska postaja aurignacianskih lovcev.* - Dela 1. razr. SAZU 24.

BROGLIO, A. 1964, Le industrie mousteriane della Grotta del Broion. - *Mem. Mus. Civ. St. Nat. Ver.* 12, 369 ss.

CORCUFF, P., P. GREMILLET, M. JOURLIN, Y. DUVAULT, F. LEROY in J.-L. LEVEQUE 1993, Reconstraction of human hair by confocal microscopy. - *Jour. Soc. Cosmet. Chem.* 44, 1 ss.

DAY, M. G. 1965, Identification of hair and feather remains in the gut and faeces of stoats and weasels. - *Jour. Zool.* 148, 201 ss.

DEBROT, S., G. FIVAZ, C. MERMOD in J. M. WEBER 1982, *Atlas des Poils de Mammifères d'Europe.* - Neuchatel.

DZIURDZIK, B. 1973, Key to identification of hairs of mammals from Poland (v poljščini). - *Acta Zool. Cracoviensia* 18, 73 ss.

GILLET, J.-C. 1963-1965, L' Ours des cavernes. - *Les chercheurs de la Wallonie. Spéléologie-préhistoire. Diffusion scientifique* 19, 124 ss.

KUNST, G. K. 1992, Hoch- und Spätglaziale Grosssäugerreste aus dem Nixloch bei Losenstein - Ternberg (O. Ö.). - V: *Nixloch bei Losenstein - Ternberg,* 83 ss, Wien

KURTÉN, B. 1968, *Pleistocene Mammals of Europe.* - London.

KURTÉN, B. 1976, *The Cave Bear Story.* - New York.

LAIS, R. 1941, Über Höhlensedimente. - *Quartär* 3, 56 ss.

LAVILLE, H. 1975, *Climatologie et chronologie du paléolithique en Périgord. Étude sédimentologique de dépôts en grottes et sous abris.* - Études quaternaires 4.

LIMBREY, S. 1975, *Soil Science and Archaeology.* - London, New York, San Francisco.

MALEZ, M. 1986, Kvartarni sisavci (Mammalia) iz Velike pećine na Ravnoj gori (SR Hrvatska, Jugoslavija). - *Rad. Zav. znan. rad JAZU* 1, 33 ss.

MALEZ, M. 1988, Pećina Hrustovača kod Sanskog Mosta i njezino paleontološko značenje. - *Naš krš* 14, 69 ss.

MORELL, V. 1994, Pulling hair from the ground. - *Science* 265, 741.

PILZ, W. *s. a.*, Kosmetik in der Frühgeschichte des Menschen. - *Haarmann & Reimer Contact* 42, 27 ss.

RAKOVEC, I. 1967, Jamski medved iz Mokriške jame v Savinjskih Alpah. - *Razpr. 4. razr. SAZU* 10, 119 ss.

RIDDL, Radio-Isotope Direct Detection Lab, Simon Fraser University.

SCHMID, E. 1958, *Höhlenforschung und Sedimentanalyse.* - Basel.

SCHMID, E. 1961, Neue Ausgrabungen in Wildkirchli (Ebenalp, Kt. Appenzell), 1958/59. - *Ur-Schweiz* 25, 4 ss.
ŠERCELJ, A. in M. CULIBERG 1985, Rastlinski ostanki v paleolitskih postajah v Sloveniji. - *Por. raz. pal. neol. Slov.* 13, 53 ss.
ŠERCELJ, A. in M. CULIBERG 1991, Palinološke in antrakotomske raziskave sedimentov iz paleolitske postaje Divje babe I. - *Razpr. 4. razr. SAZU* 32, 129 ss.
TAYLOR, R. E. 1987, *Radiocarbon dating. An archaeological perspective.* - Orlando etc.
TEERINK, B. J. 1991, *Hair of West-European Mammals. Atlas and identification key.* - Cambridge.
TURK, I., J. DIRJEC in M. CULIBERG 1988-1989, Divje babe I - novo paleolitsko najdišče in skupinsko grobišče jamskega medveda. Poskus tafonomske analize na podlagi vzorcev iz dveh sedimentnih in arheoloških kompleksov. - *Arh. vest.* 39-40, 13 ss.
TURK, I., J. DIRJEC, D. STRMOLE, A. KRANJC in J. ČAR 1989, Stratigraphy of Divje babe I. Results of excavations 1980 - 1986. - *Razpr. 4. razr. SAZU* 30, 161 ss.
TURK, I., J. DIRJEC, I. DEBELJAK in Đ. HUBER 1992, Divje babe I - poskus uporabe statistične analize množičnih živalskih ostankov v paleolitski arheologiji. IV. Posamično najdeni zobje jamskega medveda. - *Arh. vest.* 43, 29 ss.

Fossilised cave bear hairs from 45,000 years ago found at Divje babe-I in Slovenia

Translation

INTRODUCTION

Years of investigation at the multilayer Palaeolithic site of Divje babe-I, located in the Idrijca river valley in north-western Slovenia have yielded the interesting and important discovery of certain fossilised remains of hairs and their imprints.

With the recent group of Palaeolithic finds and the richest palaeontological and palaeobotanical remains found to date in Slovenia, the Divje babe-I site is of considerable regional significance. The Palaeolithic finds belong to the early Aurignacian period (1 horizon, layer 2), and a specific assemblage within the late Mousterian period (5 horizons, layers 3 to 14), characterised by a high percentage of Upper Palaeolithic tools (unpublished). The palaeontological finds cover more than 50 different species of mammals (unpublished), with the cave bear (*Ursus spelaeus*, Rosenmüller and Heinroth 1794) being responsible for the largest number of remains (Turk *et al.* 1992). The palaeobotanical remains include pollen and charcoal (Turk et al.1988-1989; Šercelj, Culiberg 1985; 1991). The typical Palaeolithic remains and the unpublished results of radiocarbon dating using the AMS method provide a good chronostratigraphic picture of the site. It belongs to the Interplenigacial of the Last Glacial period (Würm) and, at least with regard to layers 2 to 13, dates from between 35,300 and 50,800 years ago (RIDDL 734, 746, 759; Turk et al. 1989). The most reliable dating of the layers that contain Mousterian finds is based on reciprocal samples of charcoal and bone collagen (RIDDL 739+745 and 746+759) from two individual units (1 square metre, split 0.25 m to 0.30 m deep). The radiocarbon dating of different sample materials did not yield a statistically significant ($P > 0.80$) difference in age (*cf.* Taylor 1987, 125).

Systematic excavations at the Divje babe-I site began in 1980 and are still in progress at the time of writing. The remains of the hairs were found in 1994, the result of an extensive examination of sediments using a very meticulous field method, which since 1990 has involved the rinsing of all excavated sediments using sieves with holes of diameters 10, 3 and 0.5 mm.

FINDS IN THEIR NATURAL SEDIMENTARY ENVIRONMENT

All sediments at Divje babe-I are characterised by aggregates and fragments of the dolomite bedrock that houses the cave shaped during the Pleistocene. The fragments of dolomite are of various sizes, ranging from silt to boulders. The aggregates are of a smaller size, less than 10 mm in diameter on average. Their number rises exponentially in inverse proportion to their size. The 26 layers differ mostly with regard to the density of aggregates (*fig. 1*), which is easily measured in terms of weight per volume (*fig. 2*). Aggregates are fragile, more or less rounded, and often fractured (*fig. 3*). The great age of these fractures is evident from traces of vivianite and dendrites. Both are also found on the surface of the aggregates, the dolomite fragments, and the fossil bones. The fissures show that the material constituting the aggregates was once plastic, and later fractured in the process of solidification. Chemical analysis (P and K) of the aggregates showed a high phosphorus content (10% to 23% compared to the 0.02% to 0.87% range characteristic of sediments of uninhabited caves and the soil in the vicinity) and a normal potassium content, which led them to be named phosphate aggregates or grains. Layers whose smaller-sized fraction consist almost exclusively of phosphate grains and which have the highest phosphorus content were named phosphate layers.

Phosphate aggregates contain varying quantities of dolomite silt and sand within a calcium phosphate matrix. Very homogeneous aggregates are made of solidified gelatinous material, with small quantities of dolomite particles. When such aggregates fracture a network of microscopic interior channels is revealed (*fig. 4a*). The cross-sections of these channels are circular or oval, or very occasionally reniform, of various diameters. Thinner channels have diameters ranging from 0.05 mm to 0.09 mm (average diameter 0.067 mm), while wider channels range between 0.11 mm and 0.22 mm in diameter (average 0.135 mm). Measurements were made using a microscopic measuring instrument. Longitudinal sections of the channels reveal straight grooves having a more or less smooth surface with no specific structure. Rare examples display imprints of fibres on their surfaces. One such example is shown in *fig. 4b*, in which the intertwined grooves and mineralised fibres in the channel are imprinted on the surface of the phosphate grain. The rounded edges and the characteristic patina testify to the old age of the surface of this imprint, as freshly fractured aggregates contain no patina.

Some channels contain longer fibres with round cross-sections, which are usually thinner than the channel itself (*fig. 5*).Both channels and fibres frequently appear in aggregates from the phosphate layers which also contain numerous cave bear bones and teeth. Seventeen fibres were examined using an electron microscope, and twelve of these were isolated. The surface of the fibres consists of longitudinal threads of varying thicknesses observable under very high magnification (*fig. 6 a-d*). One sample has a folded, ring-like surface (*fig. 7 a2*). As seen during the examination of the channels, the fibres are also of varying thicknesses (0.035 mm to 0.115 mm, the average of 16 samples being 0.054 mm). It is thought that some samples taper (*fig. 7 b2*). All of the cross-sections were approximately circular, and some are characterised by a type of wrapping around the core (*fig. 7 a2*), while others have a hole in the centre (*fig. 7 c2*).

It was immediately thought after the discovery of these shapes, particularly the channels and grooves - the fossil fibres were discovered only after using the electron microscope - that these shapes were the imprints of bear hairs. Such thinking was prompted by the presence of a dog which was shedding its coat. How many hairs must have remained after thousands of bears had sought shade and shelter in the cave! At least three bears over one year of age died in the cave in the course of 10,000 years, decomposing in every single cubic metre of sediment in layers 2 to 5. The level of bear remains per cubic metre in layers 10 to 14 is almost ten times higher. From the billions of hairs produced by the bears, several thousand must have survived to the present day.

IMPRINTS AND FOSSILISED BEAR HAIRS - YES OR NO?

Divje babe-I is a typical cave bear den. Similar dens have been investigated in Slovenia and elsewhere in the region (Brodar M. 1959; Rakovec 1967; Brodar and Brodar 1983; Broglio 1964; Malez 1986). The Divje babe-I site contains large quantities of cave bear fossil remains unevenly distributed throughout layers both vertically and horizontally (*fig. 8*). Other finds are of a much more limited extent and are quite rare. The bones and teeth belong mostly to young bears who died during the time of teething. They constitute between 40% and 86% of the fossil remains at Divje babe-I, and their proportion varies from layer to layer. Isolated milk teeth and isolated permanent teeth in the eruption phase are intensely positively correlated across the layers ($r = 0.359$ to 0.567, $P < 0.01$ and 0.001, $n = 54$ to 166). This means that they belonged to individuals that died during the first winter hibernation alone or together with the mother. The sex distribution structure of the fossil population identified on the basis of the metric dimorphism of permanent teeth varies in relation to the age distribution (Turk *et al.* 1992). This indicates that one-year-old and two-year-old bears hibernated with their mothers and died with them. The large quantity of pollen from insect-pollinated plants in the sediments at Divje babe-I, which varies in proportion to the number of cave bear fossil remains, indicates that bears also inhabited the cave in summer, as some of these insect-pollinated plants form part of the diet of the contemporary brown bear. The cave bear was undoubtedly the only regular inhabitant of the cave, and, apart from man, was also the principal polluter of the environment. Consequently, it can be justifiably assumed that the imprints of the fossilised fibres, which appear in multitudes, are hairs from the cave bear. The possibility that the fossils are in fact human hairs, which are very similar to bear hairs in terms of both shape and dimensions, is unlikely, given the low number of Palaeolithic artefacts and the complete lack of human skeletal remains, but cannot be ruled out completely. The hair of other large mammals in the region does not match the cross-section shapes or length of the channels in the phosphate aggregates.

More than a hundred years of research and investigation of cave bear sites and fossils has given very detailed knowledge of this species (Kurtén 1976). However, to the best of the authors' knowledge, fossilised hairs have not yet been found or documented at any site, although imprints of cave bear hair were discovered in a fossil bear nest embedded in clay in the Fauzan cave in the French province of Hérault (Gillet 1963-1965 138). Fossil bear nests are quite rare, and were not preserved at Divje babe-I. As regards other preserved features of this kind, bear hair has never been mentioned (Barthe 1984; Malez 1988). However at Divje babe-I sediments there were not only imprints of hair, but also the fossilised hairs themselves, and a decision was made to undertake a detailed comparison with the hair of the brown bear, the closest living relative of the extinct cave bear.

The hair in mammals consists mostly of microfilaments of keratin, an extremely firm, resilient and resistant protein. The outer, extremely thin layer - a covering or membrane (cuticula) consists of many callous scaly cells (*fig. 9a*). The cortex, which lies under the cuticula, is composed of cells which in humans have the characteristic shape of a spindle (*fig. 9b*) within a network of fibrous keratin bundles (Corcuff *et al.* 1993). The innermost part, the medula, consists of dead cells of different visibility, which form the channel for nutrients, filled with air or an organic fluid containing pigment (*fig. 7c1*). The structure of hair varies from species to species in minute detail, and retains characteristic features even when digested, which is exploited in the research of the feeding habits of carnivores (Day 1966).

The fur of the modern brown bear (*Ursus arctos* Linnaeus, 1758), like the fur of other large mammals, consists of several kinds of hair. The basic types are the longer hairs of the overhair, and the denser, woolly hairs of the underhair. The two differ substantially both in shape and structure, and the differences between the overhair of various species or families is more pronounced. The hair on different parts of the body varies little, with the exception of the short hair covering the paws and snout (Debrot *et al.* 1982; Teernik 1991). There is little difference between the summer and winter coats of carnivores, in contrast to ruminants, who display great variations in this respect (Debrot *et al.* 1982). Several characteristics of hair are helpful in the identification of the species of origin. The size, shape and pattern of the cuticula scales vary in relation to their location on the hair. For the brown bear the pattern of the outer layer is transversal, and irregularly undulating, but transforms into a mosaic pattern nearer the root (Dziurdzik 1973; Debrot *et al.* 1982). Also specific to the species is the thickness of the cortex in relation to the diameter of the hair and the structure of the medula. Morphologically, the medula displays a variety of patterns, but visibility can be altered during the process of digestion, and the same may happen in the process of fossilisation. The medula of the hair of the brown bear has a multicellular, web-like pattern (Debrot *et al.* 1982).

The cross-sections of hairs in the outer coat vary in shape, ranging from simple circles to quite intricate patterns. The shape and diameter of the cross-sections vary radically along the length of the hair, as proceeding from the root the hair thickens, before becoming thinner towards its tip. At its thickest part the hair is usually flattened. In brown bear underhairs are usually circular or slightly reniform, measuring 0.05 mm to 0.09 mm in diameter. The cross-sections of the overhairs vary from mostly circular (Dziurdzik 1973) to oval, or occasionally reniform. The diameters of overhairs range from 0.11 mm to 0.20 mm, and the thickest hairs are circular.

Such figures serve as the basis for a comparison of fossilised cave bear hairs and the hairs of the contemporary brown bear. Comparison is difficult because the fossilised hairs are preserved only in fragments, and hairs differ not only between species but also between individuals within a species.

In most cases the cuticula itself was not fossilised. In the few samples in which the cuticula had survived it had been radically altered (*figs* 7a2; 7d2). It was assumed that during phosphatogenesis various acids and bases damaged the coating of the hairs before fossilisation. As an experiment, contemporary hairs were soaked in hydrogen peroxide. This resulted in the formation of surface patterns on the cuticula similar to those found on the cuticulae of fossilised hairs. In a sedimentary environment similar to that found at Divje babe-I, the cuticula of a human hair 10,000 years old was found preserved (Morell 1994).

The cortex of fossilised hairs is generally better preserved than the cuticula (*fig. 6a-d*), but in most cases the structure altered during fossilisation. In rare samples, however, the fibrous keratin coatings enveloping the cortex cells were preserved (*cf. fig. 6a* and *9b*). The ratio of cortex thickness to hair diameter also changed substantially. In plastic phosphate aggregates, under the influence of acids and bases, hairs were deformed before fossilisation, yielding larger imprints and smaller fossilised remains. These figures are therefore of no assistance in determination at the species level.

Two samples of fossilised hairs contain a preserved medula (*fig. 7c2*), although they lack pattern and could not be used for determination of species. The diameter of the medula in the fossilised hairs reasonably matches the diameter of the channel in brown bear hairs.

The thicknesses and shapes of fossilised hair cross-sections are most reliably preserved in the imprints on the surface and interior of the phosphate aggregates. The shape and size of smaller holes match the underhairs of the living brown bear. The same applies to most of the samples of fossilised hairs. The larger holes vary more with regard to shape and size, but match perfectly the range of sizes and shapes of cross-sections of brown bear overhairs. It is interesting that they do not exceed the size of contemporary brown bear hairs. The fossilised hairs also display the longitudinal thinning and thickening characteristics of contemporary hairs (*fig. 7b1-b2*). The hair of other larger mammals in the region does not match the shape or diameter of the holes in the fossil aggregates.

CONCLUSION

The fossilised imprints and fibres in the phosphate aggregates from Divje babe-I may be identified, in all probability, as remains of cave bear hairs, the first documented discovery of fossilised hairs from this extinct species. The fossils were reliably carbon dated using the AMS method based on reciprocal samples of charcoal and cave bear bone collagen (RIDDL, unpublished). Their average radiocarbon age is 45,450 years. This discovery opens a new course for micropalaeontology in the research of Pleistocene mammal species, towards tissue preserved by sedimentary environments and the conditions of fossilisation in numerous caves, in contrast to certain other similar late Pleistocene finds of other large mammals in more specific environments (*cf.* Kurtén 1968, pp 137-143).

APPENDIX

The EDAX method (Energy Dispersion Analysis by X-rays) was employed to examine several spots on the fresh fracture of a phosphate aggregate with imprints of hairs, several cortical sections and the surfaces of these and other fossilised hairs, and the cuticula and partial cortex of contemporary brown bear hair. All the tests yielded similar results (*fig. 10 a-c*). The chemical structure of the cortex of fossilised hairs does not differ from that of the phosphate aggregates, consisting mostly of phosphorus (P) and calcium (Ca). There was no trace of sulphur (S), the main component of contemporary hairs. On the basis of these findings it can be concluded that the remains are true fossils formed in the phosphate environment during phosphatogenesis.

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Photographs by F. Cimerman using optical and electron microscope.

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