ESR Dating In The Balanica Cave Complex, Serbia: Tracking Hominins and Paleolithic Cultures in The Middle Pleistocene

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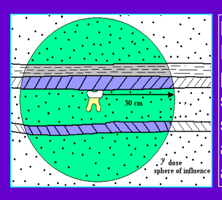
Abstract

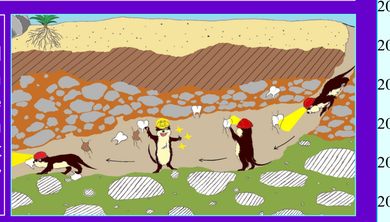
Overlooking the Sićevo Gorge, the Balanica cave complex lies ~ 15 km east of Niš, Serbia at ~ 335 m amsl. Both Mala Balanica (MB) and Velika Balanica (VB) yielded Middle Pleistocene mammal fossils, Middle and Lower Paleolithic artefacts. VB served as a permanent habitation, especially in Layers 2-3, where lithic artefacts, hearths, and charcoal particles have occurred, but MB likely hosted visits from smaller groups. MB's Layer 3b yielded a Homo heidelburgensis mandible. Both caves have matrix- supported conglomerates, where sandy, clayey silts with éboulis up to 1.5-2.0 m3 in some layers. In VB, reddish silty clay and éboulis in Layers 2a-2c overlie the brown, clayey silts and silty sands forming Layers 3a-3c, that include hearths. In VB, Layer 4c's several four collapsed stalagmitic flowstone floor reflect subsidence before MIS 11, while éboulis that show diagenetic alteration, weathering, root-etching, and post-dispositional carbonate rims, and lens with secondary carbonate cements that solidify them. Most of VB's layers sitting stratigraphically above the MB's deposits. Two from Layers 2c-3a in MB and 21 teeth from Layers 2a-4c4 in VB have been by ESR standard and isochron analyses. After > 80 associated sediment samples were measured by NAA, the time- and volumetrically veraged sediment dose rates in the caves were calculated using a 3D multi-component model using éboulis and cobble sizes and positions as mapped around each tooth from the total station, photographic, and excavation data. U concentrations in the enamel ranged from 1.0 to 9.1 ppm, while dentines ranged from 38 to 95 ppm, making it essential to understand the U uptake rates by doing isochron and coupled ESR430Th/234U analyses to improve the ages' accuracy. Isochron analyses suggest that secondary U remobilization has occurred in at least one teeth. Ages for both caves show the Balanica caves complex continued to receive sediment for > 400 ky from the early Middle to later Pleistocene.

ESR Dating in Caves

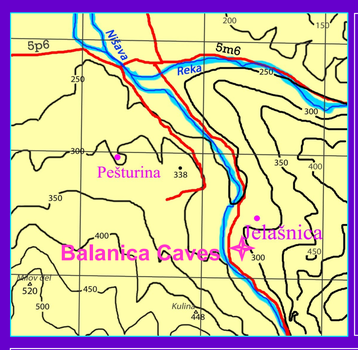


Finding $D_{ext}(t)$, the sedimentary dose rate.
From U, Th, and K in sedimentary minerals comes β and γ particles which produce the sedimentary dose rate, $D_{sed}(t)$. In sediment, γ rays penetrate ~ 30 cm, and β about 3 mm. Thus, all sedimentary components in all beds up to 30 cm from the fossil are analyzed by NAA to find their $D_{sed}(t)$ and volumetrically averaged over the 30 cm around the tooth.

The Problem with Reworking.
Reworking occurs when erosion or an animal moves a tooth from its original deposition location. If reworking occurs, more than one tooth from each layer should be dated to confirm ages. In Pesturina, the fauna suggest that rodents exists in the cave and can possibly cause a problem for dating each layer.

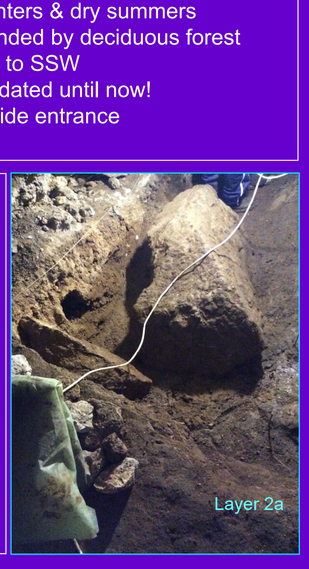


Balanica, Serbia



- 43˚10' N 21˚54' E
- ~ 20 km SW of Niš
- in southern Serbia
- overlooks the Sićevo Gorge & Nišava R.
- now 2-4ºC in winter
- now 18-20ºC in summer
- now wet winters & dry summers
- now surrounded by deciduous forest
- cave opens to SSW
- only layers dated until now!
- 1.5 x 2 m wide entrance
- 40 m deep

- > 8 geological layers
  - only to Layer 5
- Layer 2: - small-large *éboulis*
  - reddish-brown sand, silt & clay
  - retains water well!
- Layer 2a - very large *éboulis*
- Layer 2b - smaller large *éboulis*
  - well rounded & weathered *éboulis*
    - ➢ warm wet period during its deposition
- Layer 3: - lighter coloured silty clay
  - *Homo erectus* mandible in 3c
  - suggested a drier, but warm period
- lower layers - finer sediment
  - very wet period during their deposition



- 6 archaeological units
  - Middle Paleolithic lithic artefacts
  - charcoal in hearths
- fauna include
  - *Canis* (dog or wolf)
  - *Ursus* (cave bear)
  - hyena
  - *Dama* (fallow deer)
  - *Cervus elaphus* (red deer)
  - goats
  - sheep
  - other ungulates
  - birds

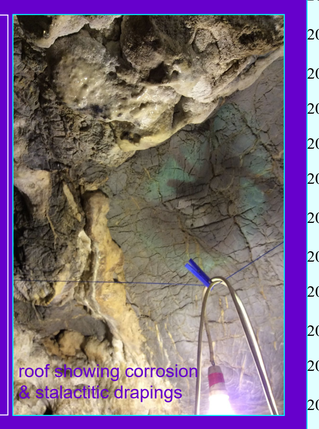


Table 1. Samples in the Study.

Number ESR	Number Catalogue	Layer	Square	Location N (cm)	Location W (cm)	Location Z (cm)	Elevation (cm)	Tooth Species	Tooth Type
AT50	2012BAL17	2(a?)	L30d			48.	327.550	cervid	cheek + bone
AT52	2012BAL19	2(a?)	L30c			28.	327.50	cervid	cheek + bone
AT51	2012BAL18	2b	M28b	~ 43	~ 56	> 60	327.463	cervid	cheek + bone
AT53	2012BAL20	2b	L26b			> 80.	327.34	cervid	cheek + bone
JT38	2018BAL214	2a1a	L24b	50	95	60	327.8	Ibex	Upper molar
JT40	2018BAL236a	2b	N26a	46	45	86		Ibex	Lower incisor

Results

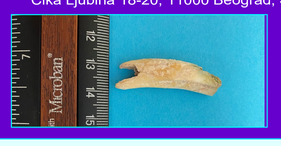


Table 2. Sedimentary Radioactivity, Balanica, Serbia.

Sample	Sq.	Unit	Location N–S X (cm)	Location E-W Y (cm)	Location Depth Z (cm)	Concentration U (ppm)	Concentration Th (ppm)	Concentration K (wt%)	Sedimentary Dose Rates $D_{sed,\beta}(t)$ (mGy/y)	$D_{sed,\gamma}(t)$ (mGy/y)	$D_{sed,\beta}(t)$ (mGy/y)	$D_{sed,\gamma}(t)$ (mGy/y)
2018BAL206	N27d					1.62	3.49	0.54	129	441	112	387
						± 0.02	0.09	0.02	13	28	11	28
2018BAL207	N27d					1.77	4.14	0.58	141	495	122	434
						± 0.02	0.10	0.02	14	32	13	31
2018BAL209	N27d					3.88	9.49	1.46	336	1145	291	1004
						± 0.02	0.18	0.04	35	72	30	70
2018BAL210	N27d					2.70	7.99	1.31	278	924	241	810
						± 0.02	0.16	0.04	29	58	25	87
2018BAL211	N27d					3.75	6.72	1.23	290	954	251	837
						± 0.02	0.14	0.03	21	10	18	7
2018BAL213	N27d					4.43	8.14	1.61	364	1170	315	1026
						± 0.02	0.16	0.04	27	12	23	11
2018BAL215	L24b					0.76	2.42	0.36	78	266	68	233
						± 0.02	0.07	0.01	6	4	6	4
2018BAL216	L24b					1.01	2.89	0.37	88	315	76	276
						± 0.02	0.08	0.01	7	3	6	3
2018BAL217	L24b					1.71	1.91	0.29	92	324	80	284
						± 0.02	0.05	0.01	7	3	6	3
2018BAL218	L24b					1.56	3.53	0.57	131	444	114	389
						± 0.02	0.09	0.02	10	6	8	6
2018BAL219	N27d					2.71	6.03	0.89	215	744	186	653
						± 0.02	0.12	0.02	16	8	13	5
2018BAL220	N26c					2.65	2.93	0.59	161	530	139	465
						± 0.02	0.08	0.02	16	34	14	32
2018BAL221	N26c					3.97	9.99	1.51	347	1188	301	1042
						± 0.02	0.18	0.04	35	75	31	73
2018BAL222	N26c					4.38	5.05	0.90	256	870	223	763
						± 0.02	0.12	0.02	24	55	24	53
2018BAL224	N26c					4.28	3.28	0.58	204	709	177	622
						± 0.02	0.09	0.02	19	45	18	43
2018BAL225	N26c					2.53	4. 14	0.69	176	596	152	522
						± 0.02	0.09	0.02	18	37	15	36
2018BAL226	N26c					2.70	8.67	1.18	264	928	229	813
						± 0.02	0.16	0.03	27	59	24	57
2018BAL227	N26c					4.22	8.36	1.20	306	1071	265	939
						± 0.02	0.16	0.03	31	67	27	65
2018BAL228	N27d					3.20	6.99	1.00	247	862	214	756
						± 0.02	0.14	0.03	25	55	22	52
2018BAL229	N27a					0.56	1.27	0.20	47	157	40	138
						± 0.02	0.04	0.01	6	10	4	10
2018BAL331	J22c					1.63	1.85	0.23	82	300	71	263
						± 0.02	0.06	0.01	9	19	7	18
2018BAL232B	N26d					2.78	2.89	0.55	159	533	138	467
						± 0.02	0.09	0.02	16	34	14	33
2018BAL233	N26d					2.31	2.16	0.41	125	422	108	370
						± 0.02	0.07	0.01	13	26	11	26
2018BAL234	N26d					2.74	2.78	0.53	154	520	134	456
						± 0.02	0.08	0.01	15	33	14	32

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2018BAL235	N26d		75	45	134	4.01	4.00	0.81	230	765	200	670
						± 0.02	0.10	0.02	23	48	20	46
2018BAL236B	N26a		46	45	86	5.02	3.22	0.75	246	818	213	717
						± 0.02	0.08	0.02	24	51	21	49
2018BAL237	N26d		25	45	86	2.78	3.54	0.76	189	608	164	533
						± 0.02	0.09	0.02	19	38	17	36
2018BAL238	N26d		25	45	88	6.71	3.96	0.80	301	1034	261	907
						± 0.02	0.09	0.02	29	64	26	63
2018BAL239	J23a		0	65	237	3.56	8.12	1.39	312	1034	270	907
						± 0.02	0.16	0.04	32	65	23	64
2018BAL240	J23a		0	35	267	2.63	9.75	1.70	334	1082	290	949
						± 0.02	0.18	0.04	33	65	31	67
2018BAL242	J23b		20	95	267	2.16	7.54	1.05	228	793	198	695
						± 0.02	0.15	0.03	24	50	21	49
2018BAL243B	N26d		20	25	86	2.77	2.86	0.51	153	522	133	458
						± 0.02	0.08	0.01	10	5	9	4
2018BAL244	N26d		75	0	78	3.90	4.74	0.86	237	799	206	700
						± 0.02	0.11	0.02	17	7	15	7
2018BAL245	N26d		75	25	76	5.95	3.67	0.83	283	950	246	833
						± 0.02	0.09	0.02	20	6	17	6
2018BAL246	N26d		100	25	78	2.19	2.28	0.46	128	426	111	373
						± 0.02	0.07	0.01	9	4	8	4
2018BAL247A	N26d		75	50	78	3.27	8.72	1.52	323	1061	281	930
						± 0.02	0.16	0.04	24	11	21	9
2018BAL247B	N26d		75	50	78	1.32	1.12	0.22	69	233	60	204
						± 0.02	0.04	0.01	5	3	5	3
2018BAL248C	M26d		75	50	75	5.15	4.21	0.85	267	898	232	788
						± 0.02	0.10	0.02	19	7	16	5
2018BAL249	M26d		100	25	82	3.80	5.35	0.85	236	814	205	714
						± 0.02	0.11	0.02	23	51	15	7
2018BAL250	M26d		100	5	76	4.26	8.25	1.71	372	1180	323	1034
						± 0.02	0.15	0.05	37	74	34	72
2018BAL251	M26d		100	10	76	5.93	5.81	1.15	334	1116	290	978
						± 0.02	0.12	0.03	34	70	30	67
2018BAL301	N25b					4.53	7.41	1.52	344	1054	299	924
						± 0.02	0.15	0.04	35	67	31	65
2019BAL310	N26a					4.55	9.50	1.69	383	1263	333	1107
						± 0.02	0.18	0.05	38	80	35	77
2019BAL311	M22c					1.93	7.86	1.67	303	917	263	804
						± 0.02	0.16	0.04	36	74	32	72
2019BAL312						4.12	9.21	1.60	359	1186	311	1040
						± 0.02	0.17	0.04	36	74	32	72
2019BAL313	M22c					3.06	13.15	2.56	410	1287	472	1468
						± 0.02	0.24	0.07	44	90	48	93
2019BAL314	M22c					1.29	6.30	1.03	196	643	170	564
						± 0.02	0.13	0.03	20	14	18	40
2019BAL315	M22c					1.67	7.02	1.24	237	760	205	666
						± 0.02	0.13	0.03	25	48	22	47

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2019BAL316A	F27b				120	2.39	7.03	1.39	275	865	239	759
						± 0.02	0.14	0.04	27	54	26	53
2019BAL316B	F27b				120	2.09	8.56	1.73	318	979	276	858
						± 0.02	0.16	0.05	32	62	30	60
2019BAL318B	F27b		48	70	132	3.78	5.30	1.33	297	913	258	801
						± 0.02	0.11	0.04	30	57	27	56
2019BAL320	F27b				124	3.77	9.97	1.64	358	1195	311	1048
						± 0.02	0.18	0.04	36	75	33	74
2019BAL321B	F27b				142	2.10	4.35	0.77	175	579	152	508
						± 0.02	0.09	0.02	17	36	15	35
2019BAL322	F27b				126	1.92	8.89	1.95	344	1024	298	898
						± 0.02	0.17	0.05	36	64	32	63
2019BAL323	F27b				114	2.13	8.30	2.07	362	1044	314	915
						± 0.02	0.16	0.05	37	66	33	64
2019BAL324	F29b					2.53	8.44	2.00	364	1076	316	943
						± 0.02	0.16	0.05	37	68	33	66
2019BAL325	F29b					2.08	5.57	1.21	237	728	206	638
						± 0.02	0.12	0.03	24	46	22	45
2019BAL326	E28b					3.61	7.71	1.34	305	1010	264	885
						± 0.02	0.15	0.04	31	64	27	62
2019BAL327	E26a					3.69	7.32	1.37	309	1006	268	882
						± 0.02	0.15	0.04	31	63	28	62
2019BAL328	E26a					3.13	2.96	0.56	170	574	147	503
						± 0.02	0.08	0.02	17	36	15	34
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Conclusions

- Secondary U remobilization occurred in at least one teeth
  - ➢ Affects the ages of the teeth
- Sediment Samples were measured by NAA
  - ➢ The concentrations of U suggest there were multiple eboulis in the sediment, affecting the ages of the teeth

- dated 2 teeth from Layer 2a
  - ✧ AT50 @ 183 ± 3 ka (OIS 6/7)
  - ✧ AT52 @ 154 ± 5 ka (OIS mid 6)
- dated 1 tooth from Layer 2b
  - ✧ AT51 @ 104 ± 2 ka (OIS 5c)
  - ✧ AT52 still to be finished
- ages in reversed order to stratigraphy!
  - ✧ $D_{ext}(t)$ ~ 10-20% of radiation
  - ✧ $D_{ext}(t)$ minor effect on ages
  - ✧ different uptake rates for each tooth?
  - ✧ reworking moved teeth, esp. AT51?
  - ✧ U remobilization in teeth?
  - ✧ Layer 2 is a debris flow?
- must date more teeth from each layer to find answers
- must find U uptake parameter
  - ✧ do coupled ESR-^{230}Th/^{234}U ages

Future Work

- To check for reworking
  - ✧ date > 3-4 teeth from both layer
  - ✧ date teeth layers below 2
- Increase accuracy for sedimentary dose rate
  - ✧ recalculate dose rates based on total station data
- To check the U uptake parameter
  - ✧ do coupled ESR-^{230}Th/^{234}U ages

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