

## RUDJER BOŠKOVIĆ INSTITUTE RADIOCARBON MEASUREMENTS XIII

BOGOMIL OBELIĆ,<sup>1</sup> NADA HORVATINČIĆ,<sup>1</sup> DUŠAN SRDOČ,<sup>1,2</sup> INES KRAJCAR BRONIĆ,<sup>1</sup>  
ADELA SLIEPČEVIĆ<sup>3</sup> and SANJA GRGIĆ<sup>4</sup>

### INTRODUCTION

In this list, we present <sup>14</sup>C ages of archaeological, geological, hydrogeological, botanical and atmospheric samples measured since our previous list (Srdoč *et al.* 1992). Chemical pretreatment and counting techniques using a methane-filled proportional counter are essentially the same as reported earlier. Sample descriptions are prepared in collaboration with collectors and submitters.

Age calculation follows the conventional protocol based on the Libby half-life of  $5570 \pm 30$  yr and using AD 1950 as the reference year. Calibrated ages (for archaeological samples only) were calculated using the program by Stuiver and Reimer (1993), generally using method A (intercepts with calibration curve), and are given here as the period of maximal probability with  $1 \sigma$  error. When method A gave two or more separate calibrated age ranges, method B was used instead. Ranges that do not contribute significantly to the overall probability were omitted.

Ages and standard deviations of samples were adjusted for stable isotope fractionation according to recommendations in Stuiver and Polach (1977), where  $\delta^{13}\text{C}$  data were not available. The fractionation correction has not been applied for groundwater samples, calcareous deposits or aquatic plants. For geological and hydrogeological samples, only the pMC data are given.

### ACKNOWLEDGMENTS

We thank E. Hernaus for sample preparation and J. Pezdič, Jožef Stefan Institute, Ljubljana, Slovenia, for stable isotope measurements.

### ARCHAEOLOGICAL SAMPLES

#### CROATIA

#### Varaždin Series

Fragments of beams from Stari Grad (Old Town), Varaždin (46°18'N, 16°21'E), 173 m asl, north Croatia. Collected and submitted 1987 by Z. Matica, Croatian Institute for Restoration, Zagreb.

*Comment* (Z.M.): Expected age: 16th–17th century.

**Z-1927. Varaždin 1** **400 ± 60**  
Fragment of a beam from the wall above the first floor of the eastern tower; cal AD 1440–1627.

**Z-1928. Varaždin 2** **330 ± 90**  
Fragment of a beam from the western wall, first floor of a high Gothic tower; cal AD 1480–1650.

**Z-1929. Varaždin 3** **520 ± 90**  
Fragment of a longitudinal ceiling beam from the high Gothic tower; cal AD 1321–1449.

<sup>1</sup>Rudjer Bošković Institute, P.O. Box 1016, 41001 Zagreb, Croatia

<sup>2</sup>Present address: Brookhaven National Laboratory, P.O. Box 5000, Upton, New York 11973 USA

<sup>3</sup>Faculty of Veterinary Medicine, University of Zagreb

<sup>4</sup>Institute of Geology, Sachsova 2, Zagreb

**Z-1930. Rudine** **510 ± 80**  
 Human bones from Grave 1, 1.5 m depth, at Rudine near Čečavac (45°24'N, 17°32'E), 467 m asl, central Croatia (Horvat 1962; Klaić 1986). Collected and submitted 1987 by D. Sokač-Štimac, Požega Valley Museum, Požega.

*Comment* (D.S.-Š.): Expected age: Roman period or Middle Ages; cal AD 1397–1449.

**Z-2420. Trilj** **650 ± 80**  
 Fragment of charred wood from a boat buried in the bed of the Ruda River, Cetinska Krajina near Trilj (45°16'N, 13°32'E), 60 m asl, south Croatia. Collected and submitted 1992 by Z. Brusić, Archaeological Museum, Zadar, south Croatia. Cal AD 1397–1449.

**Z-1939. Škrinja Sv. Šimuna (St. Simeon's shrine)** **970 ± 70**  
 Wood fragments (*Juniperus sp.*) from a coffin frame, Zadar (44°02'N, 15°15'E), south Croatia. The sarcophagus was richly decorated between 1377 and 1380 by goldsmith Francesco da Milano (Petricioli 1983). Collected and submitted Oct. 1987 by M. Domijan, Institute for Restoration, Zadar.

*Comments* (M.D.): Expected age: 14th to 17th century; cal AD 1010–1165. (A. Belamarić, Regional Institute for Restoration, Split): Wood from an old Byzantine coffin was probably used for construction of this coffin. (D.S.): Inner parts of a large log are typically 150–200 yr older than the outer parts; the use of inner parts of a tree felled at the time of the coffin construction can explain the deviation from the expected age.

#### Kopačina Cave Series

Animal bones, mostly red deer (*Cervus elaphus*) from the anterior of Kopačina Cave near Donji Humac (43°22'N, 16°32'E), 380 m asl, Brač Island, south Croatia. Samples are associated with Epipalaeolithic stone tools and wild faunal remains. Collected Aug. 1986 by B. Čečuk, Archaeological Institute of the Croatian Academy of Sciences and Arts, Zagreb, and submitted June 1992 by P. Miracle, Department of Anthropology, University of Michigan, Ann Arbor, Michigan.

*Comment* (B.Č.): Samples date the occupation of the cave and provide comparison with other Palaeolithic and Mesolithic sites in the eastern Adriatic basin, e.g., Šandalja II (Čečuk 1991). Expected age: 8000–15,000 BP.

**Z-2404. Kopačina 1** **11,980 ± 270**  
 20–40 cm depth; 12,379–11,688 cal BC.

**Z-2403. Kopačina 2** **13,160 ± 310**  
 140–160 cm depth; 14,183–13,225 cal BC.

#### Šandalja II Series

Animal bones from large ungulate mammals (*Bos*, *Bison* or *Equus*) from a cultural horizon in a cave, Šandalja limestone quarry near Pula (44°52'57"N, 13°53'48"E), 72 m asl, Istria, west Croatia (Malez 1979). Collected 1962 by M. Malez, Croatian Academy of Sciences and Arts, Zagreb, and submitted Sept. 1992 by P. Miracle.

**Z-2421. Šandalja 1** **10,140 ± 160**  
 Bones from the bottom of Layer B, 270–340 cm depth; 10,222–9134 cal BC.

**Z-2423. Šandalja 2** **13,050 ± 220**  
 Bones between Layers B and C, 340 cm depth; 13,911–13,189 cal BC.

**Z-2424. Šandalja 3** **13,120 ± 230**

Bones from the middle of Layer C, 390–440 cm depth; 14,023–13,285 cal BC.

*Comment* (P.M.): These three samples date the stratigraphy between the lower part of Layer C and the middle section of Layer B, and help determine whether the site was occupied during the last glacial maximum (*ca.* 18,000 BP). Previous measurements: GrN-4976 B (upper), 10,830 BP; GrN-4978 B (middle), 12,320 BP; Z-193 (Srdoč *et al.* 1973: 440) C (bottom), 21,740 BP. Expected age: 12,000–22,000 BP.

**Z-2422. Šandalja 4** **17,600 ± 370**

Bones from Layer H, 720–800 cm depth; 19,524–18,459 cal BC.

*Comment* (P.M.): Dates the lower part of the Šandalja sequence. The result completes previously published measurements Z-536 and -537 (Srdoč *et al.* 1979: 132–133). Expected age: >28,000 BP; cal BP 19,524–18,470.

**Relja Series**

Wood fragments from the Roman necropolis, Relja near Zadar (44°02'N, 15°15'E), south Croatia. Collected and submitted 1990 by Z. Brusić.

**Z-2242. Relja 1** **1910 ± 70**

Wood fragment from a well. Expected age: 2000 BP; cal AD 25–216.

**Z-2243. Relja 2** **2620 ± 80**

Wood fragment from a beam. Expected age 2500 BP; 827–770 cal BC.

**Z-2244. Relja 3** **2480 ± 80**

Wood fragment from a beam. Expected age: 2500 BP; 785–407 cal BC.

**Dubrovnik – Mala Onofrijeva Česma Series**

Wood fragments from a fountain, Dubrovnik (42°37'N, 18°06'E), south Croatia. Collected and submitted 1990 by J. Stošić and I. Žile, Institute for Preservation of Cultural and Natural Monuments, Dubrovnik (Žile 1993).

**Z-2229. Dubrovnik 1** **920 ± 80**

Fragment of a wooden post; cal AD 1022–1222.

**Z-2230. Dubrovnik 2** **920 ± 80**

Fragment of a wooden board; cal AD 1022–1222.

**Z-2203. Kotluša** **2930 ± 90**

Human bones on the ground inside Kotluša cave 200 m from the entrance, Civljane (43°57'N, 16°24'E), Lika, central Croatia. Collected Nov. 1989 and submitted Feb. 1990 by S. Forenbaher, Department of Archaeology, University of Zagreb.

*Comment* (S.F.): Expected age: 3500 BP; 1262–993 cal BC.

**Sisak Series**

Fragments of wooden boats from the muddy bed of the Kupa River near Sisak (45°29'20"N, 16°22'30"E), Croatia. Collected by P. Pirs-Petrinjak, Sisak Town Museum, and submitted Oct. 1992 by M. Jurišić, Institute for Preservation of Cultural Monuments, Zagreb.

**Z-2426. Sisak 1** **2000 ± 90**  
Fragment of Boat 1; cal AD 90–115 cal BC.

**Z-2427. Sisak 2** **2140 ± 90**  
Fragment of Boat 2; 356–40 cal BC.

**Z-2391. Stari Grad** **1090 ± 80**  
Fragments of wood from a fireplace in Room G, 180 cm depth, Stari Grad (43°10'N, 16°36'E), Hvar Island, south Croatia. Collected by J. Jeličić and submitted 1992 by M. Katić, Institute for Preservation of Cultural Monuments, Split; cal AD 885–1020.

#### **Nova Rača Series**

Human bones from graves below the church sacristy, 30 cm depth, Nova Rača near Bjelovar (45°47'N, 16°57'E), 175 m asl, central Croatia. Collected Dec. 1985 and submitted March 1990 by G. Jakovljević, Bjelovar Museum.

*Comment* (G.J.): Samples were dated to determine the chronology of the strata containing human bones. Expected age: Middle Ages. Dates correspond to earlier measurements: Z-2184, -2187, -2255, -2256, -2258 and -2260 (Srdoč *et al.* 1992: 160–161).

**Z-2303. Nova Rača 1** **530 ± 80**  
Bones from Grave 1, 30 cm depth; cal AD 1321–1444.

**Z-2302. Nova Rača 2** **100.6 ± 1.5 pMC**  
Bones from Grave 14, 100 cm depth.

#### **Čakovec Series**

Wood fragments from a former coach depot in Old Town, Čakovec (46°24'N, 16°26'E), northwest Croatia, undergoing systematic archaeological excavation during restoration. Collected and submitted Dec. 1992 by M. Šmalcelj.

*Comment* (M.Š.): Expected age: Middle Ages.

**Z-2436. Čakovec 48** **270 ± 110**  
Fragment of a log, Quadrant U-8, close to the wall base; cal AD 1482–1810 (92% probability; method B).

**Z-2437. Čakovec 24** **320 ± 110**  
Fragment of a board under floor, Quadrant U-9; cal AD 1450–1670 (99% probability; method B).

#### **Vindija Series**

Animal bones (*Ursus spelaeus*) from a trench in sandy sediment, Vindija cave, Gornja Voća near Ivanec (46°18'12"N, 16°14'38"E), 275 m asl, northwest Croatia. Samples were used in dating and analysis of Mesolithic material culture (Malez *et al.* 1984). Collected July 1981 by M. Malez and submitted Nov. 1992 by M. Paunović, Croatian Academy of Sciences and Arts, Zagreb.

**Z-2432. 2-Vi-G1** **18,280 ± 440**  
Layer G, 2.5 m depth. Expected age: 32,000–38,000 BP; [20,427]–19,303 cal BC.

**Z-2433. 1-Vi-F d/d** **26,600 ± 930**  
Layer F, 2.5 m depth. Expected age: *ca.* 30,000 BP.

**Z-2447. Vi-E** **18,500 ± 300**  
 Layer E. Expected age: >20,000 BP.

*SLOVENIA*

**Z-2273. Valvazorjev Grad** **110 ± 80**  
 Fragment of wood from a bell tower, Valvasorjev Grad near Medija (46°08'N, 14°46'E), central Slovenia. Collected Dec. 1990 by D. Kramberger, Institute for Protection of Cultural Monuments, Ljubljana, and submitted by J. Korošec, Slovenian Restoration Center, Ljubljana. Expected age: 17th century; cal AD 1690–1930 (99% probability; method B).

**Z-2274. Predjamski Grad** **480 ± 100**  
 Fragment of wooden lining of a niche, Predjamski Grad castle near Postojna (45°48'N, 14°07'E), southwest Slovenia. Collected and submitted 1990 by D. Kramberger.  
*Comment* (D.K.): Expected age: 14th to 16th century; cal AD 1406–1471.

**Z-2359. Hotiza, 3816/B** **7030 ± 110**  
 Fragment of an oak dugout (monoxyle), length 9.3 m, found 6 m deep in sand at Hotiza village near Lendava (46°34'N, 16°30'E), northeast Slovenia. Collected by M. Erič and submitted May 1991 by I. Nemeč, Institute for Protection of Cultural Monuments, Ljubljana (Nemeč and Erič 1994); 5972–5732 cal BC.

**Ljubljansko Barje Series**

Samples of wood from the Ljubljansko Barje basin south and southwest of Ljubljana, where systematic archaeological excavation is in progress. Collected and submitted 1987 by T. Bregant, Department of Archaeology, Faculty of Arts and Sciences, Ljubljana.

**Z-1931. Zornica – Blatna Brezovica 1** **3140 ± 90**  
 Fragment of an oak dugout (*Quercus robur*) from Zornica near Blatna Brezovica (45°58'35"N, 14°20'20"E) (Dirjec 1990); 1511–1304 cal BC.

**Z-1934. Zornica – Blatna Brezovica 2** **3670 ± 100**  
 Wooden fragment of a pile-dwelling from a cultural layer, Sector B 4 (Dirjec 1991); 2190–1891 cal BC.

**Z-1932. Preserje – Zakotek** **2310 ± 90**  
 Fragment of a wooden boat from Preserje near Zakotek (45°57'50"N, 14°23'10"E); 407–207 cal BC.

**Ajdovska Jama Cave Series**

Charcoal from Ajdovska Jama cave at Nemška Vas near Krško (45°58'N, 15°30'E), east Slovenia. Collected by M. Horvat, Faculty of Science and Arts and submitted 1990 by A. Šercelj, Slovenian Academy of Sciences and Arts, Ljubljana. Samples from systematic excavation of a Neolithic site. Dates correspond to earlier measurements, Z-1042 to -1045 (Srdoč *et al.* 1984: 451), Z-1178, -1179, -1554, -1602, -1603 (Srdoč *et al.* 1987b: 138-139), Z-1822, -1860 (Srdoč *et al.* 1989: 86) and Z-2042 to -2044, -2123, -2179 (Srdoč *et al.* 1992: 156).

**Z-2300. Ajdovska Jama 79/90** **4440 ± 70**  
 Charcoal from the bottom of a funnel-shaped pit, Layer 106, 4.41 m depth. Expected age: Paleolithic; 3303–2923 cal BC.

**Z-2301. Ajdovska Jama 20/90** **4410 ± 70**  
Charcoal from the lowest Holocene cultural layer 83, 2.64 m depth; 3260–2917 cal BC.

*SERBIA***Vladikina Ploča Series**

Wood fragment and bones from Vladikina Ploča cave, Rsovci near Pirot (43°11'26"N, 22°45'17"E), 720 m asl, southeast Serbia. Collected and submitted 1987 by D. Gavrilović, University of Belgrade.

*Comment* (D.G): Expected age: 500 BP. Dates period of cave occupation. Earlier measurements Z-1641 (Srdoč *et al.* 1989: 85) and -2096 (Srdoč *et al.* 1992: 157).

**Z-1936. Vladikina Ploča 1** **270 ± 70**  
Wood from a wall inside the cave, 20 m from the entrance; cal AD 1510–1680 (79% probability; method B).

**Z-1937. Vladikina Ploča 2** **1740 ± 90**  
Human bones from the dry part of the cave 15 m from the entrance; cal AD 221–416.

**HYDROGEOLOGICAL AND GROUNDWATER SAMPLES***CROATIA***Hrvatsko Zagorje Series**

Samples of geothermal waters from two spas in Hrvatsko Zagorje, northwest Croatia, collected for investigation of water provenience. Collected March 1990 by A. Sliepčević and N. Horvatinčić.

**Z-2306. Stubičke Toplice Spa 1** **50.1 ± 1.0 pMC**  
 $\delta^{13}\text{C} = -6.4\text{‰}$   
Geothermal water from a borehole, 48–50 m depth ( $t = 61.5^\circ\text{C}$ ,  $\text{pH} = 6.6$ ,  $\text{HCO}_3^- = 293 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -83.0\text{‰}$ ,  $\delta^{18}\text{O} = -11.0\text{‰}$ ,  $k = 650 \mu\text{S cm}^{-1}$ ), Stubičke Toplice Spa (45°56'N, 15°56'E).  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-2309. Stubičke Toplice Spa 2** **33.4 ± 0.6 pMC**  
 $\delta^{13}\text{C} = -8.5\text{‰}$   
Geothermal water from main catchment ( $t = 47.1^\circ\text{C}$ ,  $\text{pH} = 6.6$ ,  $\text{HCO}_3^- = 301 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -79.7\text{‰}$ ,  $\delta^{18}\text{O} = -10.3\text{‰}$ ,  $k = 603 \mu\text{S cm}^{-1}$ ).  $^3\text{H}$  activity:  $1.1 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Z-2308. Krapinske Toplice Spa** **11.0 ± 0.8 pMC**  
 $\delta^{13}\text{C} = -9.9\text{‰}$   
Geothermal water from public spa ( $t = 41.2^\circ\text{C}$ ,  $\text{pH} = 7.3$ ,  $\text{HCO}_3^- = 293 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -74.9\text{‰}$ ,  $\delta^{18}\text{O} = -10.4\text{‰}$ ,  $k = 504 \mu\text{S cm}^{-1}$ ), Krapinske Toplice (46°07'N, 15°49'E).  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-2365. Podsused – PDS-2** **26.5 ± 0.9 pMC**  
Thermal water from exploitation borehole at Podsused (45°49'N, 15°50'E), west suburb of Zagreb. Collected and submitted 1991 by S. Tomić, INA-Naftaplin Co, Zagreb. Hydrogeological study of thermal water properties. The result completes previously published measurements Z-1558 and -1559 (Srdoč *et al.* 1987b: 144–145).

**Eastern Slavonia Series**

Groundwater samples from piezometers. Hydrogeologic investigation of water-bearing layers to determine the mean residence time and anthropogenic influence on groundwater quality near water

supply stations in eastern Slavonia, Croatia. Collected and submitted Oct. 1987 by S. Grgić (Grgić, Horvatinčić and Miletić 1991).

**Z-1945. Kanovci – Vinkovci 1** **94.4 ± 1.5 pMC**

Groundwater from the overlying sediment above the first water-bearing Layer V-24/3, 5 m depth (pH = 7.0), Kanovci near Vinkovci (45°16'N, 18°49'E). <sup>3</sup>H activity: 4.9 ± 0.4 Bq liter<sup>-1</sup>.

**Z-1944. Kanovci – Vinkovci 2** **31.9 ± 1.0 pMC**

Groundwater from the first water-bearing Layer P-1, 45 m depth (t = 14.5°C, pH = 7.8, HCO<sub>3</sub><sup>-</sup> = 726 mg liter<sup>-1</sup>). <sup>3</sup>H activity: 0.4 ± 0.2 Bq liter<sup>-1</sup>.

**Z-1943. Kanovci – Vinkovci 3** **0.6 ± 0.5 pMC**

Groundwater from the second water-bearing Layer V-26, 82 m depth (t = 14.5°C, pH = 7.82, HCO<sub>3</sub><sup>-</sup> = 799 mg liter<sup>-1</sup>). <sup>3</sup>H activity: <0.2 Bq liter<sup>-1</sup>.

**Z-1942. Trslana – Đakovo 1** **85.7 ± 1.2 pMC**

Groundwater from the first water-bearing Layer V-27, 45 m depth (t = 13°C, pH = 7.0, HCO<sub>3</sub><sup>-</sup> = 606 mg liter<sup>-1</sup>), Trslana near Đakovo (45°18'N, 18°25'E). <sup>3</sup>H activity: <0.2 Bq liter<sup>-1</sup>.

**Z-1941. Trslana – Đakovo 2** **57.5 ± 1.0 pMC**

Groundwater from the second water-bearing Layer V-5/1, 88 m depth (t = 13.4°C, pH = 7.6, HCO<sub>3</sub><sup>-</sup> = 726 mg liter<sup>-1</sup>). <sup>3</sup>H activity: <0.2 Bq liter<sup>-1</sup>.

*Comment (S.G.):* Although the investigated areas of Vinkovci and Đakovo belong to the same hydro-geologic zone, they represent two separate hydrodynamic systems with different infiltration rates and recharge areas.

### Plitvice National Park Surface Waters

Tables 1 and 2 show the results of systematic measurements of <sup>14</sup>C activity of dissolved inorganic carbon (DIC) in surface water of the Bijela Rijeka and Crna Rijeka streams in the Plitvice Lakes area, central Croatia. These measurements were used to determine seasonal variations of <sup>14</sup>C activity and initial <sup>14</sup>C activity (Krajcar Bronić *et al.* 1992). The difference in <sup>14</sup>C activity of two springs was attributed to the geology of the recharge areas (Horvatinčić *et al.* 1989). We noticed an increase of <sup>14</sup>C activity in the downstream direction (Srdoč *et al.* 1986). Collected 1986 and 1987 by D. Srdoč and N. Horvatinčić.

TABLE 1. Bijela Rijeka Spring and Surface Water

Sample no.	Location	Date	pMC (± 1.1)	δ <sup>13</sup> C (‰)	<sup>3</sup> H (Bq liter <sup>-1</sup> )
Z-1810	Spring	06/86	79.2		4.8
Z-1813	Mill*	06/86	77.5		
Z-1778	Spring	09/86	82.3		4.2
Z-1779	Mill	09/86	87.4		4.7
Z-1824	Mill	10/86	77.2		
Z-1844	Mill	11/86	83.7	-12.5	4.2
Z-1847	Mill	12/86	83.7	-13.9	4.0
Z-1850	Mill	02/87	83.0	-12.7	4.1
Z-1876	Mill	04/87	87.4		3.9

\*Mill is located 1km downstream from the spring.



TABLE 2. Crna Rijeka Spring and Surface Water

Sample no.	Location	Date	pMC ( $\pm 1.1$ )	$\delta^{13}\text{C}$ (‰)	$^3\text{H}$ (Bq liter $^{-1}$ )
Z-1823	Bridge*	06/86	69.6		3.3
Z-1771	Spring	09/86	63.6		2.7
Z-1772	Bridge	09/86	61.5		2.9
Z-1834	Spring	10/86	60.6		3.4
Z-1825	Bridge	10/86	62.1		
Z-1848	Spring	12/86	70.7	-12.8	3.0
Z-1849	Bridge	02/87	66.7	-12.0	3.2
Z-1871	Bridge	04/87	85.3		2.2

\*Bridge is located 3 km downstream from the spring.

*Comment:* Dates correspond to earlier measurements, Z-1024, -1159, -1281, -1434, -1337, -1379 and -1425 (Srdoč et al. 1987a: 131–132).

#### SLOVENIA

##### Z-2307. Čateške Toplice Spa V-15

Geothermal water from exploitation Borehole V-15, depth 300–350 m ( $t = 63.0^\circ\text{C}$ ,  $\text{pH} = 6.3$ ,  $\text{HCO}_3^- = 242 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -79.0\text{‰}$ ,  $\delta^{18}\text{O} = -10.4\text{‰}$ ,  $k = 460 \mu\text{S cm}^{-1}$ ), Čateške Toplice Spa near Brežice ( $45^\circ 51'\text{N}$ ,  $15^\circ 35'\text{E}$ ), east Slovenia. Collected by N. Horvatinčić and A. Slipečević. Tritium activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**20.9  $\pm$  0.8 pMC**

$\delta^{13}\text{C} = -10.2\text{‰}$

#### SERBIA

##### Serbian Spas Series

Geothermal and groundwater water from central and south Serbia. This was a hydrogeological study of geothermal and cold water origin. Collected and submitted 1986 by M. Milivojević, Faculty of Mineralogy, Geology and Petrology Engineering, University of Belgrade and S. Grgić, Institute of Geology, Zagreb.

##### Z-1697. Banja Vrujci Spa

Geothermal water from exploitation borehole ( $t = 25.0\text{--}26.4^\circ\text{C}$ ,  $\text{pH} = 7.1\text{--}7.4$ ,  $\text{HCO}_3^- = 340 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -89\text{‰}$ ,  $\delta^{18}\text{O} = -11.5\text{‰}$ ), Banja Vrujci near Ljig ( $44^\circ 13'\text{N}$ ,  $20^\circ 12'\text{E}$ ). Collected May 1986. Tritium activity:  $0.8 \pm 0.2 \text{ Bq liter}^{-1}$ .

**33.4  $\pm$  0.6 pMC**

$\delta^{13}\text{C} = -7.9\text{‰}$

##### Z-1698. Ljig

Geothermal water from a borehole ( $t = 32.0^\circ\text{C}$ ,  $\text{pH} = 7.6$ ,  $\text{HCO}_3^- = 700 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -90\text{‰}$ ,  $\delta^{18}\text{O} = -11.6\text{‰}$ ), Ljig ( $44^\circ 13'\text{N}$ ,  $20^\circ 15'\text{E}$ ). Collected Oct. 1986. Tritium activity:  $1.0 \pm 0.2 \text{ Bq liter}^{-1}$ .

**8.1  $\pm$  0.5 pMC**

$\delta^{13}\text{C} = -4.5\text{‰}$

##### Z-1699. Čibutkovica

Water from a spring ( $t = 16.0\text{--}18.0^\circ\text{C}$ ,  $\text{pH} = 6.5$ ,  $\text{HCO}_3^- = 3000 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -91\text{‰}$ ,  $\delta^{18}\text{O} = -11.8\text{‰}$ ), Čibutkovica near Ljig ( $44^\circ 18'\text{N}$ ,  $20^\circ 15'\text{E}$ ). Collected May 1986.  $^3\text{H}$  activity:  $0.8 \pm 0.2 \text{ Bq liter}^{-1}$ .

**2.6  $\pm$  0.4 pMC**

$\delta^{13}\text{C} = -1.6\text{‰}$

##### Z-1700. Savinac

Geothermal water from St. Sava spring ( $t = 20.0^\circ\text{C}$ ,  $\text{pH} = 7.3$ ,  $\text{HCO}_3^- = 440 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} =$

**44.3  $\pm$  1.1 pMC**

$\delta^{13}\text{C} = -8.2\text{‰}$



–80‰,  $\delta^{18}\text{O} = -10.8\text{‰}$ ), Savinac near Gornji Milanovac (44°02'N, 20°22'E). Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**31.9 ± 0.6 pMC**

$\delta^{13}\text{C} = -8.5\text{‰}$

**Z-1701. Gornja Trepča Spa**

Geothermal water from a spring ( $t = 24.0^\circ\text{C}$ ,  $\text{pH} = 6.9$ ,  $\delta^2\text{H} = -88\text{‰}$ ,  $\delta^{18}\text{O} = -12.0\text{‰}$ ), Gornja Trepča near Gornji Milanovac (43°56'N, 20°29'E). Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**11.3 ± 0.5 pMC**

$\delta^{13}\text{C} = -7.5\text{‰}$

**Z-1702. Mataruška Banja Spa**

Geothermal water from a spring ( $t = 39.5\text{--}42.0^\circ\text{C}$ ,  $\text{pH} = 6.9\text{--}7.7$ ,  $\delta^2\text{H} = -83\text{‰}$ ,  $\delta^{18}\text{O} = -10.6\text{‰}$ ), Mataruška Banja near Kraljevo (43°31'N, 20°37'E). Collected May 1986.  $^3\text{H}$  activity:  $0.8 \pm 0.2 \text{ Bq liter}^{-1}$ .

**27.3 ± 0.6 pMC**

$\delta^{13}\text{C} = -6.5\text{‰}$

**Z-1705. Bogutovačka Banja Spa**

Geothermal water from a spring ( $t = 24.5^\circ\text{C}$ ,  $\text{pH} = 7.4$ ,  $\text{HCO}_3^- = 350 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.6\text{‰}$ ), Bogutovačka Banja (43°40'N, 20°31'E). Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**2.3 ± 0.5 pMC**

$\delta^{13}\text{C} = -3.4\text{‰}$

**Z-1710. Vrnjačka Banja Spa**

Geothermal water from exploitation borehole ( $t = 35.0^\circ\text{C}$ ,  $\text{pH} = 6.7$ ,  $\delta^2\text{H} = -87\text{‰}$ ,  $\delta^{18}\text{O} = -11.2\text{‰}$ ), Vrnjačka Banja (43°37'N, 20°55'E) near Kraljevo. Collected May 1986.  $^3\text{H}$  activity:  $1.1 \pm 0.2 \text{ Bq liter}^{-1}$ .

**32.9 ± 1.0 pMC**

$\delta^{13}\text{C} = -8.2\text{‰}$

**Z-1706. Jošanička Banja Spa**

Geothermal water from a spring ( $t = 78.0^\circ\text{C}$ ,  $\text{pH} = 7.8 - 8.3$ ,  $\delta^2\text{H} = -86\text{‰}$ ,  $\delta^{18}\text{O} = -11.6\text{‰}$ ), Jošanička Banja (43°23'N, 20°46'E), west slope of Mt. Kopaonik. Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**4.4 ± 0.5 pMC**

$\delta^{13}\text{C} = 0.13\text{‰}$

**Z-1716. Lukovska Banja Spa**

Geothermal water from a spring ( $t = 56.0\text{--}64.2^\circ\text{C}$ ,  $\text{pH} = 6.8\text{--}7.2$ ,  $\delta^2\text{H} = -73\text{‰}$ ,  $\delta^{18}\text{O} = -10.7\text{‰}$ ), Lukovska Banja (43°10'N, 21°02'E), east slope of Mt. Kopaonik. Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**9.7 ± 0.5 pMC**

$\delta^{13}\text{C} = -3.4\text{‰}$

**Z-1712. Brus**

Geothermal water from exploitation borehole ( $t = 27.0^\circ\text{C}$ ,  $\text{pH} = 7.5$ ,  $\delta^2\text{H} = -96\text{‰}$ ,  $\delta^{18}\text{O} = -11.3\text{‰}$ ), Brus (43°22'N, 21°03'E), east slope of Mt. Kopaonik. Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**4.5 ± 0.5 pMC**

$\delta^{13}\text{C} = -0.2\text{‰}$

**Z-1715. Kuršumlijska Banja Spa**

Geothermal water from exploitation borehole ( $t = 63.0^\circ\text{C}$ ,  $\text{pH} = 7.1\text{--}7.6$ ,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.6\text{‰}$ ), Kuršumlijska Banja near Kuršumlija (43°04'N, 21°16'E). Collected May 1986.  $^3\text{H}$  activity:  $0.5 \pm 0.2 \text{ Bq liter}^{-1}$ .

**71.9 ± 0.8 pMC**

$\delta^{13}\text{C} = -18.4\text{‰}$

**Z-1728. Prolom Banja Spa**

Water from a spring ( $t = 27.0^\circ\text{C}$ ,  $\text{pH} = 7.3$ ,  $\delta^2\text{H} = -89\text{‰}$ ,  $\delta^{18}\text{O} = -11.6\text{‰}$ ), Prolom Banja near Kuršumlija (43°02'N, 21°26'E). Collected June 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**6.0 ± 0.5 pMC**

$\delta^{13}\text{C} = -0.7\text{‰}$

**Z-1711. Veluće**

Geothermal water from an exploitation borehole ( $t = 17.0\text{--}21.0^\circ\text{C}$ ,  $\text{pH} = 6.4\text{--}7.0$ ,  $\delta^2\text{H} = -91\text{‰}$ ,

$\delta^{18}\text{O} = -11.2\text{‰}$ ), Veluče near Kruševac (43°32'N, 21°05'E). Collected May 1986.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

**50.7 ± 0.7 pMC**

**Z-1733. Rgošte**

$\delta^{13}\text{C} = -9.5\text{‰}$

Geothermal water from a spring ( $t = 29.0^\circ\text{C}$ ,  $\text{pH} = 7.3$ ,  $\delta^2\text{H} = -82\text{‰}$ ,  $\delta^{18}\text{O} = -11.0\text{‰}$ ), Rgošte near Knjaževac (43°33'N, 22°13'E). Collected June 1986.  $^3\text{H}$  activity:  $2.5 \pm 0.2$  Bq liter $^{-1}$ .

**47.4 ± 1.0 pMC**

**Z-1724. Manastir Rača**

$\delta^{13}\text{C} = -11.3\text{‰}$

Water from a spring ( $t = 14.0^\circ\text{C}$ ,  $\text{pH} = 7.5$ ,  $\delta^2\text{H} = -81\text{‰}$ ,  $\delta^{18}\text{O} = -11.0\text{‰}$ ), Manastir Rača near Bajina Bašta (43°56'N, 19°32'E). Collected June 1986.  $^3\text{H}$  activity:  $1.7 \pm 0.2$  Bq liter $^{-1}$ .

**0.9 ± 0.6 pMC**

**Z-1717 Bujanovačka Banja Spa**

$\delta^{13}\text{C} = 1.8\text{‰}$

Geothermal water from exploitation borehole ( $t = 45.2^\circ\text{C}$ ,  $\text{pH} = 8.2$ ,  $\delta^2\text{H} = -91\text{‰}$ ,  $\delta^{18}\text{O} = -11.2\text{‰}$ ), Bujanovačka Banja near Bujanovac (42°25'N, 21°45'E). Collected May 1986.  $^3\text{H}$  activity:  $0.6 \pm 0.2$  Bq liter $^{-1}$ .

**4.6 ± 0.5 pMC**

**Z-1729. Sijarinska Banja Spa**

$\delta^{13}\text{C} = 0.0\text{‰}$

Geothermal water from exploitation borehole ( $t = 68.0^\circ\text{C}$ ,  $\text{pH} = 6.8$ ,  $\delta^2\text{H} = -91\text{‰}$ ,  $\delta^{18}\text{O} = -11.3\text{‰}$ ), Sijarinska Banja near Lebane (42°47'N, 21°37'E). Collected June 1986.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

**7.3 ± 0.5 pMC**

**Z-1737. Neresnica**

$\delta^{13}\text{C} = -2.7\text{‰}$

Water from exploitation borehole ( $t = 20.0^\circ\text{C}$ ,  $\text{pH} = 6.8$ ,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.3\text{‰}$ ), Neresnica near Majdanpek (44°26'N, 21°43'E). Collected June 1986.  $^3\text{H}$  activity:  $0.9 \pm 0.2$  Bq liter $^{-1}$ .

**8.2 ± 0.5 pMC**

**Z-1721. Selters**

$\delta^{13}\text{C} = -2.9\text{‰}$

Geothermal water from exploitation borehole ( $t = 43.7^\circ\text{C}$ ,  $\text{pH} = 6.8$ ,  $\delta^2\text{H} = -55\text{‰}$ ,  $\delta^{18}\text{O} = -8.3\text{‰}$ ), Selters near Mladenovac (44°29'N, 20°42'E). Collected June 1986.  $^3\text{H}$  activity:  $0.9 \pm 0.2$  Bq liter $^{-1}$ .

**50.0 ± 0.6 pMC**

**Z-1732. Sokobanja Spa**

$\delta^{13}\text{C} = -8.2\text{‰}$

Geothermal water from exploitation borehole ( $t = 43.0^\circ\text{C}$ ,  $\text{pH} = 7.4$ ,  $\delta^2\text{H} = -83\text{‰}$ ,  $\delta^{18}\text{O} = -11.3\text{‰}$ ), Sokobanja near Aleksinac (43°35'N, 21°52'E). Collected June 1986.  $^3\text{H}$  activity:  $2.0 \pm 0.2$  Bq liter $^{-1}$ .

**57.8 ± 0.7 pMC**

**Z-1730. Niška Banja Spa**

$\delta^{13}\text{C} = -7.9\text{‰}$

Geothermal water from exploitation borehole ( $t = 38.0^\circ\text{C}$ ,  $\text{pH} = 7.4$ ,  $\delta^2\text{H} = -86\text{‰}$ ,  $\delta^{18}\text{O} = -11.3\text{‰}$ ), Niška Banja near Niš (43°17'N, 22°01'E). Collected June 1986.  $^3\text{H}$  activity:  $1.9 \pm 0.2$  Bq liter $^{-1}$ .

**88.8 ± 1.8 pMC**

**Z-2100. Školska Česma**

Water from a spring in Niška Banja Spa. Collected July 1988.  $^3\text{H}$  activity:  $2.2 \pm 0.2$  Bq liter $^{-1}$ .

**60.0 ± 0.7 pMC**

**Z-1731. Krivi Vir**

$\delta^{13}\text{C} = -10.3\text{‰}$

Geothermal water from a spring ( $t = 20.6^\circ\text{C}$ ,  $\text{pH} = 7.2$ ,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.2\text{‰}$ ), Krivi Vir near Niš (43°49'N, 21°45'E). Collected June 1986.  $^3\text{H}$  activity:  $3.2 \pm 0.2$  Bq liter $^{-1}$ .

- Z-1727. Pribojska Banja Spa** **2.9 ± 1.5 pMC**  
 $\delta^{13}\text{C} = -4.3\text{‰}$   
Geothermal water from a spring ( $t = 36.2^\circ\text{C}$ ,  $\text{pH} = 8.2$ ,  $\text{HCO}_3^- = 200 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.7\text{‰}$ ), Pribojska Banja near Priboj na Limu ( $43^\circ34'\text{N}$ ,  $19^\circ32'\text{E}$ ). Collected June 1986.  $^3\text{H}$  activity:  $0.5 \pm 0.2 \text{ Bq liter}^{-1}$ .
- Z-1826. Čedovo** **14.1 ± 0.8 pMC**  
 $\delta^{13}\text{C} = -7.3\text{‰}$   
Water from a spring ( $\delta^2\text{H} = -83\text{‰}$ ,  $\delta^{18}\text{O} = -10.9\text{‰}$ ), Čedovo ( $43^\circ35'\text{N}$ ,  $20^\circ00'\text{E}$ ). Collected Oct. 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .
- Z-1770. Bogatić, BR-1** **12.8 ± 0.8 pMC**  
 $\delta^{13}\text{C} = -4.8\text{‰}$   
Water from a borehole ( $\delta^2\text{H} = -89\text{‰}$ ,  $\delta^{18}\text{O} = -11.3\text{‰}$ ), Bogatić near Sremska Mitrovica ( $44^\circ50'\text{N}$ ,  $19^\circ35'\text{E}$ ), Mačva. Collected Sept. 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .
- Z-1695. Dublje** **7.5 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -2.9\text{‰}$   
Geothermal water from a borehole ( $t = 50.0^\circ\text{C}$ ,  $\text{pH} = 6.3$ ,  $\text{HCO}_3^- = 500 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -96\text{‰}$ ,  $\delta^{18}\text{O} = -12.5\text{‰}$ ), Dublje near Bogatić ( $44^\circ48'\text{N}$ ,  $19^\circ32'\text{E}$ ). Collected May 1986.  $^3\text{H}$  activity:  $1.6 \pm 0.2 \text{ Bq liter}^{-1}$ .
- Z-1827. Belotić** **3.1 ± 0.6 pMC**  
 $\delta^{13}\text{C} = -3.2\text{‰}$   
Water from exploitation borehole ( $t = 24.0^\circ\text{C}$ ,  $\delta^2\text{H} = -87\text{‰}$ ,  $\delta^{18}\text{O} = -11.5\text{‰}$ ), Belotić near Šabac ( $44^\circ49'\text{N}$ ,  $19^\circ33'\text{E}$ ). Collected Oct. 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .
- Z-1713. Suva Česma** **2.6 ± 0.4 pMC**  
 $\delta^{13}\text{C} = -2.4\text{‰}$   
Geothermal water from Suva Česma spring ( $t = 24.0^\circ\text{C}$ ,  $\text{pH} = 7.7$ ,  $\delta^2\text{H} = -77\text{‰}$ ,  $\delta^{18}\text{O} = -9.5\text{‰}$ ), Suva Česma near Prokuplje ( $43^\circ15'\text{N}$ ,  $21^\circ35'\text{E}$ ). Collected May 1986.  $^3\text{H}$  activity:  $0.4 \pm 0.2 \text{ Bq liter}^{-1}$ .
- Z-1714. Viča** **1.3 ± 0.4 pMC**  
 $\delta^{13}\text{C} = -3.7\text{‰}$   
Water from a spring ( $t = 19.0^\circ\text{C}$ ,  $\text{pH} = 8.0$ ,  $\delta^2\text{H} = -88\text{‰}$ ,  $\delta^{18}\text{O} = -11.0\text{‰}$ ), Viča near Prokuplje. Collected June 1986.  $^3\text{H}$  activity:  $1.9 \pm 0.2 \text{ Bq liter}^{-1}$ .
- Z-1722. Smederevska Palanka Spa** **8.4 ± 0.5 pMC**  
 $\delta^{13}\text{C} = 0.8\text{‰}$   
Geothermal water ( $t = 47.2^\circ\text{C}$ ,  $\text{pH} = 7.1$ ,  $\delta^2\text{H} = -87\text{‰}$ ,  $\delta^{18}\text{O} = -11.1\text{‰}$ ), Smederevska Palanka near Smederevo ( $44^\circ23'\text{N}$ ,  $20^\circ57'\text{E}$ ). Collected June 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .
- Z-1725. Kosjerić** **40.9 ± 0.6 pMC**  
 $\delta^{13}\text{C} = -11.2\text{‰}$   
Geothermal water from a spring ( $t = 23.2^\circ\text{C}$ ,  $\text{pH} = 7.0$ ,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.2\text{‰}$ ), Kosjerić near Užice ( $44^\circ00'\text{N}$ ,  $19^\circ57'\text{E}$ ). Collected June 1986.  $^3\text{H}$  activity:  $0.8 \pm 0.2 \text{ Bq liter}^{-1}$ .
- Z-1726. Rožanstvo Spa** **29.4 ± 0.6 pMC**  
 $\delta^{13}\text{C} = -11.5\text{‰}$   
Water from a spring ( $t = 17.5\text{--}20.0^\circ\text{C}$ ,  $\text{pH} = 7.3$ ,  $\delta^2\text{H} = -81\text{‰}$ ,  $\delta^{18}\text{O} = -10.9\text{‰}$ ), Rožanstvo near Užice ( $43^\circ43'\text{N}$ ,  $19^\circ55'\text{E}$ ). Collected June 1986.  $^3\text{H}$  activity:  $0.8 \pm 0.2 \text{ Bq liter}^{-1}$ .
- Z-1696. Petnica Spa, PT-2** **19.8 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -10.2\text{‰}$   
Geothermal water from Borehole PT-2 ( $t = 31.0^\circ\text{C}$ ,  $\text{pH} = 7.5$ ,  $\text{HCO}_3^- = 370 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} =$

–81‰,  $\delta^{18}\text{O} = -10.1\text{‰}$ ), Petnica near Valjevo (45°15'N, 19°54'E). Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-1734. Nikolićevo Spa** **3.9 ± 0.4 pMC**  
 $\delta^{13}\text{C} = -0.7\text{‰}$   
Water from a borehole ( $t = 36.4^\circ\text{C}$ ,  $\text{pH} = 7.5$ ,  $\delta^2\text{H} = -97\text{‰}$ ,  $\delta^{18}\text{O} = -12.9\text{‰}$ ), Nikolićevo near Zaječar (43°57'N, 22°16'E). Collected June 1986.  $^3\text{H}$  activity:  $0.4 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Z-1735. Gamzigradska Banja Spa** **15.1 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -5.3\text{‰}$   
Geothermal water from a spring ( $t = 42.0^\circ\text{C}$ ,  $\text{pH} = 7.2$ ,  $\delta^2\text{H} = -80\text{‰}$ ,  $\delta^{18}\text{O} = -11.0\text{‰}$ ), Gamzigradska Banja near Zaječar (43°54'N, 22°11'E). Collected June 1986.  $^3\text{H}$  activity:  $0.8 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Z-1723. Radaljska Banja Spa** **34.6 ± 0.7 pMC**  
 $\delta^{13}\text{C} = -14.8\text{‰}$   
Geothermal water from a spring ( $t = 28.2^\circ\text{C}$ ,  $\text{pH} = 9.2$ ,  $\text{HCO}_3^- = 70 \text{ mg liter}^{-1}$ ,  $\delta^2\text{H} = -87\text{‰}$ ,  $\delta^{18}\text{O} = -11.8\text{‰}$ ), Radaljska Banja near Zvornik (44°24'N, 19°11'E). Collected June 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-1703. Ovčar Banja Spa** **20.8 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -3.3\text{‰}$   
Geothermal water from a spring ( $t = 38.0^\circ\text{C}$ ,  $\text{pH} = 7.6$ ,  $\delta^2\text{H} = -77\text{‰}$ ,  $\delta^{18}\text{O} = -10.7\text{‰}$ ), Ovčar Banja near Čačak (43°55'N, 20°12'E). Collected May 1986.  $^3\text{H}$  activity:  $0.8 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Z-1845. Kupinovo** **29.2 ± 0.8 pMC**  
 $\delta^{13}\text{C} = -2.4\text{‰}$   
Water from a borehole, Kupinovo (44°42'N, 20°03'E). Collected Dec. 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-1736. Boleč Spa** **12.9 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -12.5\text{‰}$   
Water ( $t = 22^\circ\text{C}$ ,  $\delta^2\text{H} = -95\text{‰}$ ,  $\delta^{18}\text{O} = -12.1\text{‰}$ ), Boleč near Belgrade (44°42'N, 20°35'E). Collected June 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-1841. Grocka** **31.8 ± 0.8 pMC**  
 $\delta^{13}\text{C} = -4.5\text{‰}$   
Water from a borehole ( $\delta^2\text{H} = -57\text{‰}$ ,  $\delta^{18}\text{O} = -3.2\text{‰}$ ), Grocka near Belgrade (44°48'N, 20°49'E). Collected Dec. 1986.  $^3\text{H}$  activity:  $0.3 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Z-1938. Belgrade, IEBP-3** **2.4 ± 0.5 pMC**  
Water from exploitation Borehole IEBP-3 ( $\delta^2\text{H} = -80\text{‰}$ ,  $\delta^{18}\text{O} = -11.5\text{‰}$ ) near Belgrade (44°47'N, 20°28'E). Collected Sept. 1987.  $^3\text{H}$  activity:  $0.5 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Z-1707. Novopazarska Banja Spa** **7.7 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -3.5\text{‰}$   
Geothermal water from a borehole ( $t = 54.0^\circ\text{C}$ ,  $\text{pH} = 7.4$ ,  $\delta^2\text{H} = -89\text{‰}$ ,  $\delta^{18}\text{O} = -11.7\text{‰}$ ), Novopazarska Banja near Novi Pazar (43°06'N, 20°31'E). Collected May 1986.  $^3\text{H}$  activity:  $0.2 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Z-1708. Rajčinovića Banja Spa** **2.4 ± 0.4 pMC**  
 $\delta^{13}\text{C} = -10.0\text{‰}$   
Geothermal water ( $t = 38.6^\circ\text{C}$ ,  $\text{pH} = 8.2$ ,  $\delta^2\text{H} = -86\text{‰}$ ,  $\delta^{18}\text{O} = -10.9\text{‰}$ ), Rajčinovića Banja near Novi Pazar. Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-1709. Gornji Gradac Spa** **62.6 ± 1.0 pMC**  
 $\delta^{13}\text{C} = -10.3\text{‰}$   
Geothermal water ( $t = 21.0^\circ\text{C}$ ,  $\text{pH} = 7.2$ ,  $\delta^2\text{H} = -87\text{‰}$ ,  $\delta^{18}\text{O} = -10.3\text{‰}$ ), Gornji Gradac near Novi Pazar. Collected May 1986.  $^3\text{H}$  activity:  $1.2 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Surdulica Series**

Water samples from springs and an old mine are part of a study of the mechanism of water formation in the Surdulica geothermal system, south Serbia (Milovanović *et al.* 1989; Hadžišehović *et al.* 1993). Collected and submitted 1986 by S. Stanković, Geozavod, Belgrade, S. Grgić and B. Obelić.

*Comment:* Dates complete previously published measurements (Srdoč *et al.* 1992: 163–164).

- Z-1764. Mt. Besna Kobila** **72.2 ± 1.2 pMC**  
Water from a spring, Mt. Besna Kobila (42°28'N, 22°08'E). Collected July 1986.
- Z-1761. Stari Glog 1** **71.1 ± 1.2 pMC**  
Water from a spring ( $\delta^2\text{H} = -76\text{‰}$ ,  $\delta^{18}\text{O} = -10.0\text{‰}$ ), Stari Glog, Mt. Besna Kobila. Collected July 1986.
- Z-1804. Stari Glog 2** **69.8 ± 1.1 pMC**  
Water from a spring near Stari Glog, Mt. Besna Kobila. Collected Oct. 1986.
- Z-1807. Golemi Izvor** **76.0 ± 1.2 pMC**  
Water from Golemi Izvor spring ( $\delta^2\text{H} = -82\text{‰}$ ,  $\delta^{18}\text{O} = -11.4\text{‰}$ ), Mt. Besna Kobila. Collected Oct. 1986.  $^3\text{H}$  activity:  $70.0 \pm 0.3 \text{ Bq liter}^{-1}$ .
- Z-1809. Topli Dol** **90.0 ± 1.3 pMC**  
Springwater feeding Topli Dol river (42°40'N, 22°08'E). Collected Oct. 1986.
- Z-1765. Blagodat** **55.2 ± 1.0 pMC**  
Water from Blagodat mine ( $\delta^2\text{H} = -75\text{‰}$ ,  $\delta^{18}\text{O} = -10.9\text{‰}$ ) at Kriva Feja (42°33'N, 22°09'E). Collected July 1986.  $^3\text{H}$  activity:  $7.3 \pm 0.2 \text{ Bq liter}^{-1}$ .
- Z-1808. Crna Reka River** **39.7 ± 1.0 pMC**  
River water, Crna Reka ( $\delta^2\text{H} = -78\text{‰}$ ,  $\delta^{18}\text{O} = -10.9\text{‰}$ ) at Kriva Feja. Collected Oct. 1986.  $^3\text{H}$  activity:  $1.5 \pm 0.2 \text{ Bq liter}^{-1}$ .

**Vranjska Banja Series**

Geothermal water from Vranjska Banja Spa (42°32'N, 22°02'E) and its surroundings. Collected and submitted 1986 by S. Tomić and B. Obelić.

- Z-1718. Vranjska Banja 1** **6.0 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -6.6\text{‰}$   
Geothermal water from exploitation Boreholes A-1 and A-2 ( $t = 84.0^\circ\text{C}$ ,  $\text{pH} = 7.8$ ), Vranjska Banja. Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .
- Z-1719. Vranjska Banja 2** **4.5 ± 0.5 pMC**  
 $\delta^{13}\text{C} = -3.7\text{‰}$   
Geothermal water from exploitation Borehole A-1 ( $t = 80.2^\circ\text{C}$ ,  $\text{pH} = 7.7$ ,  $\delta^2\text{H} = -86\text{‰}$ ,  $\delta^{18}\text{O} = -11.1\text{‰}$ ), Vranjska Banja. Collected May 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .
- Z-1759. Vranjska Banja 3** **18.0 ± 0.6 pMC**  
Geothermal water from an old catchment ( $t = 80^\circ\text{C}$ ,  $\delta^2\text{H} = -81\text{‰}$ ,  $\delta^{18}\text{O} = -11.0\text{‰}$ ), Vranjska Banja. Collected July 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .
- Z-1760. Vranjska Banja 4** **4.4 ± 0.6 pMC**  
Geothermal water from an old catchment. Collected July 1986.  $^3\text{H}$  activity:  $<0.2 \text{ Bq liter}^{-1}$ .

**Z-1762. Vranjska Banja 5** **10.4 ± 0.6 pMC**  
 Geothermal water from exploitation Borehole B-1 ( $\delta^2\text{H} = -85\text{‰}$ ,  $\delta^{18}\text{O} = -11.2\text{‰}$ ) located in Vranjska Banja Spa park. Collected July 1986.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

**Z-1763. Vranjska Banja 6** **77.5 ± 1.2 pMC**  
 Geothermal water from exploitation Borehole B-1. Collected Oct. 1986.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

**Z-1802. Vranjska Banja 7** **1.3 ± 0.5 pMC**  
 Geothermal water from a spring ( $\delta^2\text{H} = -87\text{‰}$ ,  $\delta^{18}\text{O} = -11.2\text{‰}$ ) near the hotel in Vranjska Banja Spa. Collected July 1986.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

**Z-1803. Vranjska Banja 8** **2.7 ± 0.6 pMC**  
 Geothermal water from a spring near the hotel. Collected Oct. 1986.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

**Z-1805. Vranjska Banja 9** **16.8 ± 0.7 pMC**  
 Water from infiltration (14°C, pH = 7.0,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.1\text{‰}$ ) near the railway station. Collected July 1986.  $^3\text{H}$  activity:  $1.7 \pm 0.2$  Bq liter $^{-1}$ .

**Z-1806. Vranjska Banja 10** **73.6 ± 1.2 pMC**  
 Water from infiltration near the railway station. Collected Oct. 1986.  $^3\text{H}$  activity:  $1.5 \pm 0.2$  Bq liter $^{-1}$ .

**Z-1720. Toplac** **26.9 ± 0.6 pMC**  
 $\delta^{13}\text{C} = -7.8\text{‰}$   
 Geothermal water from a borehole (23.0°C, pH = 7.6,  $\delta^2\text{H} = -79\text{‰}$ ,  $\delta^{18}\text{O} = -10.7\text{‰}$ ), Toplac near Vranje (42°33'N, 21°57'E). Collected May 1986.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

#### **Bačka Series**

Collected and submitted April 1986 by M. Hadžišehović, Boris Kidrič Institute, Vinča.

**Z-1687. Bačko Novo Selo** **24.5 ± 0.7 pMC**  
 Water from Well 27 at Bačko Novo Selo (45°55'N, 19°08'E), north Serbia.

**Z-1689. Mladenovo** **16.8 ± 0.6 pMC**  
 Water from Well 4 at Mladenovo (43°17'N, 22°01'E), north Serbia.

#### **Lim Valley Series**

Tap water from Lim Valley, southwest Serbia. Collected and submitted May 1990 by M. Hadžišehović.

**Z-2231. Seljašnica** **89.5 ± 1.1 pMC**  
 Tap water from Seljašnica (43°22'N, 19°35'E).

**Z-2232. Čadinje** **94.1 ± 1.1 pMC**  
 Tap water from Čadinje (43°22'N, 19°37'E).

#### **BOSNIA AND HERZEGOVINA**

**Z-2331. Lješljani SB-1** **116.6 ± 1.3 pMC**  
 Groundwater from Borehole SB-1, Lješljani near Bosanski Novi (45°02'N, 16°25'E), Bosnia. Collected and submitted April 1991 by N. Miošić, Geoinženjering Co., Sarajevo.  $^3\text{H}$  activity:  $<0.2$  Bq liter $^{-1}$ .

**Tuzla Series**

Groundwater and mineral water from the environs of Tuzla salt mine. Samples were part of hydro-geological study. Collected and submitted March 1992 by N. Miošić.

**Z-2381. Živinice** **17.8 ± 0.4 pMC**  
Groundwater from Kiseljak near Živinice (44°27'N, 18°39'E). <sup>3</sup>H activity: 1.2 ± 0.2 Bq liter<sup>-1</sup>.

**Z-2384. Lukavac** **14.8 ± 0.6 pMC**  
Water from well Petrak near Lukavac (44°31'N, 18°32'E). <sup>3</sup>H activity: <0.2 Bq liter<sup>-1</sup>.

**Z-2382. Bokanići** **1.1 ± 0.8 pMC**  
Mineral water from borehole at Kiseljak near Bokanići (44°30'N, 18°32'E). <sup>3</sup>H activity: <0.2 Bq liter<sup>-1</sup>.

**Z-2383. Ljubače** **1.6 ± 0.8 pMC**  
Groundwater from Kiseljak near Ljubače (44°29'N, 18°36'E). <sup>3</sup>H activity: 2.8 ± 0.2 Bq liter<sup>-1</sup>.

**GEOLOGICAL SAMPLES***CROATIA***Plitvice National Park Samples**

**Z-2213. Lake Prošće** **67.5 ± 0.7 pMC**

Tufa from a submerged barrier, Lake Prošće, 5–7 m depth. Collected and submitted March 1990 by D. Srdoč and D. Petricioli, Center for Marine Research, Rudjer Bošković Institute, Zagreb.

**Lake Kozjak Series**

Samples of tufa and fragments of sunken trees from the surface of a submerged barrier dividing Lake Kozjak into Upper and Lower Basin. Dating the period of barrier growth before flooding by rising lake-water level. Collected and submitted March 1990 by D. Srdoč and D. Petricioli.

**Z-2214. Lake Kozjak 1** **72.4 ± 0.7 pMC**  
Tufa, 18 m water depth.

**Z-2215. Lake Kozjak 2** **71.2 ± 0.8 pMC**  
Tufa, 5 m water depth.

**Z-2216. Lake Kozjak 3** **97.4 ± 0.9 pMC**  
Fragment of a branch from the top of a submerged tree, growing on the crest of the tufa barrier, presently 5–6 m below the lake surface.

**Z-2217. Lake Kozjak 4** **95.9 ± 0.9 pMC**  
Fragment of a branch from the top of a submerged tree; the tree base is presently 12 m below the lake surface.

**Lake Gavanovac Series**

Tufa profiles above Lake Gavanovac. Collected Feb. 1990 by D. Srdoč. The results complete previously published measurements Z-656, -657, -659, -668, -672, -673, -677 (Srdoč, Obelić and Horvat-inčić 1980).



- Z-2204. Lake Gavanovac 1** **59.5 ± 0.5 pMC**  
Surface layer, Profile I.
- Z-2205. Lake Gavanovac 2** **66.8 ± 0.7 pMC**  
Surface layer, Profile II.
- Z-2206. Lake Gavanovac 3** **61.2 ± 0.6 pMC**  
Compact tufa, Profile III.
- Z-2362. Pag** **99.5 ± 0.9 pMC**  
Shells from a deposit along the shoreline, presently 5 m asl, saltworks southeast of Pag (44°26'N, 15°04'E), Pag Island, south Croatia. Collected July 1989 and submitted June 1991 by Lj. Marjanac.
- Z-2228. Bednja** **1130 ± 110**  
Fossil oak (*Quercus niger*) from the bed of the Bednja River near Bednja (46°10'N, 16°15'E), north-west Croatia. Collected and submitted May 1990 by M. Milinović, Zagreb.
- Comment* (M.M.): Expected age: >1000 BP.
- Lake Prukljan Series**
- Sediment, tufa and shells from brackish Lake Prukljan near Skradin (43°49'N, 15°55'E), south Croatia. The sediment sample was collected and submitted 1984 by M. Juračić, Faculty of Natural Sciences and Mathematics, University of Zagreb, and the tufa and shell samples by D. Petricioli, May 1990.
- Z-1277. Prukljan 1** **70.5 ± 1.1 pMC**  
Lake-bottom sediment, 16–25 cm depth, in 25-m-deep water near Cape Vukinac.
- Z-2366. Prukljan 2** **105.3 ± 0.8 pMC**  
Tufa from a submerged barrier, 3.5 m depth.
- Z-2367. Prukljan 3** **103.9 ± 0.7 pMC**  
Shells from a submerged tufa barrier, 3.5 m depth.
- Z-1856. Vindija** **1.7 ± 0.6 pMC**  
Speleothem from Vindija cave, Gornja Voća near Ivanec (46°18'12"N, 16°14'38"E), north Croatia. Collected and submitted 1987 by M. Malez.
- Z-2090. St. Jakov 51-12-L** **3.6 ± 0.7 pMC**  
Calcareous tufa, St. Jakov near Knin (44°04'N, 16°13'E), 140 m asl, south Croatia. Collected and submitted 1989 by Z. Velimirović, INA-Inženjering Co., Zagreb.
- Comment* (Z.V.): Expected age: Holocene.
- Z-2091. Raštevčić 71-9-L** **3.4 ± 0.6 pMC**  
Soil carbonate, Raštevčić near Zadar (44°05'N, 15°32'E), 134 m asl, south Croatia. Collected and submitted 1989 by Z. Velimirović.
- Z-2092. Smilčić 72-9-L** **9.8 ± 0.7 pMC**  
Soil carbonate, Smilčić near Zadar (44°05'N, 15°30'E), 150 m asl, south Croatia. Collected and submitted 1988 by Z. Velimirović.
- Comment* (Z.V.): Expected age: Holocene.

**Z-2093. Ljubač 3-8-K** **0.7 ± 0.7 pMC**  
Soil carbonate, Ljubački Zaliv (44°13'N, 15°13'E), 0 m asl, south Croatia. Collected and submitted 1989 by Z. Velimirović.

**Z-2094. Susak Island 4-VI-4-J** **7.0 ± 0.7 pMC**  
Soil carbonate, Susak Island (44°30'N, 14°20'E), south Croatia. Collected and submitted by Z. Velimirović.

*General Comments (Z.V.):* Samples Z-2090, -2091, -2092, -2093 and -2094 were dated for stratigraphic and sedimentologic study. (D.S.): High percentage of mineral carbonates impeded this study.

### Kninsko Polje Series

Peat from boreholes, Kninsko Polje (44°02'40"N, 16°12'35"E) near Knin, south Croatia. Collected and submitted May 1988 by V. Jurak, Faculty of Mining, Geology and Petroleum Engineering, Zagreb.

**Z-2052. NB-2** **>37,000**  
Peat, Borehole NB-2, 7.1 m depth, 225 m asl. Expected age: Würm 2/3.

**Z-2054. NB-3-1** **2210 ± 210**  
Peat, Borehole NB-3, 7.1–10.0 m depth, 219.6 m asl. Expected age: Holocene, Atlantic phase.

**Z-2053. NB-3-2** **8140 ± 250**  
Peat, Borehole NB-3, 16.4–27.0 m depth. Expected age: Holocene, before Boreal phase.

### SLOVENIA

#### Malo Polje Series

Lake chalk from a moor at Malo Polje (46°21'N, 13°51'E), 1600 m asl, Mt. Triglav, Julian Alps, northwest Slovenia. Collected and submitted 1987 by A. Šercelj, as part of systematic palynological investigation of Holocene vegetation in Slovenia.

*Comment (A.Š.):* Dates correspond to earlier measurements Z-1922 and -1923 (Srdoč *et al.* 1989: 94).

**Z-1924. Malo Polje** **19.5 ± 0.4 pMC**  
Lake chalk, 100–120 cm depth.

**Z-1925. Malo Polje** **1.8 ± 0.2 pMC**  
Lake chalk, 300–320 cm depth.

**Z-1852. Divaška Jama cave** **72.9 ± 1.1 pMC**  
Recent speleothem, "macaroni"-shaped, from Divaška Jama cave near Škocjan (45°49'N, 14°01'E), west Slovenia. Collected and submitted March 1987 by J. Urbanc, Jožef Stefan Institute, Ljubljana.

*Comment (D.S.):* Used to determine the initial <sup>14</sup>C activity of speleothems.

#### Lendava Series

Wood fragments from postglacial deposits near Lendava (46°33'N, 16°27'E), 170 m asl, northwest Slovenia. Collected and submitted 1991 by J. Pezdič, Jožef Stefan Institute, Ljubljana.

**Z-2294. Lendava 1** **7390 ± 180**  
 Fragment of wood from sandstone, 5 m depth, at Puconci (46°41'N, 16°09'E), 200 m asl, on the edge of the Panonian basin.

*Comment* (J.P.): Expected age: Late Postglacial.

**Z-2292. Lendava 3** **530 ± 130**  
 Fragment of wood from young clastic sediment, 1 m depth, near Lendava.

**Z-2431. Ljubljansko Barje** **540 ± 120**

Fragment of wood from clayey-peaty sediment, 2 m depth, Ljubljansko Barje near Ljubljana (45°56'N, 14°33'E), 320 m asl, Slovenia. Collected and submitted Oct. 1992 by J. Pezdič.

*BOSNIA AND HERZEGOVINA*

**Z-1837. Kravica Falls** **76.8 ± 1.2 pMC**  
 Recent tufa, Kravica Falls on Trebižat River near Ljubuški (43°12'N, 17°34'E), Herzegovina. Collected June 1986 by D. Srdoč.

*Comment* (D.S.): Used to determine the initial <sup>14</sup>C activity of calcareous tufa.

**Z-2364. Livno 71-14-M** **38.2 ± 0.9 pMC**  
 Siltite from an outcrop at the northeast part of Livanjsko Polje near Livno (43°50'N, 17°02'E), central Bosnia and Herzegovina. Collected and submitted June 1991 by Lj. Marjanac.

**Z-1835. Banja Ilidža Spa IB-2** **3.7 ± 0.6 pMC**  
 Calcareous deposit from Banja Ilidža Spa near Sarajevo (43°49'N, 18°18'E), Bosnia. Collected and submitted Dec. 1986 by B. Đerković, Geoinženjering, Sarajevo.

*SERBIA*

**Z-1935. Vladikina Ploča** **2.8 ± 0.6 pMC**  
 Speleothem from the top of a calcite barrier, Vladikina Ploča cave, Rsovci near Pirot (43°11'26"N, 22°45'17"E), 720 m asl, Serbia. Collected and submitted 1987 by D. Gavrilović.

*Comment* (D.G.): Expected age: 10,000 BP.

**Z-1949. Orahovo ET-71142** **26,600 ± 1500**  
 Fossil soil from Borehole BT-51, 810 cm depth, Orahovo (45°52'N, 19°46'E), 150 m asl, Bačka, Vojvodina. Collected and submitted 1987 by M. Galečić, Geoinstitut, Belgrade. Dated to help draft the geologic map of Vojvodina. This result completes previously published series Z-1952 to -1956 (Srdoč *et al.* 1992: 167). Expected age: Würm.

**Z-1993. Nišava River** **3520 ± 140**  
 Fragment of wood from the bed of the Nišava River near Pirot (43°09'N, 22°35'E), southwest Serbia. Collected and submitted 1987 by N. Antić, Niš, Serbia.

**Z-2111. Mol E-8426** **10.2 ± 0.7 pMC**  
 Clayey aleurite from Borehole K-59-A, 4.9–5.3 m depth, Mol near Ada (45°46'N, 20°08'E), 82 m asl, Bačka, Vojvodina. Collected and submitted Feb. 1989 by D. Koprivica, Geoinstitut, Belgrade. Dated to help draft the geologic map of Vojvodina.

*Comment* (D.K.): Expected age: Würm 2/3.

**Lovćenac Series**

Fossil soils from Lovćenac (45°41'N, 14°43'E) 100 m asl, Bačka, Vojvodina. Collected and submitted 1989 by M. Galečić, Geoinstitut, Belgrade.

**Z-2109. E-71263** **11.6 ± 0.8 pMC**  
Organic part of fossil soil from Krivaja River bank near Lovćenac.

**Z-2110. E-71262** **12.8 ± 0.7 pMC**  
Inorganic part of fossil soil from open profile, brickyard near Lovćenac.

**Z-1851. Bački Breg** **5.8 ± 0.6 pMC**  
Fluvial sediment from Borehole MB-1 at Bački Breg (45°55'N, 18°56'E), 85 m asl, 4.8–5.0 m depth, Vojvodina. Collected and submitted 1987 by S. Trifunović, Geological Institute, Belgrade. Expected age: Würm 3.

*MONTENEGRO*

**Z-1680. Gurdić Cave** **0.5 ± 0.5 pMC**  
Stalactite from submerged Gurdić Cave near Kotor (42°25'N, 18°47'E), Montenegro, used in studying sea-level oscillations. Collected and submitted April 1986 by P. Habič, Slovenian Academy of Sciences and Arts, Postojna, Slovenia.

*UNITED STATES*

**Z-1889. Falls Creek** **113.3 ± 1.2 pMC**  
Recent tufa deposited from freshwater at Falls Creek, Oklahoma. Collected and submitted 1987 by D. Srdoč and H. Chafetz.  
 $\delta^{13}C = -7.7\text{‰}$

*Comment:* (D.S.): This recent calcareous deposit contains a large proportion of *Oocardium stratum*.

**Turner Falls Series**

Travertine samples from Turner Falls on Honey Creek, Oklahoma. Collected and submitted May 1987 by H. Chafetz, Department of Geosciences, University of Houston (Srdoč, Chafetz and Utech 1989).

**Z-2209. HC1-1** **109.5 ± 0.9 pMC**  
Porous soft travertine.  $\delta^{13}C = -7.1\text{‰}$

**Z-2110. HC1-29** **112.0 ± 0.9 pMC**  
Very porous soft travertine.

**Z-2211 HC1-30** **109.5 ± 0.8 pMC**  
Porous homogeneous soft travertine covered with moss.

**Z-2122. 2-CBF** **1.5 ± 0.5 pMC**  
Porous layered hard travertine.

**Bridal Veil Series**

Travertine from Bridal Veil at Turner Falls. Collected and submitted 1988 by H. Chafetz.

**Z-1903. 2** **109.0 ± 1.2 pMC**  
Recent soft travertine.

**Z-1902. 3** **2.0 ± 0.6 pMC**  
Porous hard travertine.

#### White Bluff Series

Tufa from an active crest at White Bluff, Texas. Collected and submitted Dec. 1989 by H. Chafetz.

**Z-2207. 1** **106.3 ± 0.8 pMC**  
Porous, very soft travertine, partly covered with moss.

**Z-2208. 2** **98.3 ± 0.8 pMC**  
Very porous, soft travertine.

*Comment:* Dates correspond to earlier measurement Z-2191 (Srdoč *et al.* 1992: 174).

#### CZECH REPUBLIC

#### St. Jan pod Skalou Series

Travertine from Central Bohemian Karst near St. Jan pod Skalou (49°53'N, 17°02'E). Travertine barriers intersecting Kačák Creek. Collected 1985 by D. Srdoč and J. Šilar, Faculty of Science, Charles University, Prague.

**Z-1766. 1** **52.7 ± 1.0 pMC**  
Holocene travertine with embedded mollusk shells, upper barrier.

**Z-1836. 2** **53.8 ± 1.0 pMC**  
Same as above, lower barrier.

#### BOTANICAL SAMPLES

We measured of <sup>14</sup>C activity and <sup>13</sup>C content of terrestrial, marsh and aquatic plants growing in and around Plitvice Lakes. We found that aquatic mosses used carbon from the DIC in lake and stream water, whereas the source of carbon in marsh plants was atmospheric CO<sub>2</sub>. Aquatic plants using DIC in freshwater for photosynthesis are not suitable for <sup>14</sup>C dating unless the initial activity of incorporated carbon is well known (Marčenko *et al.* 1989). In several cases, the carbon isotopic composition of various parts of aquatic plants was measured.

#### Aquatic and Marsh Plants Series

Aquatic and marsh plants growing in and around Plitvice Lakes. Collected 1987 by D. Srdoč, E. Marčenko, Rudjer Bošković Institute, Zagreb, and S. Golubić, Boston University, Biological Science Center.

**Z-1958. *Fontinalis antipyretica*** **80.4 ± 0.9 pMC**  
Confluence of Bijela Rijeka and Vukmirovića streams. Collected June 1987.  $\delta^{13}C = -47.5\%$

**Z-1963. *Chara* sp.** **92.2 ± 0.6 pMC**  
Confluence of Bijela Rijeka and Vukmirovića streams. Collected June 1987.

**Z-2046. *Ranunculus trichophyllus*** **79.6 ± 0.8 pMC**  
Bijela Rijeka stream, Nenadića mill. Collected June 1987.  $\delta^{13}C = -28.7\%$

**Z-2050. *Veronica anagallis aquatica*** **111.1 ± 1.1 pMC**  
Emergent part of plant, Bijela Rijeka spring. Collected May 1988.  $\delta^{13}C = -31.0\%$

<b>Z-2051. <i>Veronica anagallis aquatica</i></b> Submerged part of plant, Bijela Rijeka spring. Collected May 1988.	<b>77.1 ± 0.7 pMC</b> $\delta^{13}\text{C} = -36.0\text{‰}$
<b>Z-1960. <i>Cratoneurum commutatum</i></b> Lake Kaluđerovac. Collected April 1987.	<b>108.1 ± 1.6 pMC</b> $\delta^{13}\text{C} = -34.6\text{‰}$
<b>Z-2039. <i>Petasites albus</i></b> Flowers, Lake Burgetić. Collected May 1988.	<b>118.9 ± 1.6 pMC</b> $\delta^{13}\text{C} = -30.6\text{‰}$
<b>Z-2040. <i>Petasites albus</i></b> Root, Lake Burgetić. Collected May 1988.	<b>116.1 ± 1.1 pMC</b> $\delta^{13}\text{C} = -28.6\text{‰}$
<b>Z-2107. <i>Corylus avellana</i></b> Leaves, Lake Labudovac shore. Collected Sept. 1987.	<b>126.5 ± 2.0 pMC</b> $\delta^{13}\text{C} = -27.0\text{‰}$
<b>Z-1767. <i>Fagus silvatica</i></b> Leaves, Plitvica stream shore. Collected Sept. 1986.	<b>124.1 ± 1.7 pMC</b>
<b>Z-1964. <i>Neckera crispa</i></b> Plitvica spring. Collected June 1986.	<b>126.7 ± 1.6 pMC</b> $\delta^{13}\text{C} = -26.1\text{‰}$
<b>Z-1959. <i>Cratoneurum commutatum</i></b> Moss sprinkled with stream water, Spiljski Vrt. Collected July 1987.	<b>104.3 ± 0.6 pMC</b> $\delta^{13}\text{C} = -40.6\text{‰}$

ATMOSPHERIC CO<sub>2</sub> SAMPLES

## CROATIA

Table 3 shows <sup>14</sup>C activity of samples of atmospheric CO<sub>2</sub> collected in Zagreb from 1983 to 1993. Ca. 125 ml of saturated carbonate-free sodium hydroxide solution was exposed to the open atmosphere.

TABLE 3. Atmospheric CO<sub>2</sub> Measured in Zagreb

Sample no.	Collection date	pMC (± 1.5)	$\delta^{14}\text{C}$ (‰)
Z-1153	1983 06/23–08/31	134.0	346.0
Z-1579	1985 07/15–09/09	122.1	226.4
Z-1749	10/25–01/06	119.2	198.0
Z-1788	1986 01/06–03/13	114.9	154.7
Z-1796	03/17–04/30	117.1	176.4
Z-1739	04/30–06/03	123.2	237.7
Z-1768	06/03–07/25	121.1	216.6
Z-1885	09/01–11/27	114.8	153.9
Z-1887	11/27–02/13	112.0	125.7
Z-2440	1987 04/30–06/19	115.4	159.6
Z-2439	06/19–12/07	116.7	172.2
Z-2108	09/01–09/01	122.5	230.9
Z-2418	1992 06/30–07/31	110.6	111.5
Z-2419	07/31–09/01	114.1	146.9

## REFERENCES

- Čečuk, B. 1991 Investigations in Kopačina cave on Brač Island. *Obavijesti Hrvatskog Arheološkog Društva* 23(3): 43–45 (in Croatian).
- Dirjec, B. 1990 Dugouts discovered during the last few years at Ljubljansko barje. In *Poročilo o Raziskovanju Paleolita, Neolita in Eneolita v Sloveniji—Predkovinske Kulture Slovenije*. Slovenian Academy of Arts and Sciences, Ljubljana, Slovenia, Occasional Publications: 135–139 (in Slovenian).
- Dirjec, B. 1991 Pile dwellings near Zornica at Blatna Brezovica. In *Poročilo o Raziskovanju Paleolita, Neolita in Eneolita v Sloveniji—Predkovinske Kulture Slovenije*. Slovenian Academy of Arts and Sciences, Ljubljana, Slovenia, Occasional Publications: 193–206 (in Slovenian).
- Grgić, S., Horvatinčić, N. and Miletić, P. 1991 Radiocarbon and tritium measurements of groundwater in eastern Slavonia. *Geološki Vjesnik* 44: 309–312.
- Hadžišehović, M., Miljević, N., Šipka, V., Golobočanin, D. and Popović, R. 1993 Isotopic analysis of groundwater and carbonate system in the Surdulica geothermal aquifer. *Radiocarbon* 35(2): 277–286.
- Horvat, A. 1962 Rudina in Požega Valley – a Roman architectural monument in Slavonia. *Peristil* 5: 11–28 (in Croatian).
- Horvatinčić, N., Srdoč, D., Šilar, J. and Tvrdíková, H. 1989 Comparison of the  $^{14}\text{C}$  activity of groundwater and recent tufa from karst areas in Yugoslavia and Czechoslovakia. In Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International  $^{14}\text{C}$  Conference. *Radiocarbon* 31(3): 884–892.
- Klaić, N. 1986 St. Michael Church and Monastery at Rudina. *Vjesnik Muzeja Požeške Kotline* 4–5: 33–59 (in Croatian).
- Krajcar Bronić, I., Horvatinčić, N., Srdoč, D. and Obelić, B. 1992 Experimental determination of the  $^{14}\text{C}$  initial activity of calcareous deposits. In Long, A. and Kra, R. S., eds., Proceedings of the 14th International  $^{14}\text{C}$  Conference. *Radiocarbon* 34(3): 593–601.
- Malez, M. 1979 Investigations of the Paleolithic and Mesolithic in Croatia. In Benac, A., ed., *Ancient History of Yugoslavian Lands*, Vol 1, *The Paleolithic and Mesolithic*. Sarajevo, Academy of Sciences and Arts of Bosnia and Herzegovina: 195–296 (in Croatian).
- Malez, M., Šimunić, A. and Šimunić, A. 1984 Geological, sedimentological and palaeoclimatological relations of Vindija Cave and its environs. *Proceedings of the Yugoslav Academy of Arts and Sciences*, 411/20: 231–264 (in Croatian).
- Marčenko, E., Srdoč, D., Golubić, S., Pezdič, J. and Head, M. J. 1989 Carbon uptake in aquatic plants deduced from their natural  $^{13}\text{C}$  and  $^{14}\text{C}$  content. In Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International  $^{14}\text{C}$  Conference. *Radiocarbon* 31(3): 785–794.
- Milovanović, B., Stanković, S., Komatina, M., Hadžišehović, M., Župančić, M., Miljević, N., Stepić, R. and Obelić, B. 1989 Isotopic investigation of the Surdulica geothermal system. In Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International  $^{14}\text{C}$  Conference. *Radiocarbon* 31(3): 893–901.
- Nemec, I. and Erič, M. 1994 Preliminary report on a fossil tree trunk from Hotiza, Slovenia. *Soboški Zbornik* 3 (in Slovenian).
- Petricioli, I. 1983 St. Simeon's Shrine in Zadar. Zagreb, Spektar.
- Srdoč, D., Chafetz, H. and Utech, N. 1989 Radiocarbon dating of travertine deposits, Arbuckle Mountains, Oklahoma. In Long, A., Kra, R. S. and Srdoč, D., eds., Proceedings of the 13th International  $^{14}\text{C}$  Conference. *Radiocarbon* 31(3): 619–626.
- Srdoč, D., Horvatinčić, N., Krajcar Bronić, I., Obelić, B. and Sliepčević, A. 1992 Rudjer Bošković Institute radiocarbon measurements XII. *Radiocarbon* 34(1): 155–175.
- Srdoč, D., Horvatinčić, N., Obelić, B., Krajcar Bronić, I. and Sliepčević, A. 1987a Rudjer Bošković Institute radiocarbon measurements IX. *Radiocarbon* 29(1): 115–134.
- Srdoč, D., Krajcar Bronić, I., Horvatinčić, N. and Obelić, B. 1986 Increase of  $^{14}\text{C}$  activity of dissolved inorganic carbon along a river course. In Stuiver, M. and Kra, R. S., eds., Proceedings of the 12th International  $^{14}\text{C}$  Conference. *Radiocarbon* 28(2A): 515–521.
- Srdoč, D., Obelić, B. and Horvatinčić, N. 1980 Radiocarbon dating of calcareous tufa: How reliable data can we expect? In Stuiver, M. and Kra, R., eds., Proceedings of the 10th International  $^{14}\text{C}$  Conference. *Radiocarbon* 22(3): 858–862.
- Srdoč, D., Obelić, B., Horvatinčić, N., Krajcar Bronić, I. and Sliepčević, A. 1984 Rudjer Bošković Institute radiocarbon measurements VIII. *Radiocarbon* 26(3): 449–460.
- \_\_\_\_\_. 1989 Rudjer Bošković Institute radiocarbon measurements XI. *Radiocarbon* 31(1): 85–98.
- Srdoč, D., Obelić, B., Sliepčević, A., Krajcar Bronić, I. and Horvatinčić, N. 1987b Rudjer Bošković Institute radiocarbon measurements X. *Radiocarbon* 29(1): 135–147.
- Srdoč, D., Sliepčević, A., Obelić, B. and Horvatinčić, N. 1979 Rudjer Bošković Institute radiocarbon measurements V. *Radiocarbon* 21(1): 131–137.
- Srdoč, D., Sliepčević, A., Planinić, J., Obelić, B. and Breyer, B. 1973 Rudjer Bošković Institute radiocarbon measurements II. *Radiocarbon* 15(2): 435–431.
- Stuiver, M. and Polach, H. A. 1977 Discussion: Reporting of  $^{14}\text{C}$  data. *Radiocarbon* 19(3): 355–363.
- Stuiver, M. and Reimer, P. J. 1993 Extended  $^{14}\text{C}$  data base and revised CALIB 3.0  $^{14}\text{C}$  age calibration program. In Calibration 1993. *Radiocarbon* 35(1): 215–230.
- Žile, I. 1993 Dubrovnik ramparts and fortifications, an analysis based on recent archaeological finds. *Dubrovnik* 3: 223–228 (in Croatian).