

**RUDJER BOŠKOVIĆ INSTITUTE
RADIOCARBON MEASUREMENTS IX**

DUŠAN SRDOČ, NADA HORVATINČIĆ, BOGOMIL OBELIĆ,
INES KRAJCAR BRONIĆ

Rudjer Bošković Institute, PO Box 1016, 41001 Zagreb, Yugoslavia
and

ADELA SLIEPČEVIĆ

Faculty of Veterinary Medicine, University of Zagreb

The following radiocarbon date list contains dates of samples from Plitvice Lakes measured since our previous list dealing with tufa from this region (Srdoč *et al.*, 1982). Tufa measurements from the Knin area in S Croatia and some localities in Bosnia are also listed. Age calculations are based on the Libby half-life (5570 ± 30) yr and reported in years before 1950. Reported ages are based on the initial activity of 85% except for lake sediments where calculations of initial activity have been performed. The modern standard is 0.95 of the NBS oxalic acid activity. Sample pretreatment and counting technique are essentially the same as described in R, 1971, v 13, p 135–140, supplemented by new techniques for groundwater processing (R, 1979, v 21, p 131–137). Statistical processing of data has been computerized (Obelić & Planinić, 1977; Obelić, 1980). The errors quoted correspond to 1σ variation of sample net counting rate and do not include the uncertainty in ^{14}C half-life.

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GEOLOGIC SAMPLES

Tufa from Plitvice Lakes area

Tufa samples from outcroppings scattered in the Plitvice Lakes area ($44^\circ 50' \text{ N}$, $15^\circ 35' \text{ E}$), central Croatia. Sixteen lakes are separated by tufa barriers; 3 major and several minor springs feed lakes and the Korana River. Measurements of ^{14}C activity of dissolved inorganic carbon in water samples as well as that of recent tufa deposited on the surface of polyamide mats and aquatic plants in the Plitvice National Park area performed since 1981 showed a systematic increase of ^{14}C activity from karst springs to the

Korana R mouth. The increase has been attributed to the influx of atmospheric CO₂ and to the contribution of terrestrial plants, through detrital decay and root respiration, and a model based on the described process was developed (Srdoč *et al*, 1986b). Dates help to determine periods of intensive tufa formation in the area. Samples coll 1981–1985 by D Srdoč.

Crna Rijeka series

Crna Rijeka brook feeds Plitvice Lakes joined by Bijela Rijeka brook at Plitvički Ljeskovac, forming rivulet Matica which discharges into the uppermost Lake Prošće. Crna Rijeka brook flows over solid tufa terraces which belong to earlier phase of tufa deposition. Mud covering riverbed contains large fraction of dolomite (Popović, Srdoč & Grgić, 1986), thus, its ¹⁴C activity does not reflect its age.

Z-702. Crna Rijeka No. 1	69.1 ± 0.6% modern 1630 ± 100
Recent tufa near waterfall, right bank.	
Z-703. Crna Rijeka No. 2	47.6 ± 0.5% modern 4630 ± 110
Surface layer of tufa upstream from bridge near waterfall.	
Z-751. Crna Rijeka No. 3	53.2 ± 0.5% modern 3720 ± 100
Tufa, right bank upstream from bridge near waterfall.	
Z-810. Crna Rijeka No. 4	48.3 ± 0.5% modern 4500 ± 120
Tufa, right bank upstream from waterfall.	
Z-1064. Crna Rijeka No. 5	8.3 ± 0.3% modern <i>δ¹³C = +1.9‰</i>
Sandy deposit covering creek bottom.	

Bijela Rijeka series

Large deposits of tufa above right bank of Bijela Rijeka brook. Tufa rocks, 10 to 12m high above ground level belong to preglacial period (Riss/Würm) as determined by ²³⁰Th/²³⁴U (Srdoč *et al*, 1986a), whereas river terrace is much younger.

Z-1050. Bijela Rijeka No. 1	0.0 ± 0.3% modern >37,000
Compact tufa, right bank of Bijela Rijeka, village Plitvički Ljeskovac.	
Z-1051. Bijela Rijeka No. 2	0.4 ± 0.4% modern 34,700 +3800 –3200
Same block as Z-1050.	

Z-1115. Bijela Rijeka No. 3 **73.6 ± 0.5% modern**
1120 ± 140
 Coarse calcareous grains, Bijela Rijeka terrace.

Z-1116. Bijela Rijeka No. 4 **3.9 ± 0.3% modern**
24,600 ± 1300
 Compact tufa, Plitvički Ljeskovac.

Z-1117. Bijela Rijeka No. 5 **2.3 ± 0.2% modern**
28,800 ± 2200
 Same block as Z-1116.

Kavga brook series

Right tributary of Matica R near Plitvički Ljeskovac.

Z-1057. Kavga No. 1 **63.3 ± 0.7% modern**
2320 ± 150
 Tufa block above brook.

Z-1058. Kavga No. 2 **60.7 ± 0.6% modern**
2700 ± 150
 Tufa from terrace above brook.

Pećina series

Spring Pećina near Plitvički Ljeskovac, left tributary of Bijela Rijeka brook.

Z-1052. Pećina No. 1 **77.5 ± 0.7% modern**
Modern
 Recent tufa deposited around spring Pećina.

Z-1055. Pećina No. 2 **69.6 ± 0.5% modern**
1570 ± 140
 Hard, porous tufa above spring Pećina.

Plitvički Ljeskovac series

Confluence of Crna Rijeka and Bijela Rijeka brooks is in tufa-covered valley near Plitvički Ljeskovac. Outcroppings of preglacial tufa and thick deposits of recent tufa are very abundant in valley.

Z-705. Ex Bio-station **65.3 ± 0.6% modern**
3200 ± 100
 Outcroppings of tufa in marshy field, presently flooded area (*cf* Z-700; R, 1982, v 24, p 356).

Z-1059. Confluence site No. 1 **71.5 ± 0.7% modern**
1350 ± 140
 Recent, porous, coarse-grained tufa covered with moss.

Z-1069. Confluence site No. 2 **1.3 ± 0.4% modern**
33,000 + 4000
– 3500

Compact, inner layer of tufa tube.

Z-1070. Confluence site No. 3 **1.8 ± 0.4% modern**
31,000 + 3300
– 2700

Porous, outer layer of tufa tube. *Comment:* tubular forms of tufa are frequent, as result of encrustation of wood branches and trunks.

Z-1135. Matica **45.8 ± 0.5% modern**
4900 ± 160

Fine-grained calcareous deposit, mixed with organic detritus, Matica rivulet mouth. Material transported by water and deposited at river mouth. Matica R flows through preglacial and Holocene tufa deposits. *Comment:* no formation of recent tufa concretions has been observed in Matica R.

Z-1031. Prošće, Spiljski vrt **77.5 ± 0.6% modern**
Modern

Recent tufa under moss, Cave garden. Measurement of initial ¹⁴C activity of recently deposited tufa.

Lake Ciginovac series

Z-1029. Ciginovac No. 1 **73.3 ± 0.6% modern**
Modern

Recent tufa under growing moss (*Cratoneurum commutatum*). *Comment:* determination of initial ¹⁴C activity of sediment in Upper Lakes (cf Z-817: R, 1982, v 24, p 361).

Z-1416. Ciginovac No. 2 **77.9 ± 0.6% modern**
Modern

Freshly deposited tufa on surface of artificial substratum (polyamide mat) immersed in water from May to Sept 1984. Microlocation: waterfall connecting lakes Prošće (upper) and Ciginovac (lower). *Comment:* determination of initial ¹⁴C activity.

Veliki Jovinovac series

Lake Veliki Jovinovac is in middle of Upper Lakes, Plitvice Natl Park. Entire area covered with thick tufa deposits.

Z-1001. Veliki Jovinovac No. 1 **74.4 ± 0.6% modern**
Modern

Dry, porous tufa, mossy shape, green algae on surface.

Z-1002. Veliki Jovinovac No. 2 **75.4 ± 0.6% modern**
Modern
 Porous tufa from cave in dry tufa barrier.

Z-1006. Lake Vir **74.9 ± 0.5% modern**
Modern
 Hard, porous, mossy structured tufa above surface of Lake Vir.

Lake Galovac series

Samples of tufa deposits lying above present level of Lake Galovac.

Z-1003. Galovac No. 1 **71.2 ± 0.6% modern**
1390 ± 110
 Hard, dry tufa near pathway, right side.

Z-1004. Galovac No. 2 **73.9 ± 0.6% modern**
1080 ± 110
 Porous tufa below pathway.

Z-1005. Galovac No. 3 **69.2 ± 0.4% modern**
1610 ± 110
 Hard tufa barrier.

Lake Gradinsko series

Thick deposits of hard and powdered tufa above surface of Lake Gradinsko.

Z-835. Gradinsko No. 1 **51.8 ± 0.4% modern**
3950 ± 90
 $\delta^{13}C = -8.4\text{‰}$
 Powdered microcrystalline calcareous deposit 2m above present level of lake (cf Z-832 to Z-834: R, 1984, v 24, p 366).

Z-836. Gradinsko No. 2 **47.0 ± 0.4% modern**
4700 ± 120
 Compact tufa 2m above lake surface, near Z-835.

Z-837. Gradinsko No. 3 **53.8 ± 0.5% modern**
3600 ± 120
 Porous tufa, mossy structured (*Cratoneurum commutatum*) ca 2m above lake surface.

Z-1056. Gradinsko No. 4 **50.0 ± 0.4% modern**
4220 ± 150
 Tufa 2m above present level of lake.

Gradina series

Isolated hill on peninsula above Lakes Gradinsko and Kozjak, with remnants of prehistoric and medieval ramparts. Hill encircled with deposits of Holocene tufa with outcroppings of preglacial tufa on top. Lake Gradinsko is in Upper Triassic well bedded dolomite containing >90% MgCa(CO₃)₂. Stromatolithic fms are very frequent. Systematic measurements of preglacial tufa using fractional dissolution revealed contamination with more recent calcareous material (see Table 1). ²³⁰Th/²³⁴U dating on samples of preglacial tufa gave age of ca 120,000 yr (Riss/Würm interglacial) (Srdoč *et al*, 1986a).

Z-830. Gradina No. 1 **61.2 ± 0.5% modern**
2600 ± 110
Powdered, microcrystalline calcareous tufa.

Z-996. Gradina No. 2 **63.4 ± 0.4% modern**
2310 ± 110
Tufa blocks used for building ramparts.

Z-997. Gradina No. 3 **62.4 ± 0.6% modern**
2450 ± 120
Tufa boulders used to build fortification. *Comment:* only Holocene tufa was used to construct fortifications at Gradina.

Z-1208. Gradina, hilltop No. 1 **2.8 ± 0.3% modern**
27,200 ± 1500
Porous tufa, Block C. Upper surface under atmospheric influence. Samples used for testing contamination with recent carbonate.

Z-1210. Gradina, hilltop No. 2 **1.5 ± 0.3% modern**
30,900 + 3200
- 2600
Compact tufa, Block S, covered by porous tufa.

General Comment: ¹⁴C measurements show that each subsequent soluble

TABLE 1
Test of fractionation of sample Z-1211 (Porous tufa, Block S)

Sample no.	Grain size (mm)	Fraction no. (%)	% modern	Age BP (yr)
Z-1268	1–5	I (30)	12.1 ± 0.4	15,600 ± 400
-1269	1–5	II (30)	5.8 ± 0.3	21,500 ± 800
-1270	1–5	III (30)	3.8 ± 0.3	24,800 ± 1100
-1271	<1	I (50)	10.8 ± 0.4	16,500 ± 400
-1272	<1	II (50)	3.6 ± 0.2	25,300 ± 1200
-1273	1	I (50)	7.8 ± 0.4	19,100 ± 600
-1274	1	II (50)	1.7 ± 0.3	31,200 ± 2400

fraction obtained from porous tufa gave successively older age indicating that surface of sample was contaminated by younger carbonates. No consistent effect of grain size on ^{14}C age is observed.

Burget series

Freshly deposited tufa on surface of artificial substratum (polyamide mat) immersed in streamwater. Waterfall connecting Lakes Burget (upper) and Kozjak (lower). *Comment:* determination of initial ^{14}C activity.

Z-980. Burget No. 1 **85.4 ± 0.7% modern**
Modern
Substratum immersed in water from June to Oct 1981.

Z-1011. Burget No. 2 **83.8 ± 0.6% modern**
Modern
Substratum immersed in water from Oct 1981 to Apr 1982.

Rječica series

Rječica brook is a major tributary to Plitvice Lakes. Tufa deposition starts at approx half-way between its springs and Lake Kozjak. Upper part of Rječica bed is cut in old tufa.

Z-1020. Rječica No. 1 **84.0 ± 0.6% modern**
Modern
Hard, porous, recent tufa from last barrier before brook discharges into Lake Kozjak.

Z-1038. Rječica No. 2 **46.3 ± 0.6% modern**
4830 ± 170
Hard tufa, riverbed.

Z-1060. Rječica No. 3 **56.3 ± 0.4% modern**
3260 ± 150
Tufa in form of small pebbles covering riverbed.

Z-1061. Rječica No. 4 **70.9 ± 0.6% modern**
1420 ± 140
Tufa from river terrace, coarse grains several mm in diameter.

Z-1068. Rječica No. 5 **89.0 ± 0.7% modern**
Modern
Freshly deposited tufa on surface of artificial substratum (polyamide mat) immersed in stream water from July to Oct 1982.

General Comment: two distinct ^{14}C activities were found in Rječica brook: recent activity of fresh tufa is from 84 to 89% modern, whereas tufa riverbed belongs to older, Holocene deposits (Popović, Srdoč & Grgić, 1986).

Lake Kozjak series

Samples of hard, porous tufa and other calcareous material presently above surface of Lake Kozjak. Tufa outcroppings around lake mark position of dried-up tributaries, and ^{14}C dating helps to reconstruct history of lake.

Z-676. Kozjak No. 1 **61.8 ± 0.6% modern**
2500 ± 100

Hard, porous tufa, resembles petrified moss (*Cratoneurum commutatum*), 7 to 8m above lake surface; sample taken from huge block of tufa emerging from lake.

Z-844. Kozjak No. 2 **69.9 ± 0.5% modern**
1530 ± 100

Hard, porous tufa from NW shore.

Z-1037. Kozjak No. 3 **53.0 ± 0.4% modern**
3750 ± 150

Powdered, microcrystalline calcareous sediment, ca 8 to 10m above lake surface.

Z-1082. Kozjak No. 4 **75.2 ± 0.6% modern**
950 ± 130

Compact tufa overgrown by moss, left approach to waterfalls connecting Lake Kozjak (upper) and Lake Milanovac (lower).

Z-1114. Kozjak No. 5 **59.8 ± 0.6% modern**
2800 ± 150

Dripstone from cave, 4 to 5m above lake surface.

General Comment: all samples belong to warm and humid periods in Holocene.

Kozjak barrier series

Core samples taken by drilling at barrier connecting Lakes Kozjak and Milanovac. Coll 1983 by S Merkt.

Z-1463. Kozjak barrier No. 1 **64.1 ± 0.5% modern**
2230 ± 150

Depth 0.5 to 1.0m.

Z-1464. Kozjak barrier No. 2 **59.9 ± 0.4% modern**
2770 ± 140

Depth 2.2 to 2.6m.

Z-1457. Kozjak barrier No. 3 **57.2 ± 0.5% modern**
2840 ± 120

Depth 3.0 to 3.2m.

Plitvica series

Plitvica brook is major tributary to Korana R, discharging into Korana at “Sastavci” (confluence). Tufa deposition starts at Crkvine, ca 1km downstream from Plitvica karst spring.

Z-1066. Plitvica No. 1 **83.0 ± 0.7% modern**
Modern

Freshly deposited tufa on artificial substratum (polyamide mat) immersed in streamwater from May to Oct 1982.

Z-1067. Plitvica No. 2 **84.6 ± 0.6% modern**
Modern

Same as Z-1066, except microlocation.

Z-1118. Plitvica No. 3 **69.9 ± 0.6% modern**
1530 ± 140

Hard, porous tufa from riverbed near Hajduković Mill.

Z-1083. Plitvica waterfall No. 1 **66.8 ± 0.4% modern**
1890 ± 140

Hard, porous tufa from river terrace above 76m high waterfall. *Comment:* recent tufa activity of Rječica brook (Z-1068, Z-1020, above) and Plitvica brook are similar.

Z-1012. Plitvica waterfall No. 2 **87.9 ± 0.7% modern**
Modern

Freshly deposited tufa on surface of artificial substratum (polyamide mat) immersed in water from Oct 1981 to Apr 1982 under Plitvica brook waterfall. *Comment:* determination of initial ^{14}C activity.

Z-1276. Novakovića brod **88.2 ± 0.7% modern**
Modern

Recent tufa under growing moss (*Cratoneurum commutatum*). *Comment:* ^{14}C activity increases along river course (Srdoč *et al*, 1986b).

Hajduković pit series

Pit, 2 to 3m deep in flat terrace (“polje”) near Hajduković Mill. Layer of charred decayed leaves entrapped between tufa deposits.

Z-1119. Hajduković pit No. 1 **66.3 ± 0.6% modern**
3260 ± 130

Charred wood in Hajduković pit surrounded by tufa layer.

Z-1204. Hajduković pit No. 2 **66.2 ± 0.6% modern**
3300 ± 130

Charred leaves in Hajduković pit surrounded by tufa layer.

Z-1205. Hajduković pit No. 3 **51.5 ± 0.5% modern**
4000 ± 130
Tufa layer above charred leaves.

Z-1206. Hajduković pit No. 4 **50.9 ± 0.4% modern**
4100 ± 130
Tufa layer below charred leaves.

General Comment: ratio of activity of tufa and that of organic material gives initial activity of tufa at this location equal to 77.3% modern.

Smolčić flat series

Outcroppings of tufa in small flat above Smolčića pećina cave. Very hard, porous tufa dated by ^{14}C and $^{230}\text{Th}/^{234}\text{U}$ method. ^{14}C dating gave inconsistent ages, depending on contamination of samples with more recent carbonates (see Table 2) whereas $^{230}\text{Th}/^{234}\text{U}$ dating pointed at warm and humid interglacials (Riss/Würm, Mindel/Riss) (Srdoč *et al*, 1986a).

Z-1213. Smolčić flat No. 1 **1.5 ± 0.3% modern**
32,000 ± 2900
Hard, compact tufa, Block N.

Z-1214. Smolčić flat No. 2 **11.9 ± 0.4% modern**
15,800 ± 400
Hard, porous tufa. Humus and rootlets in pores and crevices removed mechanically and by washing.

Smolčić cave series

Dripstones and tufa from Smolčić cave, ca 60m above present level of Korana R. Measurement of tufa and dripstone samples from same site could reveal any difference in degree of contamination with more recent calcareous material. Dripstones are considered less susceptible to contamination, as opposed to porous tufa. *Comment:* no conclusive remarks can be drawn from this series of measurement.

Z-932. Smolčić cave No. 1 **36.4 ± 0.5% modern**
6800 ± 160
 $\delta^{13}\text{C} = -7.8\text{‰}$
Core of tufa block, entrance to cave.

TABLE 2
Test of fractionation of sample Z-1213 (Compact tufa, Block N)

Sample no.	Grain size (mm)	Fraction no. (%)	% modern	Age BP (yr)
Z-1500	1–5	I (30)	3.9 ± 0.3	24,400 ± 1100
-1501	1–5	II (30)	2.9 ± 0.3	26,900 ± 1600
-1502	1–5	III (30)	1.0 ± 0.3	>37,000

Z-1008. Smolčić cave No. 2. Limestone bedrock.	0.2 ± 0.3% modern >37,000
Z-1007. Smolčić cave No. 3. Core of homogeneous tufa block.	1.6 ± 0.3% modern 31,600 ± 2800
Z-1144. Smolčić cave No. 4. Inner part of tufa covered by flowstone.	3.4 ± 0.3% modern 25,700 ± 1600
Z-1145. Smolčić cave No. 5 Outer part of tufa covered by flowstone.	5.0 ± 0.3% modern 22,600 ± 1100
Z-1146. Smolčić cave No. 6 Partly crystallized tufa.	6.0 ± 0.3% modern 21,200 ± 900

Široka Luka series

Korana village is above partly cultivated large river terrace Široka Luka. Terrace consists of calcareous material, mostly tufa, deposited by Korana R and covered with 15 to 20cm layer of soil. Dates help to reconstruct periods of development of terrace.

Z-1127. Široka Luka No. 1 Fine-grained tufa, terrace.	54.0 ± 0.5% modern 3610 ± 150
Z-1132. Široka Luka No. 2 Tufa from cultivated field.	59.2 ± 0.5% modern 2870 ± 150
Z-1133. Široka Luka No. 3 Dry tufa barrier, village Korana, 1 to 2m above river terrace.	72.5 ± 0.6% modern 1230 ± 140
Z-1134. Široka Luka No. 4 Recent tufa chips, river terrace Široka Luka under constant influence of Korana R water (DIC activity 90% modern).	83.9 ± 0.6% modern Modern

Sartuk series

Sartuk brook flows in same area of Plitvice National Park where other streams form tufa barriers. No typical tufa has been found in Sartuk. Calcareous deposits contain much less ¹⁴C, consisting of mixtures of weathered

limestone and dolomite rocks which surround Sartuk and some biogenically deposited calcite. No deposit ages can be deduced from ^{14}C measurements.

Z-1026. Sartuk No. 1 **4.4 ± 0.3% modern**

Mixture of soil and calcareous deposit.

Z-1027. Sartuk No. 2. **49.9 ± 0.6% modern**

Calcareous deposit under growing moss.

Z-1028. Sartuk No. 3 **11.2 ± 0.3% modern**

Sandy calcareous deposit. Dolomite with calcite content 5 to 10%, quartz 2 to 5% (Popović, Srdoč & Grgić, 1986).

Z-1339. Sartuk No. 4. **43.3 ± 0.5% modern**

Calcareous deposit, riverbed.

Korana River series

Measurement of ^{14}C activity of calcareous deposits, mostly tufa, along Korana R. For details see Srdoč *et al* (1986b).

Z-1019. Korana River No. 1 **93.6 ± 0.5% modern**
Modern

Recent tufa under growing moss (*Cratoneurum commutatum*).

Z-1063. Korana River No. 2 **90.8 ± 0.6% modern**
Modern

Tufa under moss on waterfall, Tušilović near Karlovac (44° 20' N, 15° 37' E).

Z-1065. Korana River No. 3 **89.5 ± 0.6% modern**
Modern

Freshly deposited tufa on artificial substratum (polyamide mat) immersed in water from Apr to Oct 1982, 0.5km downstream from confluence ("Sastavci"). *Comment*: determination of initial ^{14}C activity.

Tufa used for building at Plitvice Lakes region

Z-807. Hajduković Mill **75.5 ± 0.6% modern**
900 ± 90

Hard, porous tufa used for construction of mill.

Z-808. Crkvina **60.8 ± 0.6% modern**
2670 ± 100
 $\delta^{13}\text{C} = -8.4\text{‰}$

Hard, porous tufa block from foundation of medieval church; origin and denomination of church unknown.

Z-916. Old power station **63.8 ± 0.5% modern**
2270 ± 110

Hard, porous tufa from building housing small power station, now out of operation, Lake Burget above Kozjak.

Z-1018. Old power station **72.4 ± 0.6% modern**
1260 ± 100

Same as Z-916.

General Comment: both preglacial (Z-921: R, 1982, v 24, p 355) and Holocene tufas were hard enough to be used for construction of buildings. However, it should be pointed out that age of tufa used in construction does not indicate date of erection of building, even though it can be used as *terminus post quem non*.

Pevalek collection series

Increased activity of groundwater, tufa, and aquatic plants due to increased activity of atmospheric CO₂ in past decades caused by nuclear weapon tests can be obtained by comparison of activity of recent material with that from pre-bomb era, providing that age of latter is known. Samples coll 1919 by late academician, I Pevalek (*cf* Z-847, -848, -853, -856, -857, -907, -908: R, 1982, v 24, p 365–366).

Z-1306. Pevalek colln No. 1 **72.2 ± 0.5% modern**
1280 ± 110

Tufa around wooden branch.

Z-1307. Pevalek colln No. 2 **97.3 ± 0.6% modern**
185 ± 100

Wooden branch encrusted with tufa.

General Comment: ratio of activity of tufa and wood gives initial activity of tufa at this location equal to 74.2% modern. Present activity of tufa is 80% modern at this location.

Plitvice Lakes Sediments

Lake Kozjak sediment core

In autumn 1983 several sediment cores were retrieved from Lakes Kozjak and Prošće, Plitvice Natl Park area (Srdoč *et al*, 1986c) (Table 3). Lake Kozjak core was retrieved from 24m water depth. First 2m of core gave good stratification with sedimentation rate 0.85mm/a. Next 5m sec gave scattered ¹⁴C data in agreement with seismic records. This sec appears to have undergone mass transport and redeposition. Further 5m sec showed good stratification with sedimentation rate 1.1mm/a. Initial ¹⁴C activity of 75% modern was determined by measuring activity of top of sediment layer (*cf* Z-840 and -841: R, 1982, v 24, p 367) and pre-bomb test tufa (Z-1082: R, 1982, v 24, p 363). Piece of wood (*Abies* sp) was found in sediment core. Surrounding sediments were carefully collected. Ratio of sediment *vs* wood activity gave initial ¹⁴C activity of 74.4% modern.

TABLE 3
Lake Kozjak sediment core

Sample no.	Depth (m)	% modern	Age BP	$\delta^{13}\text{C}$ (‰ PDB)
Z-1301	0.15	74.8	Modern	
-1230	0.17	74.9	Modern	
-1372	0.00–0.20	73.3	90 ± 150	–8.7
-1302	0.72	66.3	900 ± 115	–8.6
-1303	1.07	64.0	1190 ± 115	
-1304	1.45	60.0	1710 ± 120	
-1305	1.70	55.6	2310 ± 125	
-1232	2.00	55.3	2350 ± 130	–8.8
-1347	2.40–2.60	52.2	2820 ± 130	–8.6
-1233	3.12	49.8	3210 ± 145	–8.6
-1234	3.45	51.5	2930 ± 130	–8.6
-1235	3.84	52.7	2740 ± 130	–8.6
-1236	4.30	53.7	2590 ± 130	–8.6
-1237	4.68	49.3	3290 ± 130	–8.6
-1373	4.96–5.05	49.8	3200 ± 140	–8.6
-1374	5.05–5.20	50.5	3150 ± 140	–8.5
-1375	5.20–5.35	58.4	1920 ± 120	–8.5
-1376	5.35–5.50	57.4	2070 ± 130	–8.6
-1172	5.60	54.7	2440 ± 130	
-1171	5.70	54.4	2500 ± 150	
-1173	5.80	56.9	2130 ± 140	
-1240	6.13	49.4	3500 ± 140	–8.7
-1241	6.50	46.1	3830 ± 140	–8.6
-1465	6.60–6.80	57.9	1970 ± 120	
-1242	6.86	46.1	1820 ± 120	
-1243	7.24	58.6	1900 ± 140	–8.6
-1246	8.06	53.8	2578 ± 145	–8.6
-1471	8.70–8.90	48.6	3480 ± 140	
-1250	9.20	51.0	3020 ± 150	
-1253	10.20	47.4	3590 ± 160	–8.7
-1472	10.20–10.35	43.3	4380 ± 140	
-1393	10.55–10.75	41.6	4450 ± 150	
-1369	10.90–11.08	38.2	5330 ± 160	
-1370	11.08–11.25	38.6	5240 ± 160	
-1392	11.75–11.95	35.4	5930 ± 160	
-1432	11.95–12.15	39.2	5120 ± 150	
-1348	12.15–12.35	43.4	4300 ± 150	–8.6
Wood (<i>Abies</i> sp)				
-1168	5.64	75.0	2280 ± 120	

Lake Kozjak bottom series

Sediment from bottom of Lake Kozjak. Coll 1983 by S Merkt, Niedersächsisches Landesamt f Bodenforschung, Hannover.

Z-1122. Kozjak No. 1 **69.0 ± 0.6% modern**

Bottom of lake. Water depth 43m.

Z-1123. Kozjak No. 2 **73.5 ± 0.6% modern**

Bottom of lake. Water depth 23m.

Lake Prošće sediment core

Lake Prošće core was retrieved from 17.2m water depth and reached clayey residual overlaying bedrock (Table 4). ^{14}C dating of lake sediment revealed uniform sedimentation rate of 1.4mm/a. Pollen analyses of core

sec revealed major settlement phases in Plitvice Natl Park area during last 6000 yr (Müller & Obelić, 1986).

Piece of wood (*Abies* sp) was found in sediment core and dated together with surrounding sediment which enabled determination of ^{14}C initial activity of sediment equal to 72% modern.

Tufa Deposits in Kninsko Polje

Tufa deposits in Kninsko polje (44° 02' N, 16° 11' E), S Croatia consist of Holocene and preglacial deposits. Waters of intermittent Krčić creek and perennial Krka R are rich in carbonates forming thick tufa and lacustrine sediments along their ancient and recent courses in Kninsko polje valley (cf Z-1189 to -1194; R, 1984, v 26, p 455). Tufa samples with apparent ^{14}C age > ca 20,000 yr are much older, as shown by $^{230}\text{Th}/^{234}\text{U}$ analyses (Srdoč *et al*, 1986a).

Krčić series

Samples coll 1984 by D Srdoč and B Obelić.

Z-1323. Krčić No. 1

**88.8 ± 1.1% modern
Modern**

Recent tufa under moss, Krčić brook near village Krčić. *Comment:* activity of recent tufa similar to activities measured in Plitvice Natl Park.

TABLE 4
Lake Prošće sediment core

Sample no.	Depth (m)	% modern	Age BP	$\delta^{13}\text{C}$ (‰ PDB)
Z-1441	0.00–0.40	66.2	550 ± 100	
-1398	0.80–1.00	67.6	470 ± 115	
-1658	1.20–1.40	62.6	1100 ± 100	
-1399	1.60–1.80	62.4	1110 ± 120	
-1659	2.00–2.20	60.7	1340 ± 100	
-1661	2.40–2.60	59.0	1560 ± 100	
-1407	2.80–3.00	55.7	2030 ± 120	–9.3
-1662	3.20–3.40	53.8	2300 ± 100	
-1422	3.60–3.80	53.2	2390 ± 125	
-1663	3.80–4.00	53.7	2320 ± 100	–8.9
-1424	4.20–4.40	52.0	2580 ± 130	–8.9
-1664	4.90–5.00	48.8	3090 ± 110	–9.0
-1430	5.20–5.40	47.5	3300 ± 130	–9.0
-1665	5.60–5.80	45.1	3510 ± 120	
-1431	6.20–6.40	43.8	3970 ± 140	–8.9
-1666	6.80–7.00	41.9	4320 ± 140	–8.8
-1438	7.20–7.40	43.8	3960 ± 145	–8.9
-1667	7.60–7.80	38.7	4950 ± 130	
-1436	8.20–8.40	38.4	5020 ± 150	–8.8
-1668	8.90–9.00	36.6	5400 ± 130	–8.3
-1437	9.20–9.40	34.5	5750 ± 160	–9.3
-1669	9.80–10.00	33.7	6050 ± 140	–8.5
-1433	10.20–10.40	34.5	5880 ± 170	–8.8
-1670	10.60–10.75	30.3	6920 ± 150	
-1671	11.00–11.20	29.6	7090 ± 160	
-1435	11.50–11.70	27.8	7450 ± 190	
Wood (<i>Abies</i> sp)				
-1395	11.35–11.50	36.4	7850 ± 160	

Z-1325. Krčić No. 2 **0.8 ± 0.3% modern**
> 37,000

Powdered tufa from deposit ca 12m above brook level.

Z-1321. Krčić No. 3 **30.7 ± 0.5% modern**
8000 ± 170

Sample from tufa block lying on brook terrace; first appearance of tufa downstream from Krčić karst spring.

Topoljski buk barrier series

Krka R spring in cave under Topoljski buk barrier. Samples coll and subm 1985 by S Božičević, Geol Inst Zagreb.

Z-1562. Topoljski buk No. 1 **47.9 ± 0.5% modern**
4570 ± 110

Outer layer of tufa tube, bottom of well, passage under Krčić waterfall.
Comment: age similar to Z-1193 (R, 1984, v 26, p 455).

Z-1564. Topoljski buk No. 2 **48.4 ± 0.5% modern**
4480 ± 120

Outer layer of tufa tube, same as Z-1562.

Z-1563. Topoljski buk No. 3 **70.6 ± 0.6% modern**
2770 ± 110

Mud above tufa tube (Z-1562 and -1564) in passage at Krčić waterfall.
Comment (SB): expected same age for tufa and mud.

Topolje quarry series

Tufa quarry, edge of Kninsko polje. Coll 1984 by D Srdoč and B Obelić.

Z-1311. Topolje No. 1 **1.1 ± 0.3% modern**
35,000 + 4400
– 3600

Tufa from lowest layer, Topolje quarry.

Z-1313. Topolje No. 2 **1.9 ± 0.3% modern**
31,000 + 2400
– 2000

Tufa from uppermost layer, Topolje quarry.

Z-1316. Knin **4.6 ± 0.3% modern**
23,400 ± 900

Powdered tufa from trench 2.5m deep excavated during building of new hospital in Knin. Coll 1984 by D Srdoč and B Obelić.

Tufa Samples From Bosnia

Systematic ^{14}C dating of tufa in karst regions of Yugoslavia (*cf* Z-1046 to -1049, -1164 to -1167: R, 1984, v 26, p 454–455).

Z-1351. Jajce **56.3 ± 0.5% modern**
3300 ± 130

Tufa from thick deposit above Pliva R, Jajce (44° 20' N, 17° 17' E) Central Bosnia. Coll 1984 by D Srdoč and B Obelić.

Z-1354. Janj **0.3 ± 0.3% modern**
> 37,000

Tufa from thick deposits above Janj R, Mujdžići near Jajce (44° 14' N, 17° 07' E), Central Bosnia. Coll 1984 by D Srdoč and B Obelić.

Z-1552. Banja, Fojnica **9.9 ± 0.4% modern**

Tufa from thermal spring in Banja near Fojnica (43° 58' N, 17° 54' E), alt 670m, Bosnia. Coll and subm 1985 by I Krušić, Geoinženjering Co, Sarajevo.

Kiseljak Slatina series

Tufa deposited from thermal springs Kiseljak Slatina near Banja Luka (44° 49' N, 17° 18' E), NW Bosnia. Coll 1983 and subm 1985 by D Hrustanpašić, Geoinženjering Co, Sarajevo.

Z-1459. Kiseljak Slatina No. 1 **13.2 ± 0.4% modern**

Recent porous tufa from hot mineral spring mixed with decayed organic detritus.

Z-1458. Kiseljak Slatina No. 2 **1.9 ± 0.3% modern**
30,600 ± 2500

Porous dry tufa, above water level, partly covered with humus and moss.

Z-1414. Sočkovac **5.8 ± 0.3% modern**

Tufa from borehole OS-2, Sočkovac near Gračanica (44° 39' N, 18° 18' E), N Bosnia. Coll and subm 1985 by N Miošić, Geoinženjering Co, Sarajevo.

General Comment: percent of modern carbon in recent samples indicates ratio of biogenic to inorganic carbon in freshly deposited tufa around hot springs. No age of deposits can be deduced from these data because of insufficient knowledge of aquatic chemistry and isotopic composition of hot spring water.

HYDROGEOLOGIC SAMPLES

Plitvice Lakes National Park

Surface water ^{14}C activity was measured in 1983 and 1984 to determine ^{14}C distribution patterns along the river course. For detailed discus-

sion, see Srdoč *et al* (1986b). Samples were coll by Rudjer Bošković Inst staff.

Crna Rijeka series

Cf Z-692: R, 1982, v 26, p 369.

Z-1337. Crna Rijeka No. 1 **69.2 ± 0.6% modern**
 $\delta^{13}C = -12.6\text{‰}$
River water, coll May 1984.

Z-1379. Crna Rijeka No. 2 **90.6 ± 0.6% modern**
 $\delta^{13}C = -13.2\text{‰}$
Karst spring, coll Sept 1984.

Z-1425. Crna Rijeka No. 3 **64.9 ± 0.5% modern**
 $\delta^{13}C = -13.2\text{‰}$
Spring water, coll Dec 1984.

General Comment: Crna Rijeka spring water shows large variations of ^{14}C activity of dissolved inorganic carbon (DIC). Mean residence time is 2 yr, calculated by means of exponential model (Krajcar Bronić *et al*, 1986).

Bijela Rijeka series

Z-1024. Bijela Rijeka No. 1 **85.9 ± 0.9% modern**
Spring water, coll July 1982.

Z-1159. Bijela Rijeka No. 2 **83.0 ± 0.9% modern**
Spring water, coll Oct 1983.

Z-1281. Bijela Rijeka No. 3. **84.7 ± 0.6% modern**
 $\delta^{13}C = -12.2\text{‰}$
Spring water, coll Apr 1984.

Z-1434. Bijela Rijeka No. 4 **81.3 ± 0.6% modern**
 $\delta^{13}C = -12.6\text{‰}$
River water, coll Dec 1984.

General Comment: mean residence time of 4 yr was calculated by using exponential model. ^{14}C activity and $\delta^{13}C$ of DIC in spring water are fairly constant throughout year.

Matica River series

Z-1280. Matica, mouth No. 1 **85.3 ± 0.6% modern**
 $\delta^{13}C = -11.8\text{‰}$
River water coll Apr 1984, high waters, snow melting.

Z-1336. Matica, mouth No. 2 **76.9 ± 0.6% modern**
River water coll May 1984.

Z-1381. Matica, mouth No. 3 **90.1 ± 0.7% modern**
 $\delta^{13}\text{C} = -12.1\text{‰}$
 River water coll Sept 1984.

Plitvica spring series

Cf Z-708: R, 1982, v 24, p 369.

Z-1025. Plitvica spring No. 1 **81.9 ± 0.6% modern**
 Spring water, coll July 1982.

Z-1160. Plitvica spring No. 2 **83.2 ± 1.1% modern**
 Spring water, coll Oct 1983.

General Comment: mean residence time of 3 yr was calculated by means of exponential model.

Korana River series

Z-1279. Korana No. 1 **95.2 ± 0.7% modern**
 River water coll Apr 1984, Slunj (45° 07' N, 15° 36' E) Croatia.

Z-1278. Korana No. 2 **99.0 ± 0.8% modern**
 $\delta^{13}\text{C} = -11.2\text{‰}$
 River water coll Apr 1984, village Tušilović near Karlovac (45° 23' N, 15° 37' E) Croatia.

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