BOGOMIL OBELIĆ
ADELA SLIEPČEVIĆ

Institute "Ruđer Bošković"
Bijenička 54
HR-10000 ZAGREB

CORRECTION OF RADIOCARBON AGE OF WOODEN BEAMS FROM ST. DONAT'S CHURCH IN ZADAR BY DENDROCHRONOLOGICAL METHOD

UDC 902.6:73.0323.1 (497.5) "7/8"
Original scientific paper

The results of age of two wooden beams from St. Donat's church in Zadar, obtained by radiocarbon method in 1971, are corrected by dendrochronological method. According to the corrected results of three beams, two trunks from which the beams were trimmed were felt at the end of 8th century, and one trunk at the beginning of the 9th century. This gives the terminus post quem for the construction of the church.

INTRODUCTION

St. Donat's church in Zadar in Dalmatia, S. Croatia, is unique among old-Croatian sacred buildings because it exceeds by its monumentality and style the majority of preserved buildings from that time. It was built and projected by home craftsmen, inspired by Antique, Carolingian and Ravennate architecture and therefore represents a valuable source for a study of cultural influences that affected Croatia, situated in the early Middle Ages between two great empires, Byzantine and Frankish.

On the occasion of the restoration of St. Donat's church thirty years ago the unique chance for dating of wooden beams was given, in order to determine the unknown time of the building. At that time in the first floor of the church *(matroneurri)* there were found about fifty old wooden beams used to strengthen the construction of the building. Most of them were roughly trimmed, and only 7 were decorated by scored ornaments. The experts of the Regional Institute for Protection of Cultural Monuments in Zadar sent in 1970 three not ornamented beams to the Rudjer Bošković Institute for radiocarbon dating. The results of measurements of single samples were published in the journal *Radiocarbon* (SRDOČ & alii 1973). The calculation of the estimation of time when the trunks from which the beams were made were felled was published in the journal *Peristil* (SRDOČ & alii 1973/74) and presented at the First International Symposium "^{14}C and Archaeology" held in Groningen, the Netherlands (SRDOČ & alii 1983). For the results of measurement of three samples (Z-177, Z-178 and Z-179) published in *Peristil,* the last two of them belonging to the same beam, the most probable year of felling of the tree was established to be AD 710±25. In the last paper the

result of measurement of the sample from the third beam (Z-175) was added, so the result of statistical processing gave the year AD 750±20. In both publications it was supposed that the total number of tree rings from which ali three beams were cut was 145 years. The age was calculated on the basis of half-life of ^{14}C Ti/2=(5730±40) years.

Since the time of measurement it has been established that some assumptions on which the method was based are not completely valid and the dating method has been improved by introducing some corrections. In the meantime the conventions that were used in calculation have also changed too. These facts stimulated us to revise the previous results of measurement.

DENDROCHRONOLOGICAL CORRECTION

The method of dating by radioisotope ^{14}C is based on the fact that ali naturally occuring organic materials are "marked" by this isotope as a result of cosmic ray influence. ^{14}C is introduced by metabolism into living organisms, but at the same time its amount decreases as the result of the radioactive decay. Over miUennia the equilibrium betvveen decay and the replacement of radiocarbon atoms in the biosphere is established. After the death of an organism the specific activity of ^{14}C begins to decrease according to the radioactive decay law since metabolism ceased, causing the end of the replacement of ^{14}C atoms. On the basis of this law the time that elapsed from the moment of the death to the date of measurement can be calculated.

The measurement of the age of organic samples by the ^{14}C method is based on several premises. The most important is the constant cosmic ray flux during miUennia and thus the constant production of radiocarbon. The concentration of ^{14}C atoms in recent time has been disturbed by human activities. Firstly, during the 19* cenrury by the industrial revolution the use of fossil fuels (coal, petroleum), which do not contain any ^{14}C, caused the reduction of radiocarbon isotope in the atmosphere relative to inactive ^{12}C isotope. On the other hand, after World War II great amounts of ^{14}C atoms were released into the atmosphere by nuclear and thermonuclear experiments. In

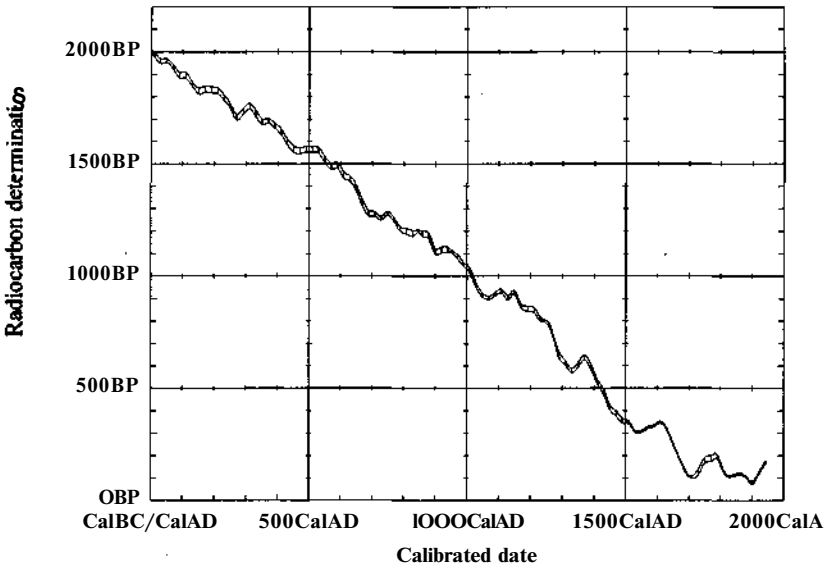

Fig. 1. Calibration curve for the last 2000 years.
SI. 1. Kalibracijska krivulja za posljednjih 2000 godina

addition, by precise measurements it has established that cosmic ray flux was not totally constant even before this time, and this is reflected in variations of ^{14}C content in the organism at the moment of death. Because of these variations the radiocarbon method gives no exact "calendar years" of a sample, but a so called radiocarbon year, that may differ by 2% to 5% from calendar years, depending on the cosmic flux intensity in that period. It is necessary, therefore, to determine the concentration of ^{14}C by an independent method and to correct the results of radiocarbon dating in order to get the true "calendar year" of the sample.

For this purpose we use calibration curves that enable us to correct the ^{14}C age. They are obtained by dendrochronological method, which determines the absolute ages of samples by counting of tree rings and by measurement of their relative width. The width of tree rings depends on climatic conditions in a certain time period and the ratio of variations of width is equal for different tree species. By comparative measurements of relative tree rings widths the chronological curves for some wood species up to 12 000 years ago were established. By comparing the precise ^{14}C measurements of tree rings with their age obtained by the dendrochronological method the variations of natural production of ^{14}C atoms in the atmosphere were found. In this way calibration curves for the correction of radiocarbon data were obtained.

Measurements have been performed in the ^{14}C and ^{3}H Laboratory of Rudjer Bošković Institute since 1968. The radiocarbon data obtained during the first decade of measurements were published without dendrochronological corrections, because at that time calibration curves did not exist. Thus, many archaeologically interesting results from that time, including the age of the beams from St. Donat's church, were not been corrected.

Calibration curves have been considerably improved and extended in recent years and today they exist in the form of computer programs. Since the yearly growth of a tree depends primarih/ on climatic conditions, the calibration curve for each climatic region the own calibration curve should be established. The existing calibration curve closest to our region is based on the German Oak chronology. For presentation of the results the program OxCal, developed at Oxford University, was used (BRONK RAMSEY 1995; 1998). Since 1985, according to the agreement of ali radiocarbon laboratories, the results should be expressed in "conventional ^{14}C year" based on (5568±40) year half-life of ^{14}C and 1950 as the starting year. The radiocarbon age obtained has the designation BP *(Before Present).* After the dendrochronological correction the "calendar years" are obtained and they are denoted by **cal** BC *(Before Chrisf)* and/or **cal** AD *(Anno Domini).* The radiocarbon age is represented by the Gaussian distribution, while the values of corrected ages, obtained by the projection of the calibration curve, are represented on the abscissa. The results of calibration are given in intervals of calibrated age that correspond to Is or 2s interval of Gaussian distribution, *i.e.* to the total probability of 68.2% and 95.4%, respectively.

CORRECTION OF RADIOCARBON RESULTS OF SAMPLES FROM ST. DONAT'S CHURCH

From the beams found in the church we used only well-preserved beams, not subjected to decomposition, with 110 to 120 tree rings that could be easily counted. Each sample was treated by 4% HC1 and 4% NaOH in order to remove possible impurities of inorganic (calcite from water, sand) or organic origin (rotting, mold, microorganisms). After thorough washing and drying the samples were subjected to pyrolisis and the resulting charcoal was burned in a stream of oxygen. CO2 thus obtained was converted to CH4 by catalytic hydrogenation and its activity was measured in a proportional counter. The mean values and corresponding standard deviations were calculated according to the relations:

$$\bar{x} = \frac{\sum_{i=1}^{n} w_1 \cdot x_1}{\sum_{i=1}^{n} w_1} \qquad (1a)$$

$$\bar{\sigma}_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n} w_1 \cdot (x_1 - \bar{x})^2}{(n-1) \cdot \sum_{i=1}^{n} w_1}} \qquad (1b)$$

where n is the number of measurements of each sample and Xi and w; are the results of measurement and their vweighting factors (w; = $1/a^2$, andCT,-is the single measurement error).

As already mentioned, we had samples ofthree beams at our disposition. The first two samples (Z-175 and Z-177) were taken from the heart ofthe first two beams, and included tree rings from 0 to 20. The corrected result ofthe age ofthe sample Z-175 (Fig.2), obtained by program OxCal gives for *2a* interval of reliabilitv the interval of calendar years cal AD 640-790. For la interval of reliability we get two intervals: cal AD 660-720 (probability 53.9%) and cal AD 740-760 (probability 14.3%). The result ofthe age ofthe sample Z-177 (Fig.3) for 2s interval of reliability gives the interval cal AD 600-690 and for Is reliability the interval cal AD 630-675. However, these results do not give the time of felling ofthe trees from which the beams were made, because the exact age ofthese three trunks is not known. Ifwe suppose that the tree when it was felled was 100 to 150 years old, the result should be "younger" by this number of years, and this means that the trunk from which the sample Z-175 was taken could have been felled at the beginning ofthe 9th century, and the trunk from which the sample Z-177 was taken at the end ofthe 8* century.

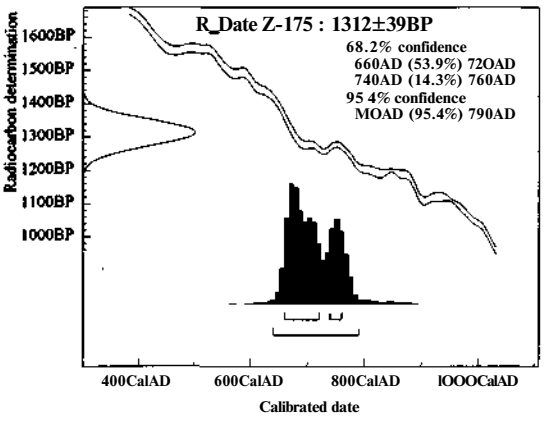

Fig.2. Corrected results of 14C age ofthe sample Z 175 (ćore ofthe beam, 0 20 tree rings)
SI. 2. Korigirani rezultat starosti uzorka Z-175 (jezgra grede, 0-20 godova)

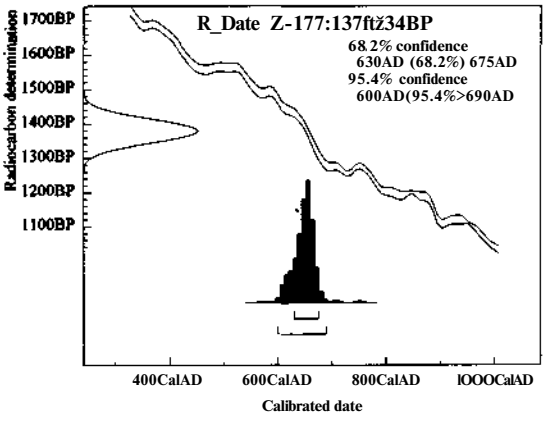

Fig.3. Corrected results of 14C age of the sample Z 177 (ćore ofthe beam, 0 20 tree rings)
SI.3. Korigirani rezultat starosti uzorka Z-177 (jezgra grede, 0-20 godova)

The more accurate determination ofthe time when the trees were felled was obtained by taking two samples from the same beam (Fig.4). Samples from the heart (Z-178, 0-10 tree rings) and from the periphery (Z-179,90-100 tree rings) were analyzed. At the Faculty ofForestry ofthe University ofZagreb, Department ofAnatomy, it was established that the beam was carved from oak *(Quercus)* and the age ofthe tree at the time when it was cut down was estimated to be (145±10) years. It was also supposed that during the treatment ofthe beam approximately (20±10) years of sapwood were removed.

The original cross section of the trunk was reconstructed according to the report of dendrochronologists (Fig.5). The calibration results for the sample from the heart (1s probability) gave the time interval cal AD 620-675 (Fig.6), and for the sample from the outer part of the trunk cal AD 670-780 (Fig.7).

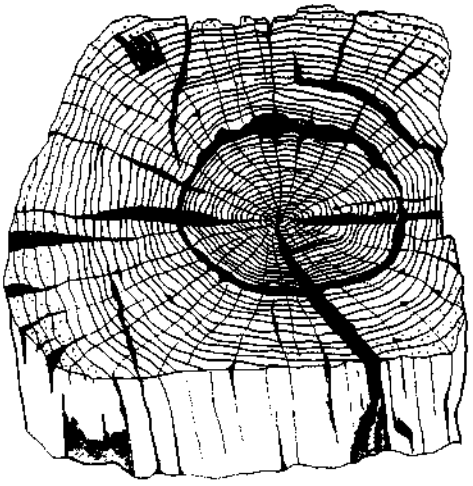

Fig.4. The sketch of the part of the third beam from which the samples Z-178 and Z-179 were taken.

S1.4. Crtež dijela treće grede iz koje su za datiranje uzeti uzorci Z-178 i Z-179.

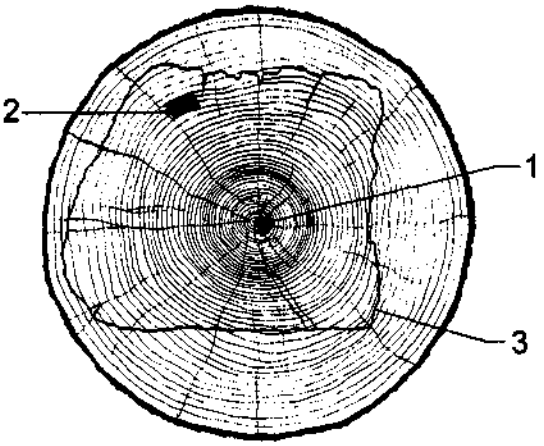

Fig.5. Reconstruction of the original cross section of the trunk from which the beam from the Fig.4 was taken; 1 - sample Z-178; 2 - sample Z-179; 3 - cross-section of the beam.

S1.5. Rekonstrukcija prvobitnog presjeka debla iz kojeg je izrađena greda sa si. 4; 1-uzorak Z-178; 2-uzorak Z-179; 3-presjek grede iz sl.4.

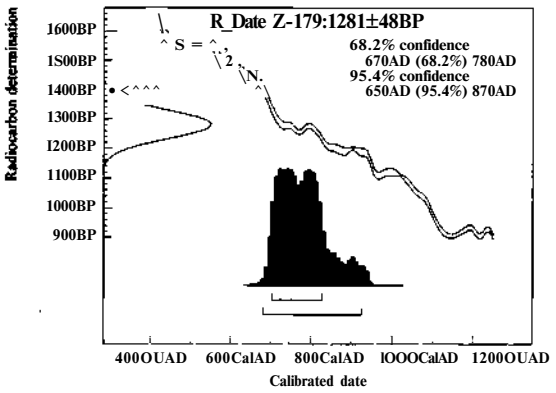

Fig.6. The corrected result of the age of the sample Z-178 (ćore of the beam, 0-10 tree rings).

S1.6. Korigirani rezultat starosti uzorka Z-178 (jezgra grede, 0-10 godova)

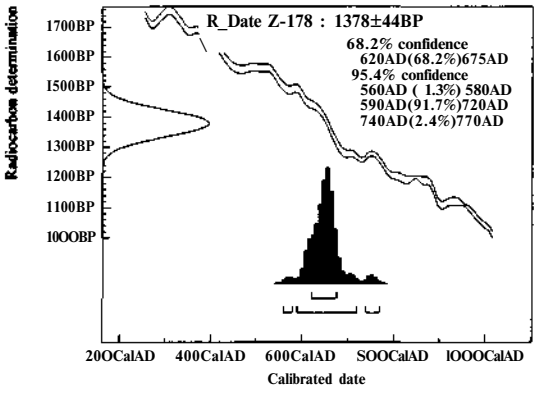

Fig.7. The corrected result of the age of the sample Z-179 (outer part of the beam, 90-100 tree rings).

S1.7. Korigirani rezultat starosti uzorka Z-179 (vanjski dio grede, 90-100 godova)

By statistical treatment of the results of the age of the two samples from the same beam, and knowing the exact number of tree-rings between them (in this case 90), we can decrease the interval of "calendar years" for the sample from the periphery of the beam, which was rather wide owing to

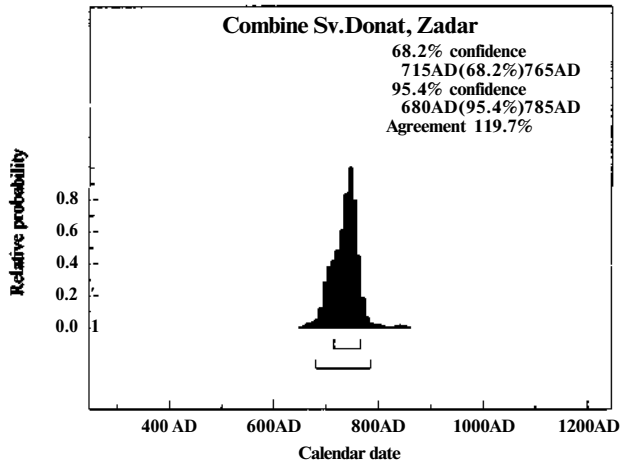

Fig.8. Corrected result of the age obtained by combination of measurements of samples Z-178 (0-10 tree rings) and Z-179 (90-100 tree rings), giving cal AD 715-765.
SI.8. Korigirani rezultat starosti iz kombinacije mjerenja Z-178 (0-10 godova) i Z-179 (90-100 godova) cal AD 715-765.

the nature of the calibration curve for this time period (Fig.7). By this procedure the interval of single measurements, calculated to be 110, was reduced to 50 years, and we got for the reliability 68.2% the "calendar year" of the sample to be cal AD 715-765 (Fig.8). If we add 50 years to the presumed age of the tree when it was felled, *i.e.* 145 years, it can be estimated that the trunk was felled at the end of the 8* century.

CONCLUSION

The results of radiocarbon measurements of the age of the beams from the St. Donat's church, corrected by the dendrochronological method, shift the time of the felling of oak trees from which they are made to the end of the 8th or to the beginning of the 9th century. The most reliable results are obtained from samples Z-178 and Z-179, which were taken from the same beam, one from the heart, and the other from the outer part (periphery). The final result was obtained by combining the results of these two samples. The small differences between the results of Z-175 and Z-177, and the combination of Z-178 and Z-179 need not be confusing, since three different trunks were involved, and they were not necessarily felled at the same time. These results support the hypothesis of I. Petricioli (KLAIĆ - PETR1CIOLI 1976) that the church was constructed in the first part of the 9* century.

LITERATURE

BRONK RAMSEY, C. 1995. Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program. *Radiocarbon,* 37/1995: 425-430.

BRONK RAMSEY, C. *The OxCal Program,* http://www.rlaha.ox.ac.uk/oxcal/oxcaLh.html (URL checked on January 15, 2000).

KLAIĆ, N. - I. PETRICIOLI 1976. *Zadar u srednjem vijeku do 1409.* Zadar, 1976: Sveučili]te u Splitu, Filozofski fakultet.

SRDOČ & alii. 1983 - SRDOČ, D. - B. OBELIĆ - A. SLIEPČEVIĆ. Precise Radiocarbon Dating of Wooden Beams from St. Donat's Church in Zadar. *PACT,* 8/1983: 319-327.

SRDOČ & alii. 1973/74 - SRDOČ, D. - A. SLIEPČEVIĆ - B. OBELIĆ. Mjerenje starosti drvene građe iz crkve sv. Donata u Zadru metodom radioaktivnog ugljika. *Peristil,* 16-17/1973-1974: 17-20.

SRDOČ & alii. 1973 - SRDOČ, D. - A. SLIEPČEVIĆ - J. PLANINIĆ - B. OBELIĆ - B. BREYER. Rudjer Bošković Institute Radiocarbon Measurements II. *Radiocarbon,* 15/1973: 435-441.

KOREKCIJA ^{14}C REZULTATA STAROSTI DRVENIH GREDA IZ CRKVE SV. DONATA U ZADRU DENDROKRONOLOšKOM METODOM

UVOD

Crkva Sv. Donata u Zadru jedinstvena je starohrvatska građevina, koja svojom monumentalnošću i stilom nadmašuje većinu sačuvanih građevina iz tog doba. Izgradili su je i projektirali domaći majstori nadahnuti antičkom, karolinškom i ravenskom arhitekturom, pa stoga predstavlja vrijedan izvor za proučavanje kulturnih utjecaja koji su vladali u ranom srednjem vijeku u Hrvatskoj, koja se tada nalazila između dva velika carstva, Bizantskog i Franačkog.

Prilikom restauracije crkve Sv. Donata prije tridesetak godina pružila se jedinstvena prilika da se datiraju drvene grede, kako bi se odredilo doba izgradnje crkve, koje nije bilo poznato. Tada je, naime, u podu matroneja otkriveno pedesetak starih drvenih greda koje su učvršćivale konstrukciju. Većina od njih bila je grubo tesana, a samo sedam je bilo ukrašeno rovašenim ornamentima. Stručnjaci Regionalnog zavoda za zaštitu spomenika kulture iz Zadra poslali su na datiranje metodom radioaktivnog ugljika ^{14}C u Institut "Ruđer Bošković" godine 1970. tri neukrašene grede. Rezultati mjerenja starosti pojedinačnih uzoraka objavljeni su u časopisu *Radiocarbon* (SRDOČ i dr., 1973), a račun procjene vremena, kada su debla od kojih su napravljene grede mogla biti posječena, objavljen je u časopisu *Peristil* (SRDOČ i dr., 1973/74), te 1981. prikazan na Prvom međunarodnom simpoziju "^{14}C and Archaeology", održanom u Groningenu u Nizozemskoj (SRDOČ i dr., 1983). U Peristilu su publicirani rezultati mjerenja triju uzoraka (Z-177, Z-178 i Z-179), od kojih su dva posljednja pripadala različitim godovima iste grede. Prema rezultatima statističke obrade mjerenja, najvjerojatnija godina obaranja drveta bila je 710±25 poslije Krista. U posljednjem radu dodan je rezultat mjerenja starosti uzorka iz treće grede (Z-175), pa je rezultat statističke obrade dao godinu 750±20 poslije Krista. U oba rada pretpostavljeno je daje ukupan broj godova debla iz kojeg su istesane sve tri grede iznosio 145 godina. Starost je računana s vremenom poluraspada ugljika Ti/2=(5730±40) god.

Premda su mjerenja starosti iz g. 1971. korektna, tijekom posljednjih desetljeća metoda je usavršavana i ustanovljeno je da neke pretpostavke na kojima se metoda zasnivala više ne vrijede. U međuvremenu promijenjeni su i standardi pomoću kojih se starost računa. To nas je potaklo da revidiramo prijašnje rezultate mjerenja.

DENDROKRONOLOŠKA KOREKCIJA

Metoda datiranja radioizotopom ^{14}C zasniva se na činjenici da je sav organski materijal u prirodi uslijed djelovanja kozmičkog zračenja "obilježen" tim izotopom, jer se on metabolizmom unosi u živi organizam, ali se istovremeno smanjuje zbog radioaktivnog raspada. Tijekom milenija uspostavila se u organizmima ravnoteža između smanjivanja i nadoknađivanja ^{14}C atoma. Nakon smrti organizma specifična aktivnost ^{14}C počinje se smanjivati prema zakonu radioaktivnog raspada, jer prestaje metabolizam, pa prema tome i nadoknađivanje raspalih ^{14}C atoma. Na osnovi tog zakona može se odrediti koliko je vremena proteklo od smrti organizma do dana mjerenja.

Mjerenje starosti organskih uzoraka ovom metodom zasniva se na nekoliko pretpostavki. Najvažnija od njih je tisućljetna postojanost toka kozmičkog zračenja i produkcije ^{14}C izotopa u atmosferi. Koncentracija ^{14}C atoma u novije vrijeme poremećena je ljudskim utjecajem: najprije je tijekom 19. stoljeća s razvitkom industrije povećana potrošnja fosilnih goriva (ugljen, nafta) koja - iako organskog porijekla - ne sadržavaju više atome ugljika ^{14}C, pa se njihova koncentracija u atmosferi smanjila. S druge pak strane, nakon 2. svjetskog rata započelo se s pokusnim nuklearnim eksplozijama u kojima su nastale velike količine ^{14}C atoma i njihova koncentracija u atmosferi naglo se povećala. Preciznim mjerenjima naknadno je ustanovljeno da tok kozmičkog zračenja ipak nije bio stalan ni prije tog vremena, pa zbog toga nije bila uvijek stalna ni produkcija ^{14}C atoma, što se odražava u različitoj koncentraciji ^{14}C atoma u tkivu organizama u času smrti. Zbog tih varijacija ovom metodom ne dobivamo točne "kalendarske godine" starosti nekog uzorka, već tzv. "^{14}C starost" koja se - ovisno o jakosti kozmičkog zračenja u nekom vremenskom razdoblju - može razlikovati od 2 do 5% od kalendarske. Potrebno je stoga koncentraciju izotopa ^{14}C odrediti nekom nezavisnom metodom i rezultate radiokarbonskog mjerenja korigirati, kako bi se dobila "kalendarska starost" uzorka.

U tu svrhu koriste se kalibracijske krivulje pomoću kojih se ^{14}C rezultati korigiraju. Tu nam pomaže dendrokronologija, metoda pomoću koje se određuje apsolutna starost uzorka brojanjem godova drveća i mjerenjem njihove relativne širine. Širina godova naime ovisi o klimatskim uvjetima koji su vladali u nekom određenom razdoblju, a odnos tih varijacija širine jednak je za pojedine vrste drveća. Usporednim mjerenjem relativne širine godova fosilnog drveća načinjena je kronologija za neke vrste drveća gotovo do unazad 12000 godina. Usporedbom preciznih mjerenja ^{14}C aktivnosti godova s njihovom točnom starosti određenom brojanjem godova ustanovljene su varijacije u prirodnoj produkciji ^{14}C atoma u atmosferi. Na osnovu njih konstruirane su kalibracijske krivulje za korekciju starosti dobivenih ^{14}C metodom.

U Laboratoriju za mjerenje niskih aktivnosti Instituta "Ruđer Bošković" starosti uzoraka metodom ^{14}C mjere se od 1968. godine. Prvih desetak godina rezultati ^{14}C mjerenja publicirani su bez dendrokronološke korekcije, budući da tada još nisu postojale kalibracijske krivulje. Mnogi rezultati arheološki interesantnih uzoraka iz tog razdoblja - a tu spada svakako i određivanje starosti greda iz crkve Sv. Donata - nisu stoga bili korigirani. Kalibracijske krivulje su tijekom zadnjih dva desetljeća sve više usavršavane i danas postoje u obliku računalnih programa. Budući da godišnji priraštaj drveta ovisi prvenstveno o klimatskim karakteristikama pojedinih regija, trebalo bi za svako klimatsko područje izraditi posebnu kalibracijsku krivulju. Za naše krajeve kalibracijske krivulje nisu izrađene, pa se koristimo kronologijom zasnovanom na mjerenju godova hrasta iz Njemačke. Za prikaz rezultata upotrebljava se program *OxCal* Sveučilišta u Oxfordu (RAMSEY 1998). Počam od 1985. prema dogovoru svih ^{14}C laboratorija, rezultati se izražavaju *"konvencionalnom ^{14}C starošću"* koja se računa s vremenom poluraspada (5568±40) god. Kao početna godina uzima se god. 1950., a starost ima oznaku BP *(Before Present)*. Nakon dendrokronološke korekcije dobiju

se *"kalendarske godine",* a te se označavaju s **cal** BC *{Before Christ),* odnosno **cal** AD *(Anno Domini).*

KOREKCIJA REZULTATA STAROSTI

Iz greda crkve Sv. Donata izdvojeni su samo dijelovi zdravog drveta, nenačetog truljenjem, kod kojih se sa sigurnošću moglo izbrojiti 110 do 120 godova.

Svaki uzorak kemijski se obrađuje u 4% HC1 i 4% NaOH da bi se uklonile moguće primjese anorganskog (kalcit iz vode, pijesak) ili organskog porijekla koje ne onečišćuju datirani uzorak uzorku (trulež, plijesan, mikroorganizmi). Spaljivanjem uzorka dobiveni CO2 konvertira se u metan čija aktivnost se mjeri proporcionalnim brojačem. Srednje vrijednosti i standardne devijacije računate su prema relacijama:

$$\bar{x} = \frac{\sum_{i=1}^{n} w_1 \cdot x_1}{\sum_{i=1}^{n} w_1} \qquad (1a)$$

$$\bar{\sigma}_{\bar{x}} = \sqrt{\frac{\sum_{i=1}^{n} w_1 \cdot (x_1 - \bar{x})^2}{(n-1) \cdot \sum_{i=1}^{n} w_1}} \qquad (1b)$$

n je broj mjerenja svakog uzorka, a *Xi* i iv; su rezultati mjerenja i njihovi faktori težine (w/ = *l/at*^{2}, a a; je pogreška pojedinačnog mjerenja).

Kao što je već spomenuto, na raspolaganju smo imali uzorke triju greda. Prva dva uzorka (Z-175 i Z-177) uzeta su iz jezgara prvih dviju greda, obuhvativši godove od 0 do 20. Korigirani rezultat starosti uzorka Z-175 (sl.2) dobiveni programom OxCal uz vjerojatnost od 95.4% (2a interval Gaussove krivulje ^{14}C mjerenja prikazane na ordinati) daje interval kalendarske starosti cal AD 640-790. Za vjerojatnost od 68.2% (1a interval pouzdanosti) dobivamo dva intervala: cal AD 660-720 (vjerojatnost 53.9%) i cal AD 740-760 (vjerojatnost 14.3%). Za uzorak Z-177 (si. 3) uz vjerojatnost 95.5% (2s interval pouzdanosti) starost uzorka nalazi se u intervalu cal AD 600-690, a uz vjerojatnost 68.2% u intervalu cal AD 630-675. Ovi rezultati, međutim, ne daju vrijeme kada su oborena debla od kojih su grede napravljene, budući da su oba uzorka uzeta iz jezgre. Točna starost ovih triju debala nije nam poznata. Ako pretpostavimo da su ona prilikom rušenja bila stara 100-150 godina, rezultat bi trebao biti "mlađi" za taj iznos, što znači da bi deblo iz kojega je uzet uzorak Z-175 moglo biti oboreno početkom IX. stoljeća, a deblo iz kojega je uzet uzorak Z-177 koncem VIII. stoljeća.

Točnije vrijeme obaranja debla dobiveno je uzimanjem dvaju uzoraka iz iste grede (si. 4). Za analizu uzeti su uzorci iz jezgre (Z-178,0-10 godova) i s periferije (Z-179,90-100 godova). Uzorak ove grede analiziran je na Katedri za anatomiju drva Šumarskog fakulteta Sveučilišta u Zagrebu. Utvrđeno je daje greda istesana iz hrastovine *(Quercus)* i procijenjeno je daje starost debla u doba sječe bila (145±10) godina. Pretpostavljeno je daje pri obradi odstranjeno oko (20±10) godova bjelike s korom. Na temelju mišljenja dendrokronologa rekonstruiranje prvobitni presjek debla iz kojeg je greda istesana (sl.5). Dendrokronološkom kalibracijom rezultata uzorka jezgre dobiven je za ls vjerojatnost vremenski interval cal AD 620-675 (sl.6), a uzorka s periferije grede cal AD 670-780 (si. 7).

Mjerenjem starosti dvaju uzoraka iz iste grede između kojih poznajemo točan broj godova (u ovom slučaju 90) može se statističkom kombinacijom obaju rezultata suziti interval "kalendarske

starosti" koji je dobiven mjerenjem uzorka uzetog s periferije grede, a koji je zbog prirode kalibracijske krivulje za taj vremenski period (si. 7) bio prilično širok. Ovim postupkom interval pojedinačnih mjerenja od 110 godina sužen je na 50 godina, pa je "kalendarska starost" uzorka cal AD 715-765 (si. 8) s pouzdanošću 68.2%. Dodamo li pretpostavljenoj starosti drveta pri obaranju 145 godova još 50 godina, deblo iz kojeg je greda istesana oboreno je pri kraju VIII. stoljeća.

ZAKLJUČAK

Rezultati mjerenja ^{14}C starosti greda iz crkve Sv. Donata, korigirani dendrokronološkom metodom, pomiču vrijeme rušenja hrastovih debala od kojih su one napravljene na kraj VIII., odnosno početak IX. stoljeća. Pritom su najpouzdaniji rezultati uzoraka Z-178 i Z-179 izvađenih iz iste grede, od kojih je jedan iz jezgre, a drugi s periferije. Konačni rezultat dobiven je kombinacijom ovih dvaju uzoraka. Manje razlike u rezultatima uzoraka Z-175, Z-177, te kombinacije Z-178 i Z-179 ne moraju zbunjivati, budući da se radi o tri različita debla koja moguće nisu oborena u isto vrijeme. Ovi rezultati potkrjepljuju pretpostavku I. Petriciolija (KLAIĆ - PETRICIOLI1976) daje crkva sagrađena u prvoj polovici IX. stoljeća.

Rukopis primljen 14.IV.1999.

Rukopis prihvaćen 18.IV. 1999.