

TATA INSTITUTE RADIOCARBON DATE LIST I

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The first series of C^{14} dates obtained in the C^{14} Laboratory of the above Institute, since it became operational in August 1961, are presented. The chemical and counting procedures adopted for the measurement of C^{14} in our laboratory have been described in some detail (Kusumgar et al., 1962). For the sake of completeness some points relevant to the determination of dates are described below.

The measurement of the specific activity of C^{14} in the samples was carried out by counting acetylene, synthesized from the sample carbon (Suess, 1954), in an Oeschger-Houtermans gas-proportional counter (Houtermans and Oeschger, 1958), at a filling pressure of 500 mm Hg. The background and net NBS oxalic-acid counting rates remained close to 1.35 and 12.2 counts/min throughout this work. Dates were calculated using the mean background and oxalic-acid standard counting rates measured before and after each set of sample countings. From the counter plateaus taken with a Co^{60} source for each sample and the observed variations in the counting rates of oxalic-acid standard, it was determined that the reproducibility and stability of the counting system are better than 0.5%. The procedure for converting samples into acetylene is that developed by Suess (1954). Minor modifications in this procedure, as adopted by Oeschger (personal communication), were introduced.

Dates are based on a value of 5568 yr for the half life of C^{14} , and 95% of the activity of oxalic acid* as the value for pre-1900 age-corrected wood. The errors given on the dates take into account errors arising from counting statistics, uncertainty in the half life value (± 30 yr), instability of the counting system ($\pm 0.5\%$) and isotopic fractionation effects ($\pm 0.2\%$) in the preparation of acetylene.** We have not made any measurements of δC^{13} ; the estimate of the error arising from this source has been based on the experience of Suess and coworkers (Bien et al., 1960) who measured C^{13} values in several wood and ocean water samples.

Wood and charcoal samples, prior to their combustion for the preparation of CO_2 , were subjected to the usual pretreatment: (a) careful inspection and surface cleaning (any rootlets present were manually picked), (b) successive extraction with hot solutions of 1% HCl, 1% NaOH, 1% HCl, and (c) washing with distilled water and drying. If a sample was too soft, the NaOH treatment was avoided to prevent its complete dissolution. Because of the variability in the nature of samples dated and the pretreatment used, we have noted these details against individual samples in the date list.

A brief archaeological description of sites Ahar, Lothal and Nevasa, from which several samples have been dated, is given. Samples from other sites have

* The standard oxalic acid was supplied to us by Prof. James R. Arnold to whom we are grateful.

** It should be pointed out, however, that the values of δC^{13} in tree rings have been found to range from -21 to -34 per mil with a standard deviation of ± 3.5 per mil (Suess, 1960). This corresponds to an error of $\pm 0.7\%$ in the specific activity of C^{14} .

been arranged alphabetically according to the name of the site. Whenever more than one measurement was made, samples are arranged in order of increasing age. This classification has been done primarily on the basis of archaeological evidence. When such an evidence is not at hand, the measured dates form the basis of this grouping. For further details about the archaeological sites, see Ghosh (1954-1960).

INTERCOMPARISON WITH OTHER LABORATORIES

In order to make an intercomparison with other laboratories we measured the C^{14} concentration in 1890 wood, and in a wood sample from the tomb of King Zoser (TF-56). In addition to these samples we discovered subsequent to our providing dates to the archaeologists that some of our samples came from the same sites previously dated by the University of Pennsylvania. In Table 1, we have made a comparison between samples which are expected to be contemporary as they derived from the same levels. Our pre-1900 standard, a rose wood sample representing the period A.D. 1885-1895, gave a net counting rate of 11.48 ± 0.09 counts/min compared to the value of 12.25 ± 0.08 counts/min observed for the oxalic-acid standard. The measured age-corrected value of $94.6 \pm 1.0\%$ oxalic acid activity as the reference value for modern wood agrees well with the international mean value of 95% adopted at the Groningen Conference 1959 (Godwin, 1959).

TABLE 1
Intercomparison of radiocarbon dates between Bombay
and other laboratories

Sample Site		C^{14} date (yrs B.P.) based on 5568 ± 30 yr for the half life of C^{14}
Charcoal	(a) Pennsylvania—P-481 ¹⁾	3879 ± 72 (mean of three determinations)
Kalibangan	(b) Bombay—TF-25	
Charcoal	(a) Pennsylvania—P-200 ²⁾) P-201 ²⁾)	3457 ± 127) 3492 ± 128)
Navdatoli	(b) Bombay—TF-59	3380 ± 105
Charcoal	(a) Pennsylvania—P-183 ²⁾	1846 ± 106
Nevasa	(b) Bombay—TF-39	1860 ± 100
Charcoal	(a) Pennsylvania—P-181 ²⁾	3106 ± 122
Nevasa	(b) Bombay—TF-40	3110 ± 110
	(a) Chicago—C-1 ³⁾	3979 ± 350 (mean of three determinations)
Wood	(b) Arizona—A-219 ⁴⁾	
(Zoser's Tomb)	(c) La Jolla—LJ 172 (Acacia) ⁵⁾)	4240 ± 150 $4120 \pm ?$)
Egypt	LJ 175 (Sycamore))	$4080 \pm ?$)
	(d) Bombay—TF-56	3990 ± 110

1) Robert Stuckenrath, Jr., Personal Communication.

2) University of Pennsylvania Radiocarbon Dates III.

3) W. F. Libby, (1952).

4) Arizona Radiocarbon Dates III.

5) H. E. Suess, (1960).

GENERAL COMMENT ON DATES

The C^{14} dates lead to certain definite conclusions regarding the proto-historic chronology of India. The central Indian chalcolithic cultures that were archaeologically placed at ca. 1000 B.C. are now found to belong to the latter half of the second millennium B.C. Also, the end of the mature Harappa culture came appreciably earlier than that estimated archaeologically. Furthermore, the late phase of Harappa culture has been shown to be considerably earlier than the date given by the archaeologists.

Lastly it may be mentioned that the C^{14} date of a sample from Utnur (Barker and Mackey, 1960) shows that there flourished a neolithic culture in the South which was contemporary to the Harappa culture of the North.

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SAMPLE DESCRIPTIONS

I. ARCHAEOLOGIC SAMPLES

Ahar (Ahad) series, Rajasthan

The mound of Ahar ($24^{\circ} 35' 9''$ N Lat, $74^{\circ} 43' 8''$ E Long), situated near Udaipur Railway Sta. (Rajasthan, India), 460 m long, 245 m broad and 15 m high, lies on the left bank of the Ahar River, a tributary of Banas. The site has proved of great significance in tracing the land route of western Asiatic cultural influences. Two main periods of occupation are evident. Period I is protohistoric and claims the major portion of the accumulation. On top of the mound alone are found traces of Period II, which is early historic. In comparison with the archaeological material from Navdatoli, the lower phase of Ahar should be earlier than Phase I of the former site.

The site was first excavated in 1954 by R. C. Agarwal, Superintendent of Archaeol., Rajasthan. The excavation was resumed in 1961 under the joint auspices of the Universities of Poona and Melbourne and supervision of Dr. H. D. Sankalia (Sankalia, 1962).

The measured dates for four charcoal samples supplied by Dr. H. D. Sankalia, Director, Deccan College, Poona, from Layers 5, 7 and 8 show a spread in time of ca. 450 yr (ca. 1750-1300 B.C.). These dates may prove the contacts of black-and-red ware of Rajasthan (Ahar) with that of the Saurashtra Harappan (Lothal). Samples from Layer 1 were found to be ca. 200 yr old, showing that this site was reinhabited in recent years.

TF-31. Copper Age Culture**3130 ± 105
1180 B.C.**

Charcoal (mixed with little mud) from Trench X, depth 1.98 m below datum, Layer 5, Field No. 2488. Selected pieces of charcoal treated with HCl and NaOH. From top layers of the Copper Age deposits.

TF-32. Copper Age Culture**3400 ± 105
1450 B.C.**

Very soft charcoal (mixed with little mud) from Trench A, depth 4.9 m below datum, Layer 5, Field No. 1038. Selected pieces of soft charcoal treated with HCl only. Some visible rootlets were present in the sample.

TF-34. Copper Age Culture**3570 ± 135
1620 B.C.**

Charcoal with little soil from Trench E, depth 11.5 m below datum, Layer 7, Field No. 2533. Selected pieces of charcoal treated with HCl and NaOH. *Comment:* the measured date of this sample, in relation to TF-31 and TF-32, is consistent with the expectations based on stratigraphic evidence.

TF-37. Copper Age Culture**3165 ± 110
1215 B.C.**

Charcoal (mixed with little mud and dirt) with little powder charcoal from Trench J, depth 12.1 m below datum, Layer 8, Field No. 2590. Selected pieces of charcoal treated with HCl only. *Comment:* this sample was expected to be older than TF-34 (Layer 7) as it is from a lower layer. Further dating of samples from the latter layer seems necessary to confirm the identification of this layer, since both TF-34 and TF-37 seem to be ideally suited for C¹⁴ dating.

TF-18. Late Medieval Culture**190 ± 90
A.D. 1760**

Charcoal (mixed with some mud) from Trench H, length (along) 5 m EW, breadth (away) 1.67 m SN, depth 0.15 m below surface, Layer 1. Selected charcoal pieces treated with HCl and NaOH. Traces of rootlets were present in the sample. *Comment:* originally all samples collected from the Ahar mound were believed to be in the neighborhood of ca. 1500-2000 B.C. After the above date was obtained, we were informed that further excavations at the site revealed the presence of polychrome glass bangles and Muslim burials which confirm this date and show that the site was reoccupied after 14-15th century A.D.

Lothal series, Gujarat

Lothal (22° 31' N Lat, 72° 15' E Long), is situated at the head of the Gulf of Cambay in Dist. Ahmedabad (Gujarat State, India). It is a low and extensive mound and represents the largest Harappan settlement in India. The site has become well-known for its most ancient dockyard, a trapezoidal structure measuring 216 m × 36.5 m. Interesting exotic finds, besides indicating seaborne trade, are valuable for fixing the dates of the site from an archaeological standpoint. On archaeological evidence, two main periods of occupation have been determined: Period I—ca. 2500-1500 B.C., Period II ca. 1500-1000 B.C. The site was excavated by S. R. Rao of the Archaeol. Survey of India

(Rao, 1961). Six samples, whose dates have been determined, were collected by S. R. Rao and submitted to us by A. Ghosh, Director General of Archaeol. in India, New Delhi-11. The site was flooded and waterlogged in the past. All samples were found to contain traces of rootlets. These were carefully removed manually before the pretreatment. *Comment:* C¹⁴ dates show that the ages of the upper levels of Period I and the entire Period II have been underestimated by archaeologists. C¹⁴ dates establish the chronological probability of contact of the black-and-red ware cultures of Lothal and Ahar.

TF-23. Harappa Culture **3705 ± 105**
1755 B.C.

Charcoal (mixed with mud and dirt) from Trench No. SRG54, Locus XLIII-XLVIII/4, depth 1.22 m, Field No. 28, Phase-VA (Period II). Sample is from posthole of mud wall of Phase VA, built on flood debris of Phase IV (Period I). Large selected pieces of charcoal treated with HCl and NaOH.

TF-19. Harappa Culture **3650 ± 135**
1700 B.C.

Charcoal (mixed with mud and dirt) from Trench No. SRG11, Locus 5B, depth 2.19 m to 2.25 m, Field No. 6, Phase VA (Period II). From debris sealing the western embankment wall of the dock. Selected soft charcoal pieces containing some mud treated with HCl and NaOH.

TF-29. Harappa Culture **3740 ± 110**
1790 B.C.

Charcoal (mixed with little mud and dirt) from Trench No. SRG55, Locus XII-XVIII/7, depth 2.11 m, Field No. 53, Phase IVA (Period I). Sample is from waterlogged debris of cesspool in which sullage water probably accumulated. Large selected pieces of charcoal sample treated with HCl and NaOH.

TF-22. Harappa Culture **3845 ± 110**
1895 B.C.

Charcoal (mixed with soil) from Trench No. SRG2, Locus E 13/9 (sealing wall of Phase III), depth 1.88 m, Field No. 29, End of Phase IIIB (Period I). Loose ashy layer sealing flood debris and wall of Phase IIIB. Sample (containing little mud) treated with HCl only.

TF-27. Harappa Culture **3840 ± 110**
1890 B.C.

Charcoal (mixed with mud and dirt) from Trench No. SRG2, Locus D13/7A, depth 1.98 m, Field No. 32A, Phase IIIB. From flood debris, loam etc. accumulated against wall of IIIB (Period I). Selected pieces of soft charcoal (containing little mud) treated with HCl only.

TF-26. Harappa Culture **3830 ± 120**
1880 B.C.

Charcoal (coarse and fine grain) from Trench SRG2, Locus D.13/7A, depth 1.98 m to 2.26 m, Field No. 32. From flood debris and loam accumulated against wall of IIIB (Period I). Selected coarse charcoal pieces treated with HCl and NaOH.

Nevasa series, Maharashtra

Nevasa (19° 34' N Lat, 74° 54' E Long), is a small town on the bank of Pravara, a tributary of the Godavari, in Ahmednagar Dist. (Maharashtra, India). Excavations revealed a sequence of cultures extending from the Chalcolithic to the Medieval periods. The site is of great importance as it shows a link between the Northern Chalcolithic and the Southern Neolithic traits. Period III (Chalcolithic) here is very rich in the variety of tools and ceramics. The central date for Period III is believed to be ca. 1200 B.C. The two subsequent early historic periods (Period IV, V) have been put within the time bracket of ca. 150 B.C.-A.D. 200. The site was excavated by Dr. H. D. Sankalia (Sankalia, Deo, Ansari and Ehrhardt, 1960). Four samples supplied to us by Dr. Sankalia have been dated. These measurements confirm the dates based on archaeological evidence influenced by C¹⁴ dates measured by the University of Pennsylvania.

TF-38. Indo-Roman Culture

1755 ± 105
A.D. 195

Charcoal in the form of charred grains (mixed with little soil). Trench 180B, depth 0.15 m below surface, Layer 4, Field No. 4197. Selected pieces treated with HCl and NaOH. Traces of rootlets were found. Sample belongs to Period V, dated ca. 50 B.C. with the help of coins and ceramics.

TF-41. Early Historic Culture

1675 ± 96
A.D. 275

Charred grains mixed with little soil from Trench 14B, Layer 2, Field No. 4463a. Depth not measured. Selected charred grains treated with HCl and NaOH. Sample belongs to Period IV, dated ca. 150 B.C. to 50 B.C. with the help of coins and ceramics.

TF-39. Early Historic Culture

1860 ± 100
A.D. 90

Charred grains with little mud from Trench 101B, depth 0.56 m below surface, Layer 4 (disturbed by pits), Field No. 4132. Selected charred grains treated with HCl and NaOH. Some visible rootlets were present. Sample belongs to Period IV dated ca. 150 B.C.-50 B.C.

TF-40. Chalcolithic Culture

3110 ± 110
1160 B.C.

Charcoal from Trench No. 181B, depth 1.34 m below surface N section, Layer 5, Field No. 4463. Selected pieces treated with HCl and NaOH. Sample believed to date ca. 1500-1000 B.C., on archaeological evidence.

Afyeh series, Nubia

Samples from Afyeh (22° 30' N Lat, 31° 50' E Long), subm. by A. Ghosh. *Comment*: this important site, dated ca. 3000 B.C. on the basis of Egyptian chronology, was excavated by the Indian Archaeol. Exped. led by B. B. Lal. The archaeological evidence unearthed is expected to throw light on the origins of Megalithic Culture of India.

TF-48. A-Group Culture**4290 $\pm$ 120
2340 B.C.**

Charcoal from Locus B5, depth 0.35 m, Stratum 2, Field No. AFH1/158. Selected pieces treated with HCl and NaOH.

TF-47. A-Group Culture**4380 $\pm$ 115
2430 B.C.**

Charcoal from Locus A4, depth 0.45 m to 0.55 m, Stratum 3, Field No. AFH1/157. Selected pieces treated with HCl and NaOH.

Burzahom series, Kashmir

Samples from Burzahom (34° 10' N Lat, 74° 52' 30" E Long). Subm. by A. Ghosh. *Comment:* these are the first dates obtained for the beginning of Neolithic economy in Kashmir and will help trace its connections from Central Asia and Iran (Lal, 1961).

TF-10. Neolithic Culture**2580 $\pm$ 100
630 B.C.**

Charcoal with mud in the form of powder. Locus III_{x1}—VII_{x1}, Trench BZH1, depth 1.55 m, Stratum 6. Sample is from "Mud Phase." Charcoal with mud in form of powder treated with HCl, CO₂ obtained by wet oxidation.

TF-15. Neolithic Culture**3390 $\pm$ 105
1440 B.C.**

Burnt material (probably birch and hay) with soil. Locus C2SW, Trench BZH3, depth 1.85 m below surface, Pit A. Burnt material treated with NaOH and HCl, CO₂ evolved by wet oxidation. No visible rootlets present.

TF-13. Neolithic Culture**3690 $\pm$ 125
1740 B.C.**

Charcoal with very little soil. Locus A2NW, Trench BZH3, depth 1.93 m below surface, Pit 12. Selected pieces treated with HCl and NaOH. Some visible rootlets were present.

Chandoli series, India

Samples from Chandoli. Subm. by Dr. H. D. Sankalia. *Comment:* sample was believed to date ca. 1500 B.C. on archaeological evidence, as well as on C¹⁴ dates from Navdatoli and Nevasa, this date list. Since Chandoli has proved to be a full-fledged Chalcolithic site having affinity with both Deccan and Central Indian Chalcolithic cultures, its dating is of primary importance. The C¹⁴ dates from Chandoli go to prove its affinity with Navdatoli and Nevasa.

TF-43. Chalcolithic Culture**2905 $\pm$ 100
955 B.C.**

Charcoal sample with some mud. Trench 8, depth 0.86 m below datum, Layer 2, Field No. 249A. Selected pieces treated with HCl and NaOH. A few rootlets were removed.

TF-42. Chalcolithic Culture**3035 $\pm$ 115
1085 B.C.**

Charcoal (mixed with soil). Trench 2, depth 0.5 m below datum, Layer 2, Field No. 249. Selected pieces treated with HCl and NaOH. Some rootlets were present.

TF-25. Kalibangan, India, Harappa Culture**3930 $\pm$ 110
1980 B.C.**

Charcoal mixed with charred bones from Kalibangan (29° 25' N Lat, 74° 05' E Long), Ganganagar, Rajasthan, Trench No. KLB-2, Square F, Locus F1-2.15 m $\times$ F2-8.20 m, depth 0.37 m below surface. Subm. by A. Ghosh. Selected pieces treated with HCl and NaOH. *Comment:* on the basis of its contacts with contemporary West Asian civilization, Harappa Culture is believed to date ca. 2500-1500 B.C. (Lal, 1962). Dating of the sample is considered important for establishing time of the existence of Harappa Culture in Rajasthan in relation to other parts of the Indian sub-continent, thereby determining the direction of the movement of the Harappa Culture.

TF-55. Lalitpur, India**3930 $\pm$ 115
1980 B.C.**

Charred wood found in a sandy layer along with Palaeolithic tools from Lalitpur (24° 42' N Lat, 78° 25' E Long), Dist. Jhansi, U. P., Trench 1, depth 0.2 m below the surface, Layer 2, Field No. 1. Subm. by Dr. H. D. Sankalia. Selected pieces treated with HCl and NaOH. *Comment:* age is much below expectation and can be explained on the basis of the possibility of redeposition, as the layer from which the sample came is sealed only by a layer of humus.

TF-59. Navdatoli, India, Chalcolithic Culture**3380 $\pm$ 105
1430 B.C.**

Charcoal (mixed with soil) from Navdatoli (22° 11' N Lat, 75° 36' E Long), Dist. Nimar, Locus NVT.Md.IV., Trench IA1, depth 2.75 m below surface, Stratum 9, Field No. 1. Subm. by Dr. H. D. Sankalia. Selected soft pieces treated with HCl. Traces of rootlets were present. *Comment:* on archaeological evidence the sample should date at least ca. 1000 B.C. (Sankalia et al., 1958). Sample was collected from a trench which was exposed for two years after excavations followed by waterlogging. As the sides of the trench had also partly collapsed, a possibility of contamination from the upper layers should be borne in mind.

Rajgir series, India

Samples from Rajgir (25° N Lat, 85° 25' E Long), India. Subm. by A. Ghosh. *Comment:* on the basis of occurrence of the Northern Black Polished Ware and punch marked coins, date is estimated to be ca. 600 B.C. (Lal, 1954-55).

TF-46. Rajgir, Early Historic Culture**2150 $\pm$ 100
200 B.C.**

Charcoal part of the burnt building material found in Pit 3 cut into Layer 5 filled with ashy materials of Layer 4 below the mud rampart, Locus VI-O m

S $\times$ 1.02 m E, depth 8.7 m below surface. From a cutting across the southern defences near SW corner bastion. Selected pieces treated with HCl and NaOH.

TF-45. Rajgir, Early Historic Culture

**2150 $\pm$ 100
200 B.C.**

Charcoal which was (coated with little mud) part of the burnt building material found in Layer No. 4 below the mud rampart, Locus VII-IX pegs, depth 7.05 m below surface from a cutting across the southern defences near SW corner bastion. Selected pieces treated with HCl and NaOH.

TF-56. Wood from Zoser's Tomb, Egypt

**3990 $\pm$ 110
2040 B.C.**

Wood sample (Acacia) supplied by Prof. J. R. Arnold of School of Sci. and Eng., La Jolla, California. The sample is identical to C-1 dated by Anderson, Arnold and Libby (Libby, 1952). Sample cut into small pieces and treated with HCl and NaOH. *Comment*: sample is believed to be 4650 $\pm$ 75 yr B.P. according to Egyptian chronology. Other C¹⁴ dates are given in Table 1.

II. GEOLOGIC SAMPLES

TF-58. Balahapura, Ceylon

**7255 $\pm$ 145
5305 B.C.**

Wood found along with precious stones, Balahapura (7° 25' N Lat, 80° 3' E Long), Sabaragamuwa, from a depth of 5.8 m below surface in gem pit, Field No. F.L.7. Subm. by K. A. Chowdhury, Dept. of Botany, Aligarh Univ. Cut into small pieces and treated with HCl and NaOH. *Comment*: sample contains micro-fibrils which show some change in their angle.

TF-57. Pelmadulla, Ceylon

**>39,000
>37,050 B.C.**

Wood found along with precious stones at Pelmadulla (7° 25' N Lat, 80° 3' E Long), Sabaragamuwa, from a depth of 17.1 m below surface in a gem pit, Field No. M.F.4. Subm. by K. A. Chowdhury. Cut into small pieces and treated with HCl and NaOH. The date is calculated by taking two standard deviations from the combined sample and background counting rates.

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