

RADIOCARBON DATING: RESULTS

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THE first series of "radiocarbon dates" of samples of archaeological and geological interest, measured by the Radiocarbon Laboratory of the Tata Institute of Fundamental Research, are presented in this paper.

The method adopted for the measurement of dates by the radiocarbon technique has been described briefly in the preceding paper of this issue. The dates are based on 95% activity of the standard oxalic acid (N.B.S. International Standard) being the value for the pre-1900 age corrected wood. Two "dates" are given for each sample in the "date list" presented in this paper, depending on the value of $\tau_{\frac{1}{2}}$, the half-life of radiocarbon, used. The first value is based on $\tau_{\frac{1}{2}} = 5568 \pm 30$ yrs., which has so far been internationally accepted. The second value (within parenthesis) is based on the value of 5730 ± 40 yrs., which seems to be a more appropriate working value based on some recent careful determinations of the half-life of radiocarbon (Godwin, "Radiocarbon Dating—Fifth International Conference," 1962; Mann *et al.*, 1961; Watt *et al.*, 1961; Olsson *et al.*, 1962).

Archaeologists making use of these radiocarbon dates should make a consistent choice of either of the values or even a different value; it is not meaningful to discuss or evaluate chronological sequences if some values are based on one half-life and others on the second. If a date, T' , is based on a given value of $\tau_{\frac{1}{2}}'$, the corresponding date, T'' , based on the value $\tau_{\frac{1}{2}}''$ is given by the relation:

$$T'' = T' (\tau_{\frac{1}{2}}'' / \tau_{\frac{1}{2}}'). \quad (1)$$

The dates refer to years before present (B.P.) taking 1950 as "present". Thus the dates given here can be converted into years B.C. by subtracting 1950 yrs. from the reported values.

INTERCOMPARISON WITH OTHER LABORATORIES

In order to make an intercomparison of our dates with those obtained by other laboratories, we have measured the radiocarbon concentration in

1890 wood, and a wood sample from the tomb of King Zoser (TF-56). In addition, we can compare our dates with those obtained by Pennsylvania Laboratory for samples derived from identical levels from the three archaeological sites, Kalibangan, Navdatoli and Nevasa. In Table I we have listed

TABLE I
Intercomparison of radiocarbon dates between TIFR and other laboratories

Sample/Site	Laboratory and Code No.	Radiocarbon date (yrs. B.P.) based on 5568 ± 30 yrs. for the half-life of radiocarbon
Charcoal	.. (a) Pennsylvania—P-481 ¹	3936 \pm 51 (mean of three determinations)
Kalibangan	.. (b) Bombay—TF-25	3930 \pm 110
Charcoal	.. (a) Pennsylvania—P-200 ² P-201 ²	3457 \pm 127 3492 \pm 128
Navdatoli	.. (b) Bombay—TF-59	3380 \pm 105
Charcoal	.. (a) Pennsylvania—P-183 ²	1846 \pm 106
Nevasa	.. (b) Bombay—TF-39	1860 \pm 100
Charcoal	.. (a) Pennsylvania—P-181 ²	3106 \pm 122
Nevasa	.. (b) Bombay—TF-40	3110 \pm 110
Wood (Zoser's Tomb)	(a) Chicago—C-1 ³ (b) Arizona—A-219 ⁴ (c) La Jolla—	3979 \pm 350 (mean of three determinations) 4290 \pm 150
Egypt	LJ 172 (Acacia) ⁵ LJ 175 (Sycamore)	4120 \pm ? 4080 \pm ?
	(d) Bombay—TF-56	3990 \pm 110

¹ Robert Stuckenrath Jr., Private Communication.

² *University of Pennsylvania Radiocarbon Dates III, Radiocarbon Supplement*, 1959, 1, 45.

³ W. F. Libby, 1952.

⁴ *Arizona Radiocarbon Dates III, Radiocarbon Supplement*, 1962, 4, 239.

⁵ H. E. Suess, 1960, preprint.

the various results along with references. The TIFR pre-1900 standard, a rose wood sample representing the period 1885-1895 A.D.*, which is not listed in Table I, gave a net counting rate of 11.48 ± 0.09 cpm. compared to that of 12.25 ± 0.08 cpm. for the oxalic acid. The observed age corrected value of $(94.6 \pm 1.0)\%$ oxalic acid as the reference value for modern wood agrees well with the international mean value of 95% adopted at the Groningen Conference 1959 (Godwin, 1959).

PRETREATMENT OF SAMPLES AND THE DATE LIST

The 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, and 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.

The sites from where the samples have been derived are arranged in an alphabetical order. A brief archaeological description of the sites has been given in all cases [for further details see Ghosh (1954-60)]. Samples belonging to the same site have been grouped in order of increasing ages based primarily on archaeological evidence. When such evidence is not at hand, the measured dates form the basis of this grouping.

GENERAL COMMENT ON DATES

C^{14} dates presented here lead to certain definite conclusions regarding protohistoric 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. In point of time, the western chalcolithic cultures appear as derivatives from the central chalcolithic. Also, the end of Harappa culture came appreciably earlier than estimated archaeologically. Furthermore, the late phase of Harappa culture has been shown to be considerably earlier than that estimated by archaeologists. It also appears that the devolution of Harappa culture did not take very long.

Lastly, the C^{14} date of a sample from Utnur (Barker and Mackey, 1960) has shown that the southern neolithic culture was contemporary with the Harappa culture of the North.

* Our pre-1900 standard wood sample, *Dalbergia latifolia* (rose wood), derives from Coimbatore (Madras), elevation 1900 ft. above m.s.l. The tree was cut in 1961.

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SAMPLE DESCRIPTIONS

*I. Archaeological Samples**Afyeh, Nubia, EGYPT*

Samples from Afyeh ($22^{\circ} 30' N. Lat., 31^{\circ} 50' E. Long.$), submitted by Shri A. Ghosh. Comment: this important site, dated *ca.* 3000 B.C. on the basis of Egyptian chronology, was excavated by the Indian Archaeological Expedition led by Shri 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, Afyeh, Nubia 4290 ± 120 (4415 ± 120)
Charcoal from Locus B5, depth 0.35 m., Stratum 2, Field No. AFH 1/158. Selected pieces treated with HCl and NaOH.

TF-47. A-Group Culture, Afyeh, Nubia 4380 ± 115 (4510 ± 120)
Charcoal from Locus A4, depth 0.45 to 0.55 m., Stratum 3, Field No. AFH1/157. Selected pieces treated with HCl and NaOH.

Ahar (Ahad), Rajasthan, INDIA

The mound of Ahar ($24^{\circ} 35' 9'' N. Lat., 74^{\circ} 43' 8'' E. Long.$), situated near Udaipur Railway Station (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. By a 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 Shri R. C. Agarwal, Superintendent of Archaeology, Rajasthan. The excavation was resumed in 1961 under the joint auspices of the Universities of Poona and Melbourne under the 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 yrs. (*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 yrs. old, showing that this site was reinhabited in recent years.

TF-18. Late Medieval Culture, Ahar 190 ± 90 (200 ± 95)

Charcoal (mixed with some mud) from Trench H, length (along) 5 m. E.W., breadth (away) 1.67 m. S.N., 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 neighbourhood of *ca.* 1500–1000 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.

TF-31. Copper Age Culture, Ahar 3130 ± 105 (3220 ± 110)

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, Ahar 3400 ± 105 (3500 ± 110)

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, Ahar 3570 ± 135 (3675 ± 140)

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, Ahar* 3165 ± 110 (3255 ± 115)

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 as it is from a lower layer was expected to be older than TF-34 (Layer 7). Further dating of samples from the later layer (Layer 8) seems necessary to confirm the identification of this layer, since both TF-34 and TF-37 seem to be ideally suited for C¹⁴ dating.

Burzahom, Kashmir, INDIA

Samples from Burzahom (34° 10' N. Lat., 74° 52' 30" E. Long.), submitted by Shri 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, Burzahom* 2580 ± 100 (2655 ± 105)

Charcoal with mud in the form of powder. Locus III_x—VII_x, Trench BZH1, depth 1.55 m., Stratum 6. Sample is from Phase II. Charcoal with mud in the form of powder treated with HCl, CO₂ obtained by wet oxidation.

TF-15. *Neolithic Culture, Burzahom* 3390 ± 105 (3485 ± 110)

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

TF-13. *Neolithic Culture, Burzahom* 3690 ± 125 (3800 ± 125)

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

Chandoli, Maharashtra, INDIA

Samples from Chandoli (19° N. Lat., 74° E. Long.). Submitted by Dr. H. D. Sankalia. Comments: samples were believed to date ca 1500 B.C. on archaeological evidence, as well as on the basis of C¹⁴ dates for 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, Chandoli 2905 ± 100 (2990 ± 105)

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, Chandoli 3035 ± 115 (3120 ± 120)

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.

Kalibangan, Rajasthan, INDIA

TF-25. Harappa Culture, Kalibangan 3930 ± 110 (4040 ± 115)

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. × F2-8·20 m., depth 0·37 m. below surface. Submitted by Shri 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 to *ca.* 2500–1500 B.C. (Lal, 1962). Dating of the sample is considered important for establishing the time of 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.

Lalitpur, Uttar Pradesh, INDIA

TF-55. Lalitpur 3930 ± 115 (4040 ± 125)

Charred wood found in a sandy layer along with Palaeolithic tools from Lalitpur (24° 42' N. Lat., 78° 25' E. Long.), District Jhansi, U.P., Trench 1, depth 0·2 m. below the surface, Layer 2, Field No. 1. Submitted 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.

Lothal, Gujarat, INDIA

Lothal (22° 31' N. Lat., 72° 15' E. Long.) is situated at the head of the Gulf of Cambay in District 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 sea-borne 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 Shri S. R. Rao of the Archaeological Survey of India (Rao, 1961). Six samples, whose dates have been determined, were collected by Shri S. R. Rao and submitted to us by Shri A. Ghosh, Director-General of Archaeology 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 seem to 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, Lothal 3705 ± 105 (3815 ± 110)

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, Lothal 3650 ± 135 (3750 ± 40)

Charcoal (mixed with mud and dirt) from Trench No. SRG11, Locus 5B, depth 2·19 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, Lothal 3740 ± 110 (3845 ± 115)

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, Lothal* 3845 ± 110 (3960 ± 115)

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, Lothal* 3840 ± 110 (3950 ± 115)

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, Lothal* 3830 ± 120 (3950 ± 125)

Charcoal (coarse and fine grain) from Trench SRG2, Locus D 13/7A, depth 1.98 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.

Navdatoli, Madhya Pradesh, INDIA

TF-59. *Chalcolithic Culture, Navdatoli* 3380 ± 105 (3475 ± 110)

Charcoal (mixed with soil) from Navdatoli (22° 11' N. Lat., 75° 36' E. Long.), District Nimar, Locus NVT. Md. IV, Trench IA1, depth 2.75 m. below surface, Stratum 9, Field No. 1. Submitted by Dr. H. D. Sankalia. Selected soft pieces treated with HCl. Traces of rootlets were present. Comment: on archeological evidence the sample should date to 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.

Nevasa, Maharashtra, INDIA

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 District (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 (Periods IV, V) have been put within the time bracket of *ca.* 150 B.C.-200 A.D. 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 which was to some extent influenced by C¹⁴ dates measured by the University of Pennsylvania.

TF-38. *Indo-Roman Culture, Nevasa* 1755 ± 105 (1805 ± 110)

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.—200 A.D. with the help of coins and ceramics.

TF-41. *Early Historic Culture, Nevasa* 1675 ± 95 (1720 ± 100)

Charred grains mixed with little soil from Trench 14B, Layer 2, Field No. 4463 *a.* 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, Nevasa* 1860 ± 100 (1910 ± 100)

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, Nevasa* 3110 ± 110 (3200 ± 110)

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.

Rajgir, Bihar, INDIA

Samples from Rajgir (25° N. Lat., 85° 25' E. Long.), India. Submitted by Shri 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. Early Historic Culture, Rajgir 2150 ± 100 (2210 ± 100)

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

TF-45. Early Historic Culture, Rajgir 2150 ± 100 (2215 ± 105)

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 S.W. corner bastion. Selected pieces treated with HCl and NaOH.

TF-56. Wood from Zoser's Tomb, Egypt 3990 ± 110 (4110 ± 110)

Wood sample (Acacia) supplied by Prof. J. R. Arnold of School of Science and Engineering, 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 ± 75 yrs. B.P. according to Egyptian chronology. Other C¹⁴ dates are given in Table I.

II. Geological Samples

TF-58. Balahapura, Ceylon 7255 ± 145 (7470 ± 150)

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. Submitted by Shri K. A. Chowdhury, Department of Botany, Aligarh University. 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

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. Submitted by Shri 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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