Radiocarbon Dating in Determining the Antiquity of Cultural Remains in India

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Abstract

Numerical dating of ancient cultures is based on dating of archaeological remains, mostly by radiocarbon (C^{14}) method. The contribution highlights the antiquity of the Indian Culture. The fact of the antiquity of Indian culture- sites being much more than generally believed is illustrated from published dates from many sites especially in the Northern India. Considering that users of the radiocarbon dates are generally unfamiliar with radiocarbon dating method, the article also deals with the basic principles of radiocarbon dating even as avoiding intricate details of the technical processes or the mathematical aspect. The approaches in the modern AMS and conventional LSC are introduced. The understanding of the principles is important even for those who only use the dates because a correct application is not possible if we don't understand the meaning of the dates and limitations of the method.

Seldom a discovery in Chemistry had such an impact on the thinking in so many fields of human endeavor, seldom has a single discovery generated such wide public interest- Nobel Committee Citation for Willard F Libby (1960).

Introduction

Most of the great civilizations of the world have evolved near rivers. It, therefore, appeared surprising that Gangetic Plain had not yielded that many evidences for ancient civilisations. Before the mid of 20th century, finding

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an exact date for archaeological material was not possible. But with the advent of radiocarbon dating method and later Thermo Luminescence (TL) and Optically Stimulated Luminescence (OSL) methods, the numerical dating became feasible. The radiocarbon dating may claim credit for dates for most of the archaeological material anywhere in the world. With its ability to date commonly occurring materials like charcoal and wood, and its range of about 50,000 years BP, the method gains a unique place in archaeological approach.

The discovery and evolution of the radiocarbon dating method got Willard F. Libby the Noble prize for Chemistry in1960, but this method has got application in many fields including Palaeobotany, Geology, Hydrology and Archaeology etc. Libby (1955, 1982) has chronicled the development of the method with technical details. The book edited by Taylor *et. al.* (1992) and another one written by Faure (1986) gives detailed account of the evolution of the method. Libby attributed the birth of the idea to a paper by Korff and Danforth (1939) which reported the observation of neutrons in the atmosphere. The radiocarbon method and its application are based on knowledge of Chemistry, Nuclear and Cosmic Ray Physics, electronics and of the fields in which it is intended to be applied such as Archaeology, Anthropology, Sedimentology, Palaeoclimatology and Palaeobotany. Initially solid carbon was used, gradually giving way to methane counting (by gas proportional counter), benzene counting (by Liquid Scintillation Counter) followed by Accelerator Mass Spectrometry which also uses solid carbon (graphite). In India, Tata Institute of Fundamental Research, Mumbai; Physical Research Laboratory, Ahmadabad and Birbal Sahni Institute of Palaeobotany, Lucknow, are the institutions that have contributed to the radiocarbon dating of archaeological samples. There are some other laboratories too such as at Hyderabad and Roorkee dealing with radiocarbon measurement but in water samples.

The Basis of Radiocarbon Dating

(i) The Principle of Dating using Radioactivity

The method is based on the principal of change in amount of radiocarbon (C^{14}) with time at a known rate. Radiocarbon is a radioactive isotope of carbon with atomic weight of 14. Radiocarbon is radioactive and so it decays with the half life of 5730 years (Godwin, 1962). In the beginning, though, the dates were calculated using a half life of 5568 years, and still used in publications. This means whatever amount of radiocarbon we start with, it will reduce to its half in 5730 years. By this rule of half, the process will go on which means that the remainder will reduce to further half (i.e. ¼ of the original material) in another 5730 years and so on. The measurement of the left over radiocarbon can give an idea of how much time has lapsed. The implicit assumption is that the archaeological context sought to be dated is contemporary to the component being dated. For example, we usually presume that the age deduced for a piece of charcoal found at an archaeological site is also the age for that the inhabitants of that site. Similarly, the soil or sediment contains organic carbon of plant origin. When dated, the age of the sediment can be considered to represent time period when the plant was last alive.

(ii) Radiocarbon in the Sediment

The question is how radiocarbon gets into the sediment, carbonate and other deposits, organisms or the atmosphere is natural. Radiocarbon could not be coming from the Sun. We know that Sun has only helium- production due to nuclear fusion occurring in its core. Whatever other elements are there in the Sun, they have been there for four and a half billion years as they were inherited from the Nebula from which the Sun formed. So, if any radiocarbon was there at the time of formation of the Sun, it would have been reduced to zero by this time. The occasional influx of cometary material etc. is inconsequential especially in respect of radiocarbon. Thus the radiocarbon in the atmosphere cannot be coming from the Sun as Solar Energetic particles or solar wind. Similarly cosmic sources can be ruled out.

In 1934, F.D.N. Kurie (1934) demonstrated that bombardment of nitrogen with fast neutron yields radiocarbon. Kamen produced radiocarbon by bombarding C^{13} as graphite with deuterium. Soon it emerged that slow

neutrons can also produce radiocarbon. Given the very high abundance of nitrogen in the atmosphere dominated by N^{14}, one is poised to think of the possibility of radiocarbon production from the reaction of neutron on N^{14} nuclei in the atmosphere (n, p reaction). This is a simple way to explain why we should have any radiocarbon in the atmosphere. Around the same time, the cosmic ray workers had been looking at neutrons in the Earth's atmosphere. An observation was made that the concentration of neutrons increases as one goes up from ground into the atmosphere. So, these neutrons are not coming from the earth. This increasing trend continues up to about 15 km but then it reverses, meaning that the maximum neutron production occurs at an altitude of about 15 km. The two observations together suggested that neutrons are neither coming from ground nor from space. The cosmic ray particles may generate neutrons peaking in number at about 15 km as a result of interaction with the atmospheric nuclei. This is because there the combination of target (nitrogen) abundance, energy and flux of cosmic rays optimises for maximum neutron production. The subsequent cosmic ray observations confirmed that the production of radiocarbon indeed happens in the atmosphere in this manner. Neutron has a short life span as a free particle but neutrons are produced continuously due to cosmic rays' reaction with atmospheric atoms leading to the production of the observed radiocarbon in the atmosphere.

The main reaction is:

$${}_{7}N^{14} + {}_{0}n1 = {}_{6}C^{14} + {}_{1}H^{1} \qquad (99\%) \qquad (1)$$

{Cross section= 1.7×10^{-24} cm^2}

Other reactions:

$${}_{8}O^{17} + {}_{0}n^{1} = {}_{6}C^{14} + {}_{2}He^{4} \qquad \text{(v. low cross section)} \qquad (2)$$

$${}_{5}B^{11} + {}_{2}He^{4} = {}_{6}C^{14} + {}_{1}H^{1} \qquad \text{(v. low cross section)} \qquad (3)$$

Oxidation leads to formation of carbon dioxide and over a time scale of a few years, the gas spreads all over. So, we find that the radiocarbon-concentration in the atmosphere is more or less uniform. The

inhomogeneity introduced between latitudes (due to nuclear tests) also vanished a few years after tests were stopped.

While assimilating the carbon dioxide, plants also get radiocarbon along with the two stable isotopes C^{12} and $C^{13,}$ thus making radiocarbon also a part of the plant. Once that plant is chopped off, or it dies, there is no more intake of radiocarbon.

Now on the two stable isotopes don't change in quantity while the radiocarbon starts decaying exponentially with a half life of 5,730 years. That means if a plant dies or is chopped off, after 5,730 years it will be left only with half of the original radiocarbon (N_0) that is what it has today. But the quantity of stable carbon isotopes C^{12} and C^{13} will remain the same. Another 5,730 years, and the left over amount of radiocarbon will reduce to further half that is one quarter of the original. The law of exponential decay for radioactivity allows exact calculation of the left over radiocarbon N:

$$N= N_0 e^{-\lambda t} \qquad (4)$$

Here λ is the decay constant and't', the time lapsed.

Using this, the equation for age (in years) turns out to be

$$t = 19.035 \times 10^3 \log (A_0/A) \qquad (5)$$

Here A and A_0 respectively represent radiocarbon activity measured (present) and the original activity when the plant was alive. Karlen *et al.* (1966) reported a value of 13.56 ± 0.07 decay per minute/g for equilibrium with the atmosphere.

In course of time, the plant debris gets mixed in the soil. It may be carried to the basins. This plant material is also eaten by the animals and these herbivorous are eaten by some carnivorous animals. Therefore all living beings end up acquiring some amount of radiocarbon in them and, therefore, we all have certain Radioactivity within us.

One way to understand the principle of radiocarbon dating, in fact of any radiometric dating, is to consider a set of radioactive atoms. We know that radiocarbon, has a half life of 5,730 years. So if we find only half of the initial number of radiocarbon atoms left, the time lapsed is estimated to be 5,730 years. If this is one fourth of the number, the age is double i.e. 11460 years and so on. But this requires knowing the initial radiocarbon in the sample. This value is decided by the measurement on the atmospheric air before contamination by bomb- produced radioactivity. This value for the atmosphere is derived from the measurements on wood sample of pre- bomb and pre- industrial era (1840- 1860). The oxalic acid standard from the National Bureau of standards, USA(NBS No. 4990) allows wider use for inter laboratory comparison. The activity of the wood is 95% of this standard.

But there is another complication viz. secular variation in the cosmic ray flux.

- The cosmic ray flux on earth is modulated by the Solar magnetic activity and the entry into different geographical regions on Earth is governed by geomagnetic field. Neither of the magnetic field is constant. So the radiocarbon production in the atmosphere has been variable. Therefore, if we measure radiocarbon in today's atmosphere and base our calculations on this value, we are likely to go wrong.
- Since the industrial activities started picking up in the 19^{th} century, radiocarbon in the atmosphere has been diluting (called 'Suess Effect') due to the addition of 'dead carbon' from burning of the fossil fuels. The Fossil fuels, being very old materials, do not contain any radiocarbon. Now, when we burn it, that 'dead' carbon is getting added to the atmosphere and the proportion of radiocarbon is going down.
- The nuclear tests in 1950's, particularly during 1955- 1969, added the neutron- reaction- generated radiocarbon to the air. In this way, the bomb- produced radioactivity and the dilution due to addition of the

dead carbon (carbon free from C^{14}) are working in the opposite way on the radiocarbon level in the atmosphere.

So all through the last 50,000 years or so (the range for radiocarbon dating), the level of radiocarbon in the atmosphere could not have been the same. But correction for that can be applied if we know radiocarbon levels at different points of time in the past. This has been made possible by measuring radiocarbon level in the tree rings, corals and stalagmite samples which represent different periods, as determined by an independent dating method viz. uranium- thorium method. For the time being, we will take it that we know that radiocarbon level in the atmosphere has been 13.56 ± 0.07 DPM/g and whatever decrease is observed in the sample, will be governed by the time lapsed. Later calibration is performed and we get age in calendar years.

Another complexity is introduced by isotopic fractionation. We presume that carbon 12, 13 and 14 have always maintained their ratio in the sample being studied but fractionation, that is change in the ratio of C^{12}, C^{13} and C^{14}, can take place in principle. There can be an exchange of isotopes with the surrounding, something very common in marine conditions. Measurement of the stable isotopic ratio (C^{12}/ C^{13}) can give us an idea of the fractionation, and necessary correction which is typically less than 2%. This is in addition to the fractionation introduced during the sample- processing which can be minimized, however, by subjecting the sample and the standard to the same procedures.

Similarly, if the sample is from a place where there is a volcano nearby, then volcano would be emitting carbon- containing materials free from radiocarbon. Consequently, things growing near the volcano will be poor in radiocarbon and hence will have apparent ages higher than actual. The mixing of organic carbon from some other source (having a different age) with the sediment can also result in erroneous ages.

The materials that can be dated by the Radiocarbon Method include geological deposits like carbonates, coral, mollusk or other calcareous

deposits as well as biological materials like wood, charcoal, seeds, twigs, pollen grains and so on. Even a variety of anthropogenic deposits and agricultural produce are possible to date, for example burnt bones, iron slacks, resin glues, cloth, leather, paint etc. However, not all laboratories date all of the above materials. If the amount of organic carbon in the sample is very small, we have to resort to Accelerator Mass Spectrometry (AMS) dating which is capable of detecting and measuring radiocarbon quantity as small as a milligram. In the Liquid Scintillation Counter - based conventional method, which we follow at Birbal Sahni Institute of Palaeobotany, about a gram or more of organic carbon is desired in the sample (typically 300 grams of sediment) to get a meaningful date.

(iii) Measurement of Radiocarbon in the Samples

There are two methods in vogue for measuring radiocarbon in the sample. One can prepare benzene from the sample and place it in a Liquid Scintillation Counter (LSC) for radiocarbon measurement which we term LSC method. The practice of preparing methane is more or less abandoned.

The alternative of Accelerator Mass Spectrometry (AMS) involves directly counting the radiocarbon atoms in the samples. Its efficiency is 100 to 1000 times compared to liquid Scintillation Counting as AMS can detect about 1% of the radiocarbon atoms present. It is achieved by first bringing the carbon of the sample in a graphite- pellet shape. The radiocarbon is extracted by sputtering with cesium atoms, and in the process negative ions are produced. There are no negative nitrogen ions possible. The NH^- molecular ions can be eliminated being of different mass. Positive ion production by electron bombardment would have led to dominatingly larger number of N^- (the same mass as radiocarbon) due to dominating abundance in the atmosphere. By accelerating the negative ions through electric field, filtering out/ removing the isobars like $^{13}CH^-$, $^{12}CH_2^-$, $^7Li_2^-$ using stripper gas or foil, and then analysing by passing the accelerated negative ions through a magnetic field, the amount of radiocarbon can be measured. The idea of difficulty may be gauged from the fact that the undesired background is

about a billion times bigger than the desired radiocarbon. This method is becoming popular despite the requirement of bigger and more expensive set-up. The Inter University Accelerator Centre (IUAC), New Delhi already has AMS and is now in an advanced stage to use that for radiocarbon also.

Fig.1: The benzene preparation system at Birbal Sahni Institute of Palaeobotany, Lucknow.

The decay of radiocarbon is by beta mode:

$_{6}C^{14} \rightarrow {}_{7}N^{14} + \beta + \upsilon^{*}$ (anti- neutrino)+ Q

In applying the LSC approach, the pre-treatments for different sets of samples like peat and sediment; charcoal, wood, paper or cloth; and carbonates etc. can be different. All samples have to be physically checked to remove rootlets etc. Some materials like carbonate (e.g. coral) are treated with 10% hydrochloric acid after cleaning to release carbon dioxide. Some like charcoal and sediment are given acid and alkali treatment before being combusted in oxygen flow to obtain carbon dioxide. After ensuring complete combustion to carbon dioxide and purification, the carbon dioxide is converted into acetylene and acetylene into benzene using appropriate catalysts for both stages. The actual process is detailed and lengthy after which, ultimately, we are able to get all the desired carbon from the sample in the form of benzene, preparing the stage for the process of performing the counting of the beta decays in the Benzene sample to estimate the radiocarbon amount present.

A commercially available Ultra Low Level background Liquid Scintillation Counter, **(Quantulus 1220)** is used for radiocarbon counting at BSIP. The counter has strong lead shielding to avoid interference from cosmic rays as well as radiations like gamma rays emanating from radioactivity in the surrounding. By adding scintillator to the benzene, beta decay is caused to be accompanied by a luminescence in the benzene. The use of a set of photomultiplier tubes and sophisticated electronics incorporated in the counter, facilitate counting of the luminescence due to beta decay of radiocarbon atoms. The counts per minute are indicative of the quantity of radiocarbon and make it possible to calculate age.

(v) Calculation of Age and Correction

For the calculation of age, the amount of radiocarbon present in the sample is compared to the initial abundance. It is essential to know radiocarbon level in the sample initially. The plant and the atmosphere are in equilibrium as long as the plant is alive (though the ratios of the 3 isotopes slightly differ in the 2 reservoirs). So we should know the radiocarbon concentration in the atmosphere. But atmospheric radiocarbon has been changing for several reasons like changes in the cosmic ray flux, Solar and Earth's magnetic fields and consequent modulation and entry of cosmic rays etc. Estimation of these changes individually is not possible but there is an easier way to solve the problem. The abundance of radiocarbon in the atmosphere is reflected in the tree rings which form annually and hence provide year-wise records. Precise measurements on samples from the individual tree rings allow to build up the past variations in the radiocarbon level. The radiocarbon level in the atmosphere has been deduced to be about 12 to 14% higher than today in 11,000 (dendro) years ago. There are tree ring chronologies going back in time as much as 10,000 years or more. The stalagmite and coral samples dated by Uranium-Thorium method are also used for calibration for going beyond what is possible by tree rings. The calibration allows us to correct the errors in age estimations caused by variation in the atmospheric radiocarbon abundance in the past.

In any kind of dating, we must be very clear as to what it is it that we are dating. In radiocarbon dating, we are dating the point of time when the process of assimilation of radiocarbon into plant from the atmosphere stopped. If that sediment flows to the ocean and there is a secondary deposition, the deduced age will be about 400 years older (also location-dependent) than the actually contemporary terrestrial sample, this is because they have derived their material from the older one and also because the mixing of water in the ocean takes time. The ages determined at BSIP and quoted in this article are calibrated dates, using appropriate calibration curves and have been rounded to the nearest 10 years.

It is necessary to ensure that the measurements made are really correct. Inter laboratory comparisons are carried out every few years, the latest having been done in 2008 under coordination of Marian Scott of University of Glasgow. BSIP has been participating in them. The samples are distributed all over the world as blind samples and different laboratories measure radiocarbon in those samples. In all the materials of our interest, our measurements (A_m) agreed reasonably with the international consensus values (A_c) as shown in Table 1 **(Nautiyal *et. al*. 2010)**. The Barley mash sample turned out to be modern as was also reflected in the consensus values

Table-1

	Consensus Value (Ac)	**Ours (Am)**	**Deviation (%) 100 (Am-Ac)/Ac**
Charcoal (P)	80.457	81.49	+1.28%
Wood (M)	73.9	73.6	- 0.4%
Wood (L)	75.719	78.06	+3.1%
Murex Shell (R)	73.338	74.61	+1.7%
Humic Acid (U)	23.079	23.4	+1.39%

Table 1: Radiocarbon Activity as Percentage of Modern Carbon (PMC) in standard samples distributed under VIRI.

Radiocarbon Dating of Archaeological Remains

The dating of archaeological materials had been limited to radiocarbon dating till about two decades ago. In the recent times, the Thermo Luminescence and OSL dating has also been applied to a variety of materials like pottery and quartz successfully. However, the data base for archaeological artifacts is still largely based on radiocarbon dates. Radiocarbon dating has been applied to a variety of material recovered from sites spread all over the country. Earlier, a number of reports appeared for sites in the Western India of today and of pre-partition days. During the past few years, considerable occurrence and discovery of archaeological sites have also been reported for Ganga Plains. This is not surprising because civilisations are known to have generally blossomed near great rivers. Radiocarbon dating of archaeological materials in India, done mostly at BSIP Lucknow, applied to charcoal, wood etc from these sites has built up a very strong data base to enable us to have a perspective on the issue of antiquity of civilisation in India (Nautiyal and Sekar 2008).

In this article, the discussion has been based on those samples which dated to be older than 2000 BC. The younger dates have also been mentioned in case they occur along with older dates.

The work done by K.S. Saraswat and colleagues at BSIP; Rakesh Tewari and colleagues at Uttar Pradesh State Archaeology Department, Lucknow; RS Bisth and colleagues of the Archaeological Survey of India (ASI) and others has conclusively shown that plant-derived materials were well known and used at early Harappan settlements like **Banawali** (29°37’5”N, 75°23’6”E), Hissar district in Haryana. The material collected under R.S. Bisth of ASI and studied by K.S. Saraswat (2007) included fruits of South Indian soap nut tree (*reetha), shikakai* and *aanwla*. The materials recovered also included mixture of these three. The first two trees being common in Southern India and *aanwla* in Gujarat, the presence and use at a distant place like Banawali speaks also for the standards of communication/ transportation in those days. The radiocarbon dating at BSIP indicates that all these things were known to Indians about 4,750- 4,500 years ago. This is indicative of the advanced state of civilisation during that period.

At **Kunal** (29° 30'N, 75° 41'E, Ratia tahsil, Hissar district, Haryana), **c**arbonised seed and grains were found along the palaeochannel of Saraswati. The samples were dated to be between 3016 BC to 2577 BC (Lal 1997, 2002; Saraswat and Pokharia, 2003). They divided the findings in three sub periods:

Sub Period IA: 3000- 2850 BC
Sub period IB: 2850- 2600 BC
Sub Period IC: 2600- 2500 BC

According to B.B. Lal, no samples from the earliest three levels seem to have been dated indicating that there may be older specimens at the site, taking the antiquity to still older times which may be as old as 4th millennium BC.

The Neolithic culture at **Tokwa** (24°54'20"N, 83°21'65"E)**, Mirzapur (UP),** situated at the confluence of Belan and Adwa rivers**,** yielded charred remains of a variety of plants. Excavation was carried out by Misra *et al.* (2004) of Allahabad University. The dating of charcoal samples at BSIP yielded three dates though one of them differed considerably from the other two (Pokharia 2008).

Table- 2

BS No.	Trench	Depth (m)	Layer	Age (Cal BP)
2354	H-8	2.20- 2.25	12A	3810-3570
2369	H-8	3.00- 3.30	14	7930-7510
2370	I- 8	2.43- 2-53	16	3640-3410

Table-2: The radiocarbon dates for Tokwa samples (charred remains).

Charcoal is a very common material used for dating. Three charcoal samples were dated and the two ages turned out to be over 3500 BP. One age is, however, much higher. We will know what the real situation is if more sample are dated. But even if the (average) date of 7,720 BP or so is ignored (because it was suspected by the researcher that this could be a result of mix-

up), the civilization in this region dates back to over 3500 Cal. BP as evidenced in botanical remains in the form of charred cereals including rice. However, lack of husk and there being several features in cultivated rice being common with the wild rice, make the authors term the identification as cultivated rice suspect. The dates are similar to those from **Lahuradewa** samples. Some of the Lahuradewa samples also yielded much older dates.

The dates of domesticated rice from **Lahuradewa** (26°46'N, 82°57'E) lake deposits, in **Sant Kabir Nagar district (UP),** also led to interesting results. The excavation was done by the State Archaeology Department (UP).

Table- 3

BS. No.	Location (Period)		Age (Cal BP)
1951	Lower most	(IA)	> 6100
1967	,,	(IA)	> 7250
1950	Upper Level	(IB)	> 4000
1939	Lowest Fe yield	(III)	> 3100

Table-3: The radiocarbon date extracts for charcoal from Lahuradewa (Sant Kabir Nagar).

The dates for cultivated rice from Lahuradewa (Table-3) were inferred on the basis of LSC- based radiocarbon dating of wood charcoal reported by Tewari *et al.* 2006. The lower most samples gave ages older than 6,100 Cal. BP and 7, 250 Cal. BP. The upper level (1B) gave an age of a little more than 4,000 BP and the lower iron bearing sample yielded an age of about 3,100 BP. The direct AMS dating of barley grains (period II) yielded 2700 Cal. BC (or about 4650 Cal BP) as reported by Tewari *et al.* (2006). The AMS dating of the associated rice-husk carried out at AMS, Erlangen-Nuremberg, Germany pushed the date of rice cultivation further back into time viz. to about 6,400 Cal. BC.

The samples of sediments for phytolith study were collected from a trench of 2.8 m depth at the lake shore. The study was conducted by a multidisciplinary team, by studying the grains of rice, barley etc. (Tewari *et al.* 2006 and references therein) and phytoliths found at the site followed by

dating the associated charcoal by LSC at BSIP and rice-husk by AMS. The AMS date on rice- husk is reported to be even older at about 8, 360 Cal. BP (based on personal communication from Sarawat to Saxena *et al*. 2006) while the age for wild variety is another 2000 years older. The phytoliths are basically microscopic silica particles, providing clues to the shape and size of the cells of the living plant tissues. There were two samples for the wild rice phytoliths at 2.7 m depth and for cultivated rice at 2.4 m depth. Increase in cultivated rice and decrease in the wild rice on going up from the bottom of the trench was reported. Distinction between wild and cultivated rice (O*ryza sativa* L) was based on some features like a larger number of scales at edges of the fans of the phytoliths (the distinction being set at 9), the signatures of the processing and also the higher smoothness and regularity of the scales. If there is an error in judging that, as the decision is based on statistically decided criterion, we may mistake the wild rice for cultivated rice.

Thus the age of domesticated rice deduced on the basis of Accelerated Mass Spectrometer (AMS) dating of rice husk as well as wood charcoal turned out to be even older than LSC- based dates. If the identification of the cultivated rice is correct, the results are very significant indicating rice being grown as early as 8,300 years ago in Gangetic plains.

The site of **Samudrakup mound** (25^0 26'10''N, 81^0 54'30''E) at **Jhusi (Allahabad, UP)** is a multicultural site evincing deposits of Neolithic, Chalcolithic, Early iron Age, NBPW as well as Sunga and Kushan period, Gupta period and early Medieval period (Misra *et al*. 2004). The site situated at the confluence of Ganga and Yamuna, also yielded a rich collection (in a charred/carbonised form) of rice, barley, dwarf wheat, horse gram, linseed, *aanwala* etc. and cereal, pulses, oilseeds from more than one season in addition to pottery. The dating of the charcoal samples was carried out at BSIP laboratory (Pokharia *et al.* 2009) and ages are similar to those from Lahuradewa and Koldihwa.

Table- 4

BS	Trench	Depth (m)	Layer	Age (Cal BP)

2524	SF-7	13.37- 13.47	50	7609- 7590
2525	SF-7	12.99-13.14	47	8140+_220
2526	SF-7	13.70-1380	53	7110-7880

Table-4: Radiocarbon dates for charcoal from Samudrakup mound Jhusi (Allahabad).

Kanmer (Kachchh), Gujarat (23°23'N, 70°52'E) is an archeological site. It is also known as Bakar Kot and is close to the Little Rann of Kutch. In a joint study involving researchers from BSIP, Institute of Rajasthan Studies, Gujarat State Department of Archaeology, Research Institute of Humanity and Nature (Japan) and DG (PG) College, Kanpur, multi- pronged analyses were carried out. In total, 25 samples were dated, nine by the conventional method at BSIP and 16 by the Acceleratory Mass Spectrometry at Palaeo-Laboratory Co. Ltd., Japan (Pokharia *et al.* 2011). The Accelerator Mass Spectrometry dates on rice grains as well as the radiocarbon dates by the conventional method in India turned out to be older than what anybody had expected. The LSC dates ranged from 3660 BC to 1785 BC while AMS dates on charcoal and grains ranged from 2564 BC to 1785 BC.

The samples dated were charcoal samples and along with these a rich collection of rice, barley, dwarf-wheat, gram, linseed, *aanwla*, cereal, pulses, oil seeds have been found. Earlier there was a practice of one crop every year prevalent in the region, but conclusion from this study was that farmers practiced double cropping even here during those times, most likely due to climate change. This was for the first time that such evidence was seen in Gujarat (Pokharia *et al.* 2011).

There are many other sites such as Balu and Kaithal in Haryana, showing evidence of a number of economically important plants from latter part of the third millennium BC (Saraswat and Pokharia, 2002) and evidence of rice from Malhar in Chandauli district (UP) dated in 4620 Cal BC (Tewari *et al.* 2000).

The perception that India can't have ancient cultural records is a result of a mind setup shaped over centuries but it is now changing. There have been

certain other myths too. In a less ancient example is the case of custard apple which was believed to be a gift of Portuguese to us during 16th century. But now there are at least at three sites known in Punjab and Uttar Pradesh (India) where evidence of custard apple or *sharifa* (*Annona squamosa L.*) has been found and the dates come out to be more than 3,500 year BP. So occurrence of custard apple dates back to a time period much before Portuguese came to India (Pokharia et al., 2009). This doesn't fall in the scope of the subject of this article, which is focused on the period older than 2,000 BC. Nor does it ascribe any greatness to our culture, but shows that there may be other incorrect myths too necessitating serious scrutiny.

Conclusions

All physical dating methods used in Archaeology are based on sound principles, be it Radiocarbon dating, Thermo Luminescence dating or Optically Stimulated Luminescence dating. But all methods cannot be always applied to every sample. If we have a pottery sample, it may be better to use Thermo Luminescence. If the pottery sample has reasonable amount of radiocarbon, then we can use Accelerator Mass Spectrometry Radiocarbon method also to date it. Even if we have an iron item and it contains carbon, added during its making, it may be possible to date by AMS. If the sample is in form of quartz, feldspar etc. then we can resort to OSL. So, we have to apply a method depending upon our sample, sample-history, its age and also the sample amount. All the methods have some or the other underlying assumptions, which must be appreciated for a correct interpretation.

In the Indian subcontinent, there are several archaeological sites, which have now yielded evidences of culture and evolution that date back to times far beyond what was believed earlier. The evidences, though, are not always fool- proof. For instance, in some cases identification may have scope for further improvement such as refinement in distinction between cultivated rice and the wild rice, which is not very easy.

We also will have to consider the palaeoclimatic and palaeogeographic information while building up the cultural history. There are examples where a river changed its course or dried up for tectonic or some other reasons, thus influencing the habitation. In Gujarat, the climate changes modified the way people were farming. For illustration, a younger (than 2000 BC) case is being cited here. In Khajnavar (Saharanpur district, UP) in a seismic zone, there is evidence of habitation and desertion about 2600a BP and 1400a BP respectively. It was followed by another settlement at about 850a BP**.** The site was abandoned, most likely, due to an earthquake at about 350a BP (Thakur *et al*. 2010). So, we will also have to incorporate the palaeoclimatic and palaeogeographic information while building up the archeological theories as they cannot be completely disassociated. Such sites may have even earlier records.

The sample and the date both are important, but what is of the greatest significance is the connection between the dated sample and the cultural context and this is where there is scope for be errors to creep in. For example, a charcoal piece is collected from a site, then dating the charcoal to know the age of the culture is meaningful if the charcoal is contemporaneous to the culture. The correctness of the date for the culture critically depends upon the correctness of the relationship of the sample with the culture. There are cases where there is a mix-up about this.

A century old Archaeological Survey of India (ASI) plans to adopt a very modern approach by introducing many new scientific aspects and by establishing several laboratories. Being the biggest Indian organization involved in archeological research, with this transformation, the things will change for much better. The ASI and many others like Indian Archeological Society, New Delhi; Deccan College, Pune and groups such as at Aligarh, Allahabad, Baroda, Goa, Hyderabad, Lucknow, Mumbai, Patna, Udaipur and Varanasi are engaged in such work. But results are bound to be better with higher level of collaboration because today Archaeology is a multi-disciplinary field. Arriving at truth will require treading many paths. An open but careful mind is the first requisite for the right discoveries and a multi- pronged approach to understand our rich past culture is necessary.

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