first excursion into the field. Figure 3 shows the pulses received at 50 Mcy/sec from another cloud, in this case either more active or closer to the aircraft. Figure 4 shows, in addition, the temperature and potential gradient records for the same period. The pulses received at both 30 and 50 Mcy/sec emanated from clouds whose total existence was in an environment where temperatures were several degrees above 0°C. Thus some sort of electrification is established for warm clouds involving the extremely rapid rearrangement of charge required for the production of the observed electromagnetic emission.

In addition to making these measurements, the audio output derived from the higher frequency emission was monitored. From the audio response, the observer could learn that the cloud under study was the source of the radio signals received because of the increase or decrease in the rate and intensity of the pulses as the aircraft approached or receded from a cloud. In regions of strong electric field near a cloud, the cloud noise was replaced by corona noise from points of the aircraft or from the antennae tips. That this noise is distinctly different from the noise of the cloud can be seen by comparison of Figs. 1 or 3 with Fig. 5. This difference, along with the recording of a strong electric field, should provide positive evidence of corona and the interpretation of spurious radio noise.

The signals at 30 and 50 Mcy/sec not associated with lightning or aircraft corona were absent in the vicinity of both mature thunderstorms and the smaller clouds that had reached the peak of their growth and had started to evaporate. The intermittent nature and short duration of these pulses, as seen in Figs. 1 and 3, suggest the existence of many microdischarges in clouds whose temperatures are entirely above 0°C and therefore give evidence of growing electrification without the presence of the ice phase. The growth of the electrification in these clouds may be associated with the mechanism responsible for the observed radio emission in discrete pulses. If this is true, the electrification process, at least of warm clouds, may be related to the smaller scale turbulent and cellular motions in the clouds, either through polarization or charge concentration in the smaller irregularities which subsequently interact at close range to produce a rapid rearrangement of the charge in the manner required to produce the electromagnetic emissions observed. Thus the process of cloud electrification, at least in warm clouds, may include an electrification mechanism quite different from any so far proposed.

J. DOYNE SARTOR
National Center for Atmospheric Research, Boulder, Colorado

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Harappa Culture: New Evidence for a Shorter Chronology

Abstract. *Radiocarbon dates suggest a total time spread of 550 years, from about 2300 to 1750* B.C., *for the Harappa culture.*

The possibility of dating Harappa culture on the basis of written evidence is as yet precluded by our present inability to decipher the Indus script. The date bracket generally accepted as being safe (*1, 2*), about 2500 to 1500 B.C., is based mainly upon Gadd's classical paper (*3*) on seals of the Indus type found in Mesopotamia. With the availability of carbon-14 dates for Damb Sadaat, a site showing Harappan contact, Fairservis (*4*) showed that the earliest date for Harappa culture was about 2100 B.C. Although at that time he retained the total span of about 1000 years, he later suggested a much shorter bracket on anthropological considerations (*5*).

In recent years a large number of carbon-14 dates have become available for some of the important Harappan and allied sites. An analysis of this new evidence strongly suggests a shorter Harappan chronology. I now propose a maximum date bracket of about 2300 to 1750 B.C. for the total time spread of Harappa culture. This shorter bracket is not contradictory to the archeological evidence.

Radiocarbon dates for three main Harappa sites—Mohenjodaro, Kalibangan, and Lothal—and three allied sites—Damb Sadaat, Kot Diji, and Niai Buthi—are given in Table 1. The time brackets discussed in this report are based on 5730 ± 40 years as being the value of the half-life of radiocarbon.

The main Harappan sites from which samples of middle and late levels have been dated are Kalibangan (Rajasthan) and Lothal (Saurashtra). Only one sample representing upper levels of Mohenjodaro has yet been dated; unfortunately, no dates are available for Harappa. All the relevant radiocarbon dates are plotted in Fig. 1. The end of Harappa culture is easily determined from the available dates. A cross-check on the beginning of the culture is available from dates for Damb Sadaat and Kot Diji. Niai Buthi probably provides a check for the date of early Harappa culture.

The mean dates for the upper levels of Kalibangan and Lothal, based on samples TF-25 and TF-150, and TF-23 and TF-19, are 1960 ± 75 and 1840 ± 85 B.C., respectively (*6*). These have to be compared with the single date for the upper level of Mohenjodaro (TF-75) of 1755 ± 115 B.C. The three dates are seen to be consistent with a mean date of 1880 ± 50 B.C. for the end of Harappa culture at these sites. However, since Mohenjodaro was probably one of the most important Harappan seats, the culture may have continued longer there than at Kalibangan and Lothal. In view of this, we consider 1750 B.C. as a probable date for the end of Harappa culture. This estimate is also well supported by the radiocarbon dates available for several post-Harappan Chalcolithic cultures in India (*7*).

The earliest dates for Kalibangan and Lothal have to be based on an extrapolation since the lowermost levels have not been dated. However, Fig. 1 shows that safe limits for the beginning of Harappa culture at these sites can be obtained easily since all the upper levels have been dated. Considering the stratigraphic divisions, we conclude that the Harappa culture at Kalibangan and Lothal started not earlier than 75 and 150 years, respectively, before the lowermost levels for which radiocarbon dates have been obtained.

The mean dates for the lowermost dated levels of Kalibangan and Lothal, based on samples TF-147 and TF-145, and TF-22, TF-27, and TF-26, are 2040 ± 75 and 2000 ± 70 B.C., respectively. Taking one standard deviation on the mean of the earliest and latest dates (Table 1), so as to obtain a maximum difference, and considering the extension limits of 75 and 150 years as discussed previously, we obtain for the maximum time interval, values of 250 and 300 years for Kalibangan and Lothal, respectively.

For Damb Sadaat, five carbon-14 dates are available, four of which are for period II (DS-II) which, on the basis of archeological evidence, provides the anterior limit for the beginning of Harappa culture. These dates are not inconsistent; however, since the errors on L-180C, L-180E, and P-522 are very large, we have considered the date for sample P-523 of 2200 ± 76 B.C. to be more important. Taking one standard deviation on this date, a safe estimate for the beginning of the Harappa culture is obtained as 2275 B.C. For Kot Diji, we have four internally consistant radiocarbon dates for the pre-Harappan culture. Archeological evidence shows that the destroyers of this culture were Early Harappans (*8*). For the uppermost levels, representing pre-Harappan culture, we have a date of 2100 ± 138 B.C. for P-195. A safe estimate for the Early Harappans who invaded the site is similarly obtained as 2238 B.C., taking one standard deviation on the date 2100 B.C.

Table 1. Radiocarbon dates (B.C.) used in this paper for reconstructing the Harappan chronology.

Station index No.	Radiocarbon date (years B.C.)	Period
	Damb Sadaat	
L-180B (*10*)	2320	DSI
L-180C (*10*)	2220	DSII
L-180E (*10*)	2220	DSII
P-523 (*11*)	2200	DSII
P-522 (*11*)	2550	DSII
	Kalibangan	
P-481 (*11*)	2050	Late (mid ?)
TF-25 (*12*)	2090	Late
TF-150 (*13*)	1910	Late Harappan
TF-139 (*13*)	1930	Middle Harappan
TF-151 (*13*)	1960	Middle Harappan
TF-147 (*13*)	2030	Lower Middle
TF-145 (*13*)	2050	Lower Middle
	Kot Diji	
P-195 (*14*)	2100	Late Kot Diji I
P-180 (*14*)	2250	Middle Kot Diji I
P-179 (*14*)	2330	Middle Kot Diji I
P-196 (*14*)	2600	Early Kot Diji I
	Lothal	
TF-23 (*12*)	1865	Phase V A
TF-19 (*12*)	1800	Phase V A
TF-29 (*12*)	1895	Phase IV A
TF-22 (*12*)	2010	Phase III B
TF-27 (*12*)	2000	Phase III B
TF-26 (*12*)	2000	Phase III B
	Mohenjodaro	
TF-75 (*13*)	1755	Late
	Niai Buthi	
P-478 (*11*)	1900	Kulli

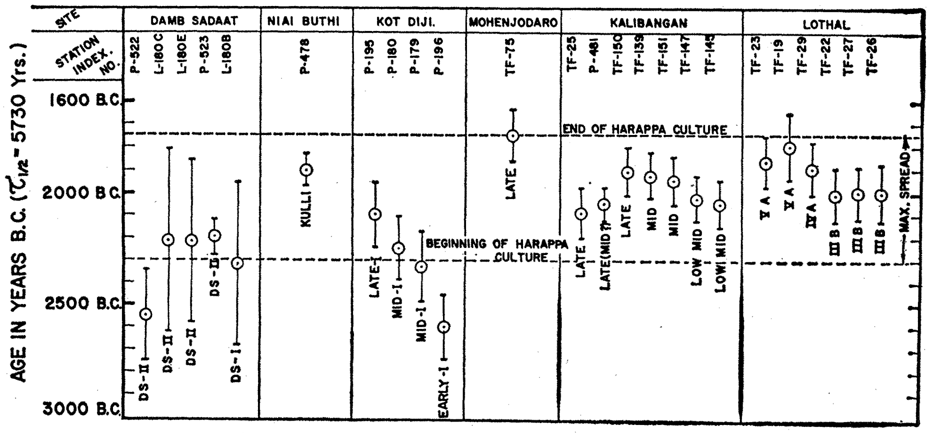

Fig. 1. Harappa and pre-Harappan cultures.

The various aforementioned radiocarbon dates for the main and allied Harappan sites lead to a consistent time bracket. First, a consistent limit of 1750 B.C. for the end of Harappa culture emerges from the carbon-14 dates for Mohenjodaro, Kalibangan and Lothal, which antedates the post-Harappan Chalcolithic sites. The earliest dates for the Harappa culture at Kalibangan and Lothal, and Damb Sadaat and Kot Diji are 2200 and 2250 B.C., respectively, which are also consistent within the errors of dating. As a safe limit we have therefore adopted 2300 B.C. as the date for the beginning of Harappa culture. This corresponds to a total time span of about 550 years. The time spans at Kalibangan and Lothal were deduced to be 250 and 300 years, respectively. Considering that the period of 550 years (2300 to 1750 B.C.) corresponds to an extreme time bracket, it cannot be said definitely as yet that the Harappa culture was shorter lived at these sites. The carbon-14 dates and archeological evidence for Harappan sites will be discussed in detail by Agrawal (*7*).

The proposed date bracket of about 2300 to 1750 B.C. is certainly considerably shorter than the traditionally accepted bracket of about 2500 to 1500 B.C. But if we critically examine the latter estimate for the Harappan chronology we find that, on archeological considerations also, it is larger than warranted.

First, the whole chronology is based mainly on a dozen seals of the Indus type which were found in Iraq (*3*), in some sort of datable contexts in old excavations at a time when scientific stratigraphy was not practiced. Second, even this evidence is too meager to justify the enlargement of the bracket to a millennium. Considering these facts, Wheeler (*9*) stated that "the ends of the bracket are insecurely dated." Piggot (*1*) also concedes that "the only close point of contact [of Harappa culture] with the West . . . is between years 2300 and 2000 B.C." In a recent paper, Fairservis (*5*) says, "I am not convinced that the Harappan of Sind at least represents an occupation by that culture of anything close to the thousand year span which is accepted at present. . . . I would expect that it was nearer 500 years."

The foregoing discussion shows the attempts of the archeologists, although with some hesitation, to propose a shorter chronology for the Harappans. Now, on the basis of radiocarbon dates, one can assert a shorter date bracket of about 2300 to 1750 B.C. for the total time span of Harappa culture.

D. P. AGRAWAL
Tata Institute of Fundamental Research, Colaba, Bombay 5, India

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High-Pressure Phase Transition in Tin Telluride

Abstract. *At 18 kilobars, tin telluride transforms from a sodium chloride–type structure to an orthorhombic crystal structure (space group* Pnma*). This structural change is accompanied by a 360-percent increase in electrical resistivity.*

Tin telluride is an $A^{IV}B^{VI}$ compound analogous to PbS, PbSe, PbTe. At atmospheric pressure these four compounds have a cubic crystal structure (*1*) of the sodium chloride type. Tin telluride is a semiconductor with a very high apparent carrier concentration due primarily to the large number of tin vacancies in its crystal lattice (*2*).

The resistance of SnTe was measured as a function of pressure with a modified "belt" high-pressure apparatus similar to that described by Hall (*3*). The apparatus was calibrated with the following accepted transition pressures (*4*): bismuth I-II, 25 kb; thallium, 37 kb; and barium, 59 kb. Silver chloride was used as the pressure-transmitting medium, and the conical high-pressure gaskets were made of pyrophyllite. The specimens were cylindrical compacts of SnTe measuring 1.5 mm in diameter by 20 mm in length.

Table 1. Analysis of the x-ray data obtained at 20 kbar; *d* is in Angstrom units.

d_{obs}	d_{calc}	*hkl*	I_{obs}	I_{calc}
3.54	3.54	2.01	20	8
3.08	3.13 3.02	011 111	40*	100*
2.91	2.93 2.90	301 400	100	45
2.68	(Tin)			
2.41	2.43 2.43	311 410	60	37
2.16	2.24 2.19 2.12	002 020 411	50	36
1.96	1.96 1.94	112 302	10	11
1.86	1.88 1.86 1.86	212 511 221	30	33
1.72	1.74	420	30	20
1.62	1.61	502	10	3
1.54	1.56 1.55 1.55 1.51	022 701 122 512	10	16
1.43	1.45 1.45	322 800	10	9
1.37	1.38 1.38	131 422	10	16
1.29	1.30 1.30	331 522	10	8

* Intensity calculations predict strongest reflection at 111. At elevated pressures, anisotropic bonding often leads to preferred orientation, which might explain the strongest reflection at 400.

The effect of pressure on the electrical resistance of SnTe is shown on Fig. 1. The curve shows that the resistance of SnTe decreases gradually with increasing pressure. At 18 kb, however, there is a rapid, 360-percent increase in resistance, after which the resistance again drops smoothly with increasing pressure. The discontinuity in the resistivity curve at 18 kb indicates a first-order structural transformation, while the smooth drop in resistance beyond the maximum represents the effect of pressure on the resistivity of the high-pressure phase (phase 2). This transformation is completely reversible. The pressure was increased and decreased successively several times with each specimen and each cycle yielded the same resistivity curve.

The transformation at 18 kb was confirmed by x-ray diffraction patterns obtained with an opposed-diamond-anvil high-pressure x-ray camera similar to the unit described by Piermarini and Weir (*5*). Figure 2 is a photograph of the diffraction patterns of SnTe obtained at 1 atm and at 20 kb, and Table 1 is a summary of the x-ray data at 20 kb.

These data show that the high-pressure phase of SnTe has an orthorhombic structure (space group *Pnma*) analogous to the structure of the atmospheric-pressure phase of SnS and SnSe (*6*). The lattice parameters of the high-pressure phase of SnTe are a = 11.59 Å, b = 4.37 Å, and c = 4.48 Å, corresponding to a calculated density of 7.21 g/cm^3 for four molecules per unit cell. This is an 11-percent increase in density over phase 1 at atmospheric pressure.

The average compressibility K, $(\Delta V/V_0\Delta P)$ of the low-pressure NaCl-type phase is 2.3×10^{-3} kb^{-1} between atmospheric pressure and 8.2 kb, determined from the lattice parameters at these pressures. By extrapolation, the density of this phase is 4 percent greater at 18 kb than at 1 atm. There is thus a net increase of 7 percent in density when the NaCl-type structure transforms to the orthorhombic structure at 18 kb.

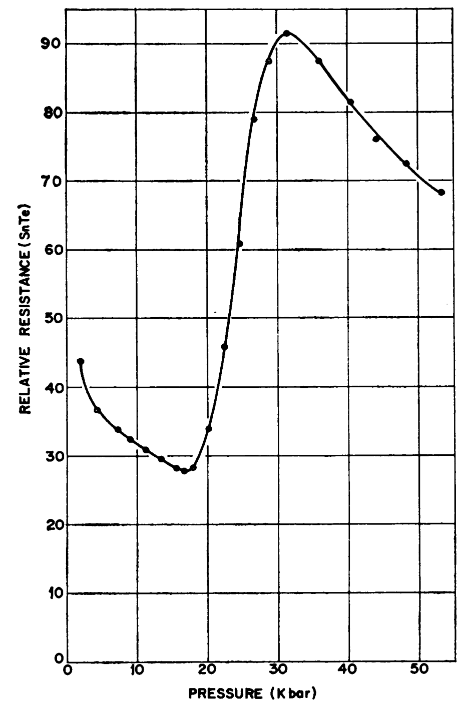

Fig. 1. The effect of pressure on the resistance of SnTe.

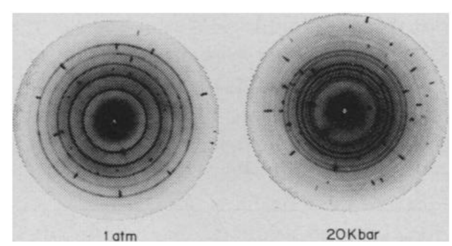

Fig. 2. X-ray diffraction patterns of SnTe obtained at 1 atm and 20 kb.

JAMES A. KAFALAS
Massachusetts Institute of Technology, Lincoln Laboratory, Lexington*
ANTHONY N. MARIANO
Kennecott Copper Corporation, Ledgemont Laboratory, Lexington, Massachusetts

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