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1 - The Archeological Problem

The first archeological works on the pottery of the islands of the Amazon river were made about a century ago (1).

The systematic investigations of B.J. Meggers and C. Evans (2) established that since pre-columbian times these islands have been occupied in turn by several successive tribes. On the island of Marajo, five archeological phases corresponding to different levels of cultural occupation were identified: the Ananatuba (the oldest); the Mangueiras; the Formiga; the Marajoara, and the Aruã phases were identified by their different pottery styles (2).

It is important to emphasize that pottery is practically the only evidence for the existence of these cultures. This is in fact a general aspect of the archeological problem of the Amazon bassin, since the nature of the soil restricts the availability of litic artifacts and the density of vegetation is such that any vestiges of matter of bio-organic origin is practically

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non existent.

For these reasons thermoluminescence dating methods are of primary interest of this area; but until now no systematic study has been reported using this technique with the Amazonian pottery.

2 - The Carbon-14 Dates

Two of the five phases have been dated by this method: the Marajoara phase and the Ananatuba phase (3). For the first phase, two series of measurements are reported:

a) The Ilha dos Bichos series, site PA-J-21 on Marajo Is., ($0^{o}50'$ S Lat $48^{o}55'$W Long) which yielded three inconsistent dates:

SI 199, cut C, level 78 to 98 cm ..... 1260 ± 200 y ;
SI 200, cut C, level 1.35 to 1.75 m ..... 550 ± 500 y ;
SI 201, cut B, level 2.00 to 2.25 m ..... 2020 ± 280 y .

b) The Frei Luis series, site PA-J-36 on Marajo Is. ($0^{o}50'$S Lat $40^{o}50'$ W Long), which yielded the following dates:

SI 386, cut A, level 45 to 60 cm ..... 1470 ± 200 y ;
SI 387, cut A, level 60 to 75 cm ..... 1380 ± 200 y .

Thus, SI-199, SI-386 and SI-387 are consistent and curently reported for the Marajoara phase dates (4).

The Ananatuba phase has been dated from charcoal found at the PA-J-26 Castanheira site ($1^{o}00'$S Lat, $48^{o}40'$ W Long), cut A, level 40 to 50 cm (5). The value found of 2930 ± 200 y. yielded the earliest ceramic complex on Marajo island and in fact was much earlier than anticipated.

3 - Descriptions of Samples

The samples investigated were shards of Ananatuba, Mangueiras and Marajoara phases, from the same stratigraphic levels as the C-14 dated charcoal samples:

PA-J-26 B - 30 to 40 cm ..... Ananatuba 78
PA-J-26 B - 40 to 50 cm ..... Ananatuba 79
PA-J-26 A - 30 to 40 cm ..... Mangueiras 69
PA-J-21 C - 78 to 98 cm ..... Marajoara 48
PA-J-36 A - 45 to 60 cm ..... Marajoara 161
PA-J-36 A - 60 to 76 cm ..... Marajoara 162

The six ceramics samples were composed of pedological alteration of a micaceous clay containing small quantities of small (10-20µm) deterial quartz grains. From thin section studies it appears that the clay minerals constituting the ceramics were used in a crude state, without any preceeding processing, except for Marajoara sample 161 in which a siliceous vegetal tempering was employed.

The presence of carbonaceous (bitumeous) residues in the ceramic matrix indicated that the firing temperature was less than 700-800°C. The sherds are coated with a clear coating approximately 1 mm thick which appears to be kaolinite based, a phase frequently present in tropical ferralitic soils.

The siliceous residue obtained after an acid, treatment of the finely crushed ceramics, which was used for TL analysis, was composed of cristalline materials - quartz and detrital feldspar - as well as amorphous materials. The later comprises both materials of mineral origin, silicate residues from the heated clay, and spores and phytollites naturally disposed in the clay matrix. For Marajoara sample 161, only fragments of siliceous wood, probably precalcinated, were intentionally added (6).*

4 - Experimental Procedures

Fragments from the internal part of the sherds were pulverized in a mortar. The powder was washed in 6N HCl for 24 hours. After thorough washing with water, alcohol and acetone the fine phase was deposited on stainless steel discs, using the technique of Zimmermann (7).

The thermoluminescence measurements were made using a

furnace described elsewhere (8) and a photomultiplier Radio--technique XP 1230 with a quartz light guide behing an optical filter MTO 380C' (maximum transmission at 380nm). The photons detected were counted in a multichannel analyser SA 40 B operating in the multiscaling mode.

Two series of thermoluminescence curves are shown in figure 1, corresponding to Marajoara 48 (Fig. 1A) and to Marajoara 162 (Fig. 1B). Well reproducible, these curves illustrate the general behaviour of all the samples, which exhibited a peak near 100°C (with the irradiated samples), probably due to a small amount of quartz and a large tail-extending out to more than 500 C (feldspar ?).

The curves shown in figure 2A, corresponding to Marajoara 161, differ from those of figure 1A (Marajoara 48) by the presence of a marked level of parasite light above 400°C. This light is probably associated with the presence of fragments of siliceous vegetals, as mentioned earlier. The thermoluminescence glow curves obtained with a sample of these fragments extracted under microscope from the sherds is shown in figure 2B. After this heating and exposition to 2 k rad β radiation dose, these fragments yield a very weak light intensity (Fig. 2C).

5 - Internal and Environmental Radioactivity

Table 1 lists the concentrations of U, Th, K deduced from gamma spectrometry measurements (9). About 15 to 50 g of samples, sealed in 4 cm x 4 cm lucite cylindrical containers, were measured in a gamma-gamma coincidence spectrometer consisting of two NaI(Tl) scintillators of 12.7 cm x 12.7 cm. The samples are placed between the two detectors, which are surrounded by iron and lead shielding, each of 15 cm thickness. Coincidence spectra are obtained by a 4096 channel X-Y bi-parametric pulse--height analyser. Uranium is measured via its daughter ^{214}Bi, which emits cascade gamma rays of energies of 0.609 and 1.120MeV; Thorium-232 from cascade gamma rays of 0.583 and 2.614 MeV emitted by ^{208}Tl. 40K is measured with the same equipment but by direct (non-coincidence) measurement of the 1.46 MeV gamma rays. The errors in this method do not exceed 5%.

The specific dose obtained by W.T. Bell (10) has been used to calculate the annual beta dose. The results are listed in column 1, table II.

To calculate the contribution from alpha particles, we compared the TL's from irradiated samples with alpha particles of ^{238}Pu and beta particles of Sr-Y^{90}. The beta dose equivalent to the total annual alpha radiation dose has been calculated using the expression

$$d_{equ} = \frac{TL\alpha}{TL\beta} \cdot \frac{\text{applied } \beta \text{ dose}}{\alpha \text{ flux } Pu^{238}} \cdot \phi$$

where TLα, TLβ are the induced TL from the two types of radiation and ϕ the annual flux of alphas at the internal part of the sample calculated using the figures given by M.J. Aitken and S.G. Bowman(11).

The environmental gamma radiation contribution has been calculated from the U, Th and K concentrations at different depths for soil samples collected at the Ilha dos Bichos site on Marajo Is. The average value obtained, 127 ± 20 mrad, is assumed to be representative of the environmental contribution for all the sites investigated; however, further work is required with soils from different sites to confirm this assumption.

6 - Results

Column 1 in table III lists the archeological radiation doses obtained by irradiation with a Sr-Y^{90} source. The errors given include the error of source calibration.

The total annual doses are listed in column 2. Column 3 lists a correction factor which accounts for the water impregnation of the sherds and the soil. These values were obtained from measurements in a water porosimeter. We have assumed that the moisture content varies according to the wet and dry seasons at Marajo, which correspond to 9 months of satured humidity and 3 months of dryness. The moisture content of the soil has been assumed to be identical to that of the measured sherds. The possible error due to this assumption is small since it effects only the gamma contribution which does not exceed one fourth of the total dose.

The TL ages are listed in column 4, and the C-14 ages in column 5.

7 - Discussion

The values for dates obtained by TL are in general satisfactory, as can be ssen from the comparison with those obtained by the C-14 method. For the older samples, the two sets of values are coincident in the limit of the errors. This illustrates the applicability of thermoluminescence for the study of the Amazon basin cultures which, as was stated at the beginning rests almost entirely on pottery evidence.

For the Marajoara phase, two of the dates obtained are comparable in value with those of C-14. In spite of the large difference between TL and C-14 ages for the Marajoara 48 sample, it is important to observe that the age 628 ± 70 y is in the limit of ages accepted by archaeologists for this phase.

A more complete study, including all archaelogical phases of the Marajo Is. is being undertaken by the method described above and also by dating the separate minerals of the sherds.

8 - Acknowledgements

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Figure Captions

Fig. 1 A. TL glow curves of seven discs from Marajoara sherd 162

Lower curves: three TLN glow curves
Upper curves: four (TLN + 924 rad) glow curves

B. TL glow curves of seven discs from Marajoara sherd 48

Lower curves: three TLN glow curves
Intermediate curves: three (TLN + 462 rad) glow curves
Upper curve : (TLN + 924 rad) glow curves

Fig. 2 A. glow curves from Marajoara 161 sherd, upper curves correspond to a supplementary irradiation of 924 rad.

B. glow curve of five, about 1 mm size silicic wood, fragments sorted from the ceramic.

C. glow curve of these fragments exposed to 2 krad radiation dose.

TABLE I

RADIOELEMENTS CONCENTRATIONS

SAMPLE	U(ppm)	Th(ppm)	K %
Ananatuba 78	2,2	13,30	1,13
Ananatuba 79	2,4	13,52	1,10
Marajoara 161	1,91	10,30	0,88
Marajoara 162	4,16	17,30	1,77
Marajoara 48	3,80	16,40	1,33
Mangueiras 69	2,80	13,20	1,39

TABLE II

COMPUTED ANNUAL RADIATION DOSES (mrad/year)

SAMPLE	1 β	2 α	3 γ	4 TOTAL
Ananatuba 78	168.5	222.0	127	517.5
Ananatuba 79	169.5	269.5	-	566.0
Marajoara 48	134.0	233.0	-	494.0
Marajoara 161	264.0	357.0	-	748.0
Marajoara 162	218.0	287.0	-	632.0
Mangueiras 69	199.5	321.0	-	647.5

Column 1 : deduced from concentrations in (V, Th, K) (Table I) and from the specific radiation doses calculated by W.T. Bell (ref. 10).

Column 2 : equivalent β doses (see text).

Column 3 : approximate environmental radiation dose rate (see text).

TABLE III

Céramiques	Archaeological Radiation doses	Annual Radiation doses	θ	TL Age (B.P)	C^{14} Age (B.P)
Ananatuba 78	1624 ± 5%	517.5 ±7.5%	0,92	3411 ± 300	
Ananatuba 79	1526 ± 5%	566 ±7.5%	0,88	3063 ± 275	2930 ± 200
Mangueiras 69	1812 ± 6%	647.5 ± 8 %	0,92	3042 ± 275	
Marajoara 161	785 + 8% - ?	494 ± 9 %	0,92	1730 + 200 -?	1470 ± 200
Marajoara 162	610 ± 5%	748 ± 9 %	0,88	928 ± 90	1370 ± 200
Marajoara 48	365 ± 5%	632 ±9.5%	0,92	628 ± 70	1260 ± 200

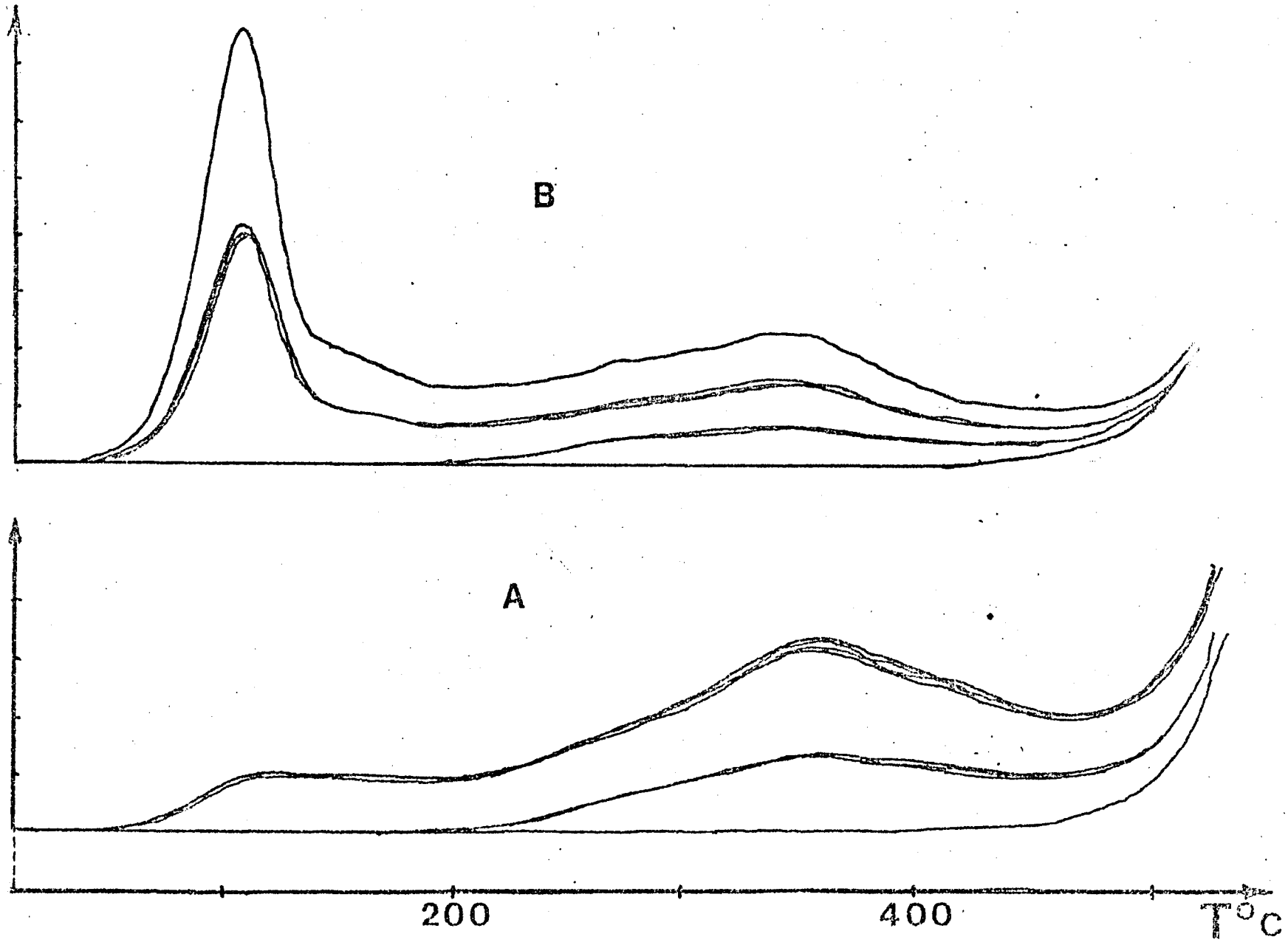

Fig. 1

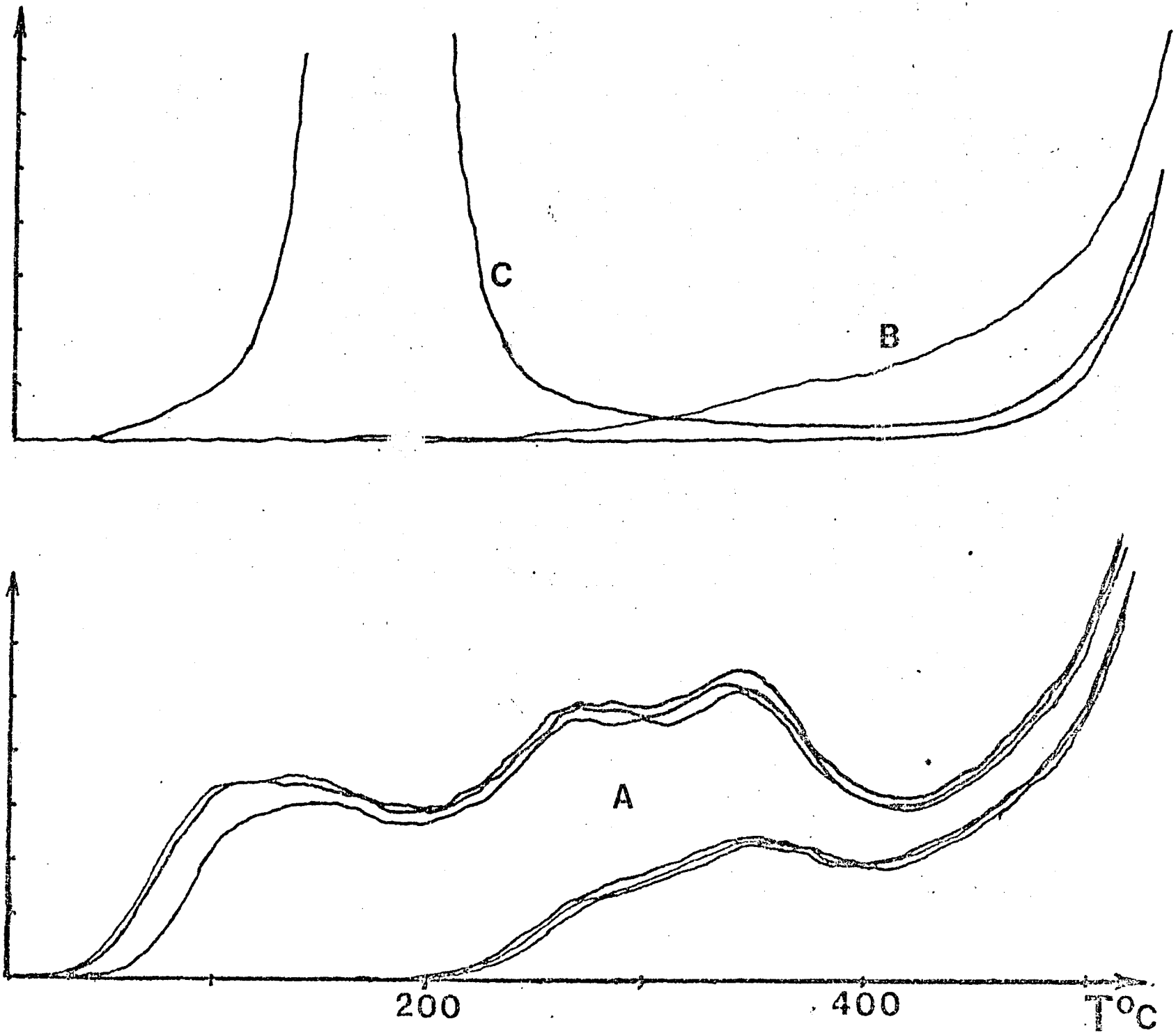

Fig. 2