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A MODEL TO DATE STONE AGE SITES WITHIN AN AREA OF ABNORMAL UPLIFT IN SOUTHERN FINLAND

Abstract

A shoreline displacement model is developed for a small area comprising the so-called Porvoo-Askola-Lapinjärvi uplift anomaly. The model consists of two shoreline displacement curves derived through regression analysis of radiocarbon-dated positions of the Baltic water level, and it permits by means of mathematical calculations or a diagram the dating of waterside Stone Age sites within the study area. The dates obtained are in agreement with the general chronology recently proposed by Dr. A.Siiriäinen.

Introduction

The relative chronology of the Finnish Stone Age was introduced as the result of the joint research of RAMSAY and ÄYRÄPÄÄ some fifty years ago (RAMSAY 1920, 1926; ÄYRÄPÄÄ 1926, 1930). It was based on the fact that, due to the upheaval of the Fennoscandian land mass, the present altitudes of the prehistoric waterside dwelling sites are proportional to their ages, the older the site the higher it will occur. More comprehensive research has recently shown the order of cultural succession as presented by ÄYRÄPÄÄ (1926, 1930, 1934, 1940, 1950, 1955) to have been fairly correct (SIIRIÄINEN 1969, 1970, 1971, 1972, 1973). The dating system employed by SIIRIÄINEN has the advantage of being also applicable to inland sites and of being partly based on radiocarbon-dated levels leading, consequently, to a chronology relatable to radiocarbon dates.

Although SIIRIÄINEN's system gives good results throughout most of Finland, it seems to show discrepancies in certain areas. For instance in the Porvoo-Askola-Lapinjärvi area, which SIIRIÄINEN (1969, 1972, 1973), as ÄYRÄPÄÄ (1929) had previously done, attributes to local irregularies of the land uplift. Since my research was to deal with this particular area it was obvious that SIIRIÄINEN's model could not be used, and a different more adequate model had to be found.

My intentions were to study the settlement pattern and culture change within a small area in southern Finland (the Porvoo river valley) and, to start with, a series of paleogeographical maps were required to examine the settlement pattern and its response to the changing landscape through time. This

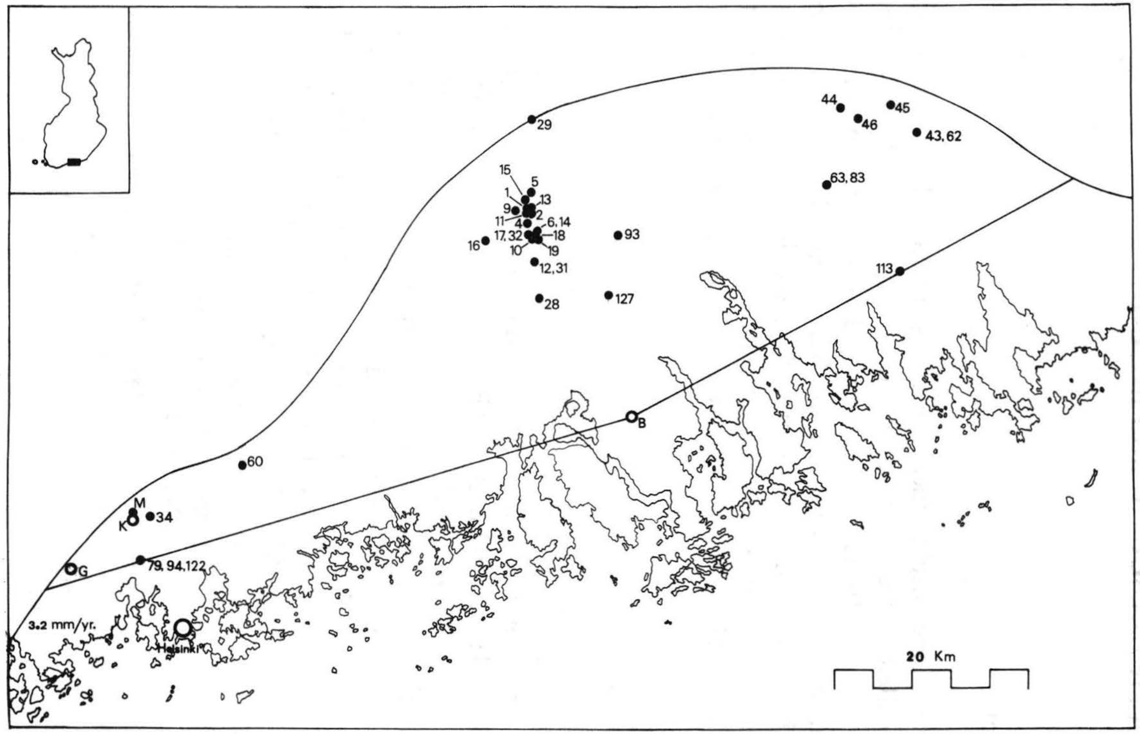

Fig. 1. The study area. The dots represent the archaeological sites of Table 2, the circles sites with dated positions of the sea level: B = Bastuberg, G = Gallträsket and K = Kilteri.

could be achieved by developing a model representing the shoreline displacement in the study area. The present paper deals with the development of such a model.

The geographical situation and extension of the study area can be observed from fig. 1. The area is bounded by the farily regular arch made by KÄÄRIÄINEN's (1963, 1966) 3.2 mm/yr. uplift isobase and two radius-like straight lines which join the isobase with a more or less centrally situated point at Bastuberg. The somewhat strange boundaries are functional and not arbitrarily chosen. The Bastuberg bog is roughly symmetrically centered with respect to the arch formed by the present uplift isobases in the area (see KÄÄRINÄINEN's map 1963, 1966) and this is very convenient because there are some well-dated positions of the Baltic level from this bog (ERONEN 1974). In the same way, there are similar data concerning some points by the 3.2 mm/yr. isobase, hence its choosing as a boundary seems appropriate.

Thanks to numerous investigations the study area counts with suitable radiocarbon dates and its geological and archaeological histories are well documented (e.g. AILIO 1909; RAMSAY 1920, 1926; ÄYRÄPÄÄ 1922, 1925, 1926, 1929, 1930, 1950, 1955: SAURAMO 1923, 1937, 1954, 1958; CLEVE 1929; AARIO 1935a, b; HYYPPÄ 1935, 1937, 1950, 1966; LEPPÄAHO 1935; LUHO 1944, 1956, 1957, 1965, 1967; VIRKKALA 1953; TYNNI 1956, 1966; DONNER 1964, 1966, 1969a, 1970; EDGREN 1969; SIIRIÄINEN 1969, 1972, 1973; NIEMELÄ 1971; ALHONEN 1972; FORSTEN 1972; ANONYMOUS 1974; ERONEN 1974, 1976a; FORSTEN & BLOMQVIST 1974; NUÑEZ 1975, 1978a, 1978b; RAUHALA 1975; VÄKEVÄINEN 1975; also AAONBA).

On the basis of these sources the history of the area may be summarized in the following manner: By c. 10500 bp the area had become ice-free, but most of it was to remain submerged for a long time (cf. HYVÄRINEN 1975). By c. 9000 bp, approximately the time of the Ancylus transgression maximum, a great part of the area was still under water. It was probably around this time when Mesolithic man began to exploit the area. A considerable extension of land emerged as the result of the rapid Ancylus regression which seems to have taken place between 9000 and 8500 bp. The level of the Baltic rose again during the Litorina period reaching its peak around 7000 bp. The amplitude of this transgression renged from a couple of metres at Espoo to several metres at Bastuberg. The displacement of the shoreline seems to have been regressive after the peak of the Litorina transgression. The adoption of pottery (phase Ka I1) occurred sometime during the second half of the seventh millenium bp. The Combed-ware culture developed through all its phases until around 4000 bp. The present paper only deals with the period 9000–4500 bp. All dates, unless otherwise specified, are in conventional radiocarbon years ($t_{1/2}$ = 5568 yrs.). The symbols for the cultural phases are those used by SIIRIÄINEN (1969) with the exception of 'S', which here is taken to represent the whole preceramic stage.

Some basic concepts and assumptions

There are indications that the updoming of Fennoscandia is broadly speaking fairly regular (DONNER 1966, 1969a, 1970). Moreover, the present pattern of uplift isobases as despicted by KÄÄRIÄINEN (1953, 1963, 1966) seems to correlate with that of the highest Litorina isobases according to the geological data (cf. ERONEN 1974; SAURAMO 1958; HYYPPÄ 1937, 1963, 1966). However, the existence of irregularities in the uplift has also been noticed. There are indications of a hinge in southeastern Fennoscandia (DONNER 1966, 1969a, 1970; SIIRIÄINEN 1969, 1972, 1973; SAARNISTO & SIIRIÄINEN 1970) and of the drifting of the centre of uplift (ERONEN 1974). Furthermore HÄRME (1961, 1966) has pointed out the possibility of local uplift irregularities due to the differential movement of crustal blocks, and more recent research seems to support this theory (TUOMINEN et al. 1973). Nevertheless SIIRIÄINEN's (1969, 1972, 1973) model 'which assumes a regular uplift' gives consistent results throughout the Finnish mainland outside the Porvoo-Askola-Lapinjärvi area. These apparently contradicting results could be reconciled if the errors associated with the archaeological data were of the same or greater magnitude than the possible differences caused by local uplift irregularities.

In any event, a radiocarbon-controlled shoreline displacement model was developed and successfully tried. This model, the development of which is described further below, was based upon the following considerations:

1. The rate of present uplift within the study area is not very fast (3.2–2.5 mm/yr., KÄÄRIÄINEN 1963, 1966) nor does it seem to have considerably decreased during the past 7000 years (cf. ERONEN 1974) and considering that the updoming is fairly smooth, the errors introduced by using a generalized ideal model should remain small.
2. The great distance from the study area to the centre of uplift (over 400 Km) renders the possible error resulting from its drifting neglegible.
3. As long as the model is based on radiocarbon-dated positions of the water level the shoreline displacement diagrams should remain fairly correct.
4. The error associated with some of the archaeological data is of the same magnitude or greater than the possible differences resulting from local uplift irregularities.
5. On the basis of the four precedent considerations we can assume a regular uplift which has been taking place along a pattern of isobases similar to that of today. From this follows that within the study area distances from the centrally situated bog of Bastuberg should be proportional to altitudes; in other words, the horizontal and vertical distances from Bastuberg should be proportional. This is probably best explained by the schematic illustration of fig. 2.

Actually the basic concepts of this model are very similar to those of SIIRIÄINEN's (1969, 1972, 1973): A regular uplift occurring more or less in the same fashion through time and a correlation between altitudes and radial distances from a central zone or base line. The main difference between the two models is the size of the area involved.

The model

The position of the Baltic water level with respect to a site a through time can be defined as a continuous function of time $F_s(t)$ in the following manner:

(1) $F_s(t) = b(t) + u_s(t)$,

where b(t) and $u_s(t)$ are both continuous functions respectively representing the position of the water level of the Baltic with respect to the present one and the isostatic uplift at the site in question. If we had enough dated positions of the water level within a certain area, it would be possible to derive a fairly accurate approximation for F(t) in that area. Suitable points can be secured from radiocarbon-dated transgression and isolation levels in sediments of bogs and lakes. More points can be obtained by using radiocarbon-dated archaeological sites, provided that they have been carefully tied to their contemporary shoreline through a clear lower limit of finds (cf. NUÑEZ 1978a). Unfortunately, we do not count with enough of such points in the study area and, consequently, we must wait until these are produced.

On the other hand, the research carried out by BERGLUND (1964, 1971) in Blekinge, southern Sweden, provides us with a fairly well dated curve for the shoreline displacement in that area. The Blekinge area is situated close to the present zero isobase, about half way between this and the 0.5 mm/yr. isobase (see ERONEN 1974 p. 94). The shoreline displacement at Blekinge can be defined as follows:

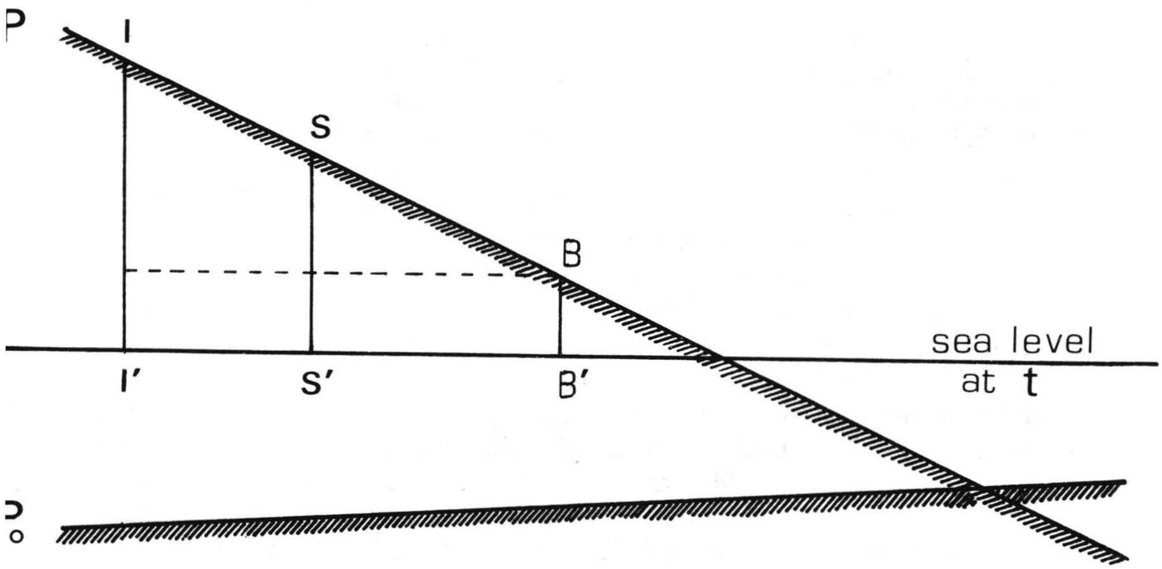

Fig. 2. Schematic representation of any radial cross-section of the study area from an initial position P_o at to a second position P after a time t. B, S, I are respectively Bastuberg, a site S and the 3.2 mm/yr. isobase. If H = II' – BB', h = SS' – BB', D = B'I' and d = B'S', then: h/H = d/D.

(2) $F_{Bl}(t) = b(t) + u_{Bl}(t)$,

where $u_{Bl}(t)$ is the isostatic uplift at Blekinge. Substituting for b(t) in (1) we have:

(3) $F_s(t) = F_{Bl}(t) - u_{Bl}(t) + u_s(t)$

And if we define:

(4) $U_s(t) = u_s(t) - u_{Bl}(t)$, then

(5) $F_s(t) = F_{Bl}(t) + U_s(t)$.

The shoreline displacement at Blekinge, $F_{Bl}(t)$, can be expressed as a polynomial of the form:

$$F_{Bl}(t) = a_0t^0 + a_1t^1 + a_2t^2 + \ldots + a_nt^n,$$

which can be arrived at through a regression program by the method of the least squares. The points to be used are the dated positions of the water level (Table 1 no. 1–16) and a few additional points taken from BERGLUND's (1964, 1971) results in order to control the curve. These were $F_{Bl}(73) = 0$, $F_{Bl}(57) = 7.6$, and $F_{Bl}(25) = 2.0$. The best fit obtained was a fifth degree polynomial with the following coefficients (for t in centuries bp):

$a_0 = -154.0701$	$a_3 = 0.1025392 \times 10^{-1}$
$a_1 = 15.63338$	$a_4 = -0.8120146 \times 10^{-4}$
$a_2 = -0.5858677$	$a_5 = 0.2184093 \times 10^{-6}$

$F_{Bl}(t)$ cannot be expected to behave outside the interval t = 73–25 cent. bp owing to the lack of points fed to the computer. The younger portion of the curve may be approximated by joining $F_{Bl}(30)$ to $F_{Bl}(0)$ set to be zero with a straight line. $F_{Bl}(t)$ wihtin the interval t = 73–0 cent. bp has been plotted in fig. 3.

The function representing the idealized land uplift is less complex and therefore easier to define. Since $u_{Bl}(t)$ and $u_s(t)$ are continuous differentiable (smoothly changing) functions their substraction is also, and may be derived as follows: ERONEN (1974) has two dated positions of the sea level at the Bastuberg bog, which having its threshold at c. 28.5 m a.p.s.l. has undergone transgression and isolation around 7250 and 6230 bp (see Table 1 no. 17, 18). Recalling (5) we have:

(6) $U_B(t) = F_B(t) - F_{Bl}(t)$, and
$U_B(72.5) = 28.5 - 1.5 = 27.0$ m
$U_B(62.3) = 28.5 - 7.1 = 21.4$ m.

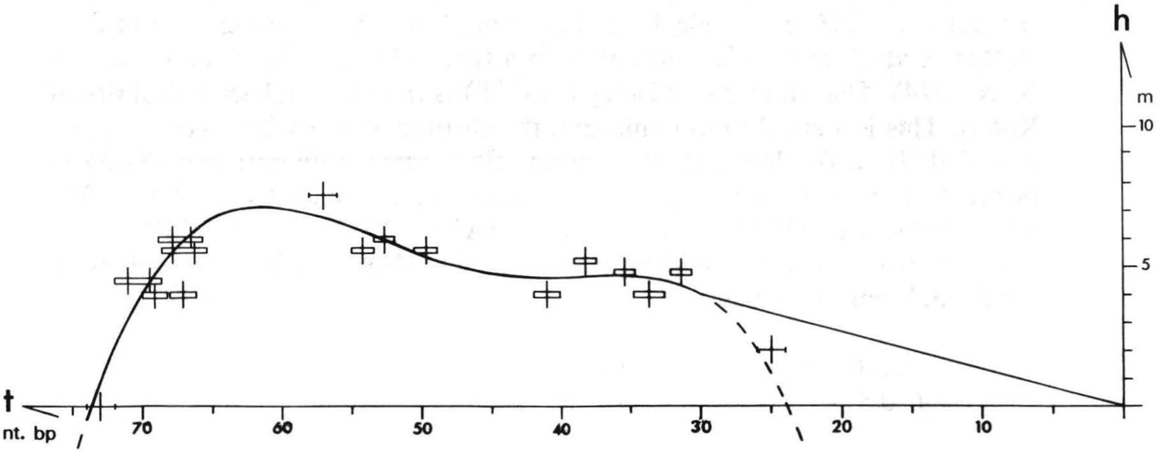

Fig. 3. The curve representing the shoreline displacement at Blekinge. Explanation in the text.

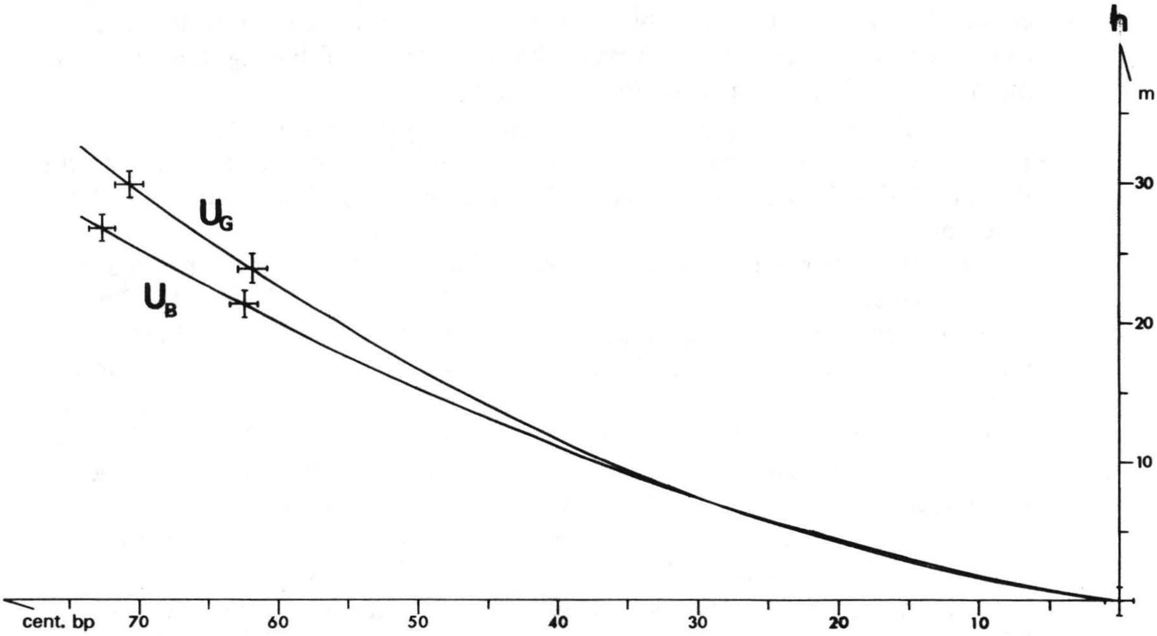

Fig. 4. Best fits for the uplift functions at Bastuberg ($h = U_B(t) = 0.0029t^2 + 0.1589t$) and Gallträsket by the 3.2 mm/yr. isobase ($h = U_G(t) = U_{32}(t) = 0.0044t^2 + 0.1133t$).

Also there are two dated water levels from two sites located only c. 6 Km apart, both situated by the 3.2 mm/yr. isobase of present uplift. One of the dates, c. 6200 bp (Table 1 no. 17) comes from the isolation level of Gallträsket, a small lake in Kauniainen with a threshold of c. 31 m a.p.s.l. (ERONEN 1974). The other date (Table 1 no. 18) is from the archaeological site of Kilteri. This is a small preceramic site, the altitude of which has been carefully recorded. Here the lower limit of quartz finds agrees well with the 33–34 m position of the sea level at c. 7000 bp. according to the geological data (ERONEN 1974; ALHONEN 1972; cf. also AARIO 1935a, b; HYYPPÄ 1935, 1937, 1950). Thus, in the same way as in Bastuberg, we have the following for the 3.2 mm/yr. isobase:

$$U_{32}(61.8) = 31.0 - 7.2 = 23.8 \text{ m}$$
$$U_{32}(70.5) = 33.5 - 3.6 = 29.9 \text{ m}.$$

With these four points and setting the sea level to be zero at t = 0 when possible, we can obtain least square fits for both $U_B(t)$ and $U_{32}(t)$. The best fits are the parabola pair of fig. 4. The type of function generally thought to represent the isostatic upheaval is the exponential function (OKKO 1967), but parabolic best fits have also been obtained for periods not immediately following deglaciation (e.g. DONNER & JUNGNER 1975).

It could at this point be argued that the use of computer would not have been necessary for tracing the curves, especially such simple ones as the uplift curves ($U_B(t)$ and $U_{32}(t)$) but, apart from the possible subjective element associated with hand-drawn curves, the advantages of having the curves in mathematical form already justify the procedure.

On the basis of the above calculations $F_B(t)$ and $F_{32}(t)$ can now be plotted wihtin the interval t = 73–0 cent. bp, but this does not include the period 9000–7300 bp associated with the early Mesolithic occupation of the study area.

On the other hand, there are some radiocarbon dates for the regression of the Ancylus Lake in southern Finland (ERONEN 1974, 1976a, b). The regression seems to have taken place rapidly, within a period of about 500 years, and it can be considered to be a fairly synchronous event in the shoreline displacement of the Baltic (ERONEN 1976a). On this basis $F_B(t)$ and $F_{32}(t)$ within the interval t = 90–85 cent. bp can be represented by a single curve derived from ERONEN's radiocarbon-dated levels at the bogs of Bastuberg and Hangassuo (Table 1 no. 21–23). TYNNI (1966) has also a date (c. 8600 bp) for the Ancylus regression at Askola, but it seems slightly too young when compared with ERONEN's Hangassuo dates. ERONEN's dates were preferred because they provide a less violent regression. Hangassuo is only some 30 Km NE of the study area, between the present 3.4 and 3.6 mm/yr. isobases, but since the regression seems to have taken place within 500 years the error introduced by using these dates is not significant.

The remaining interval t = 85–70 cent. bp could be approximated with the help of some of the geological data. Knowing the date and minimum levels

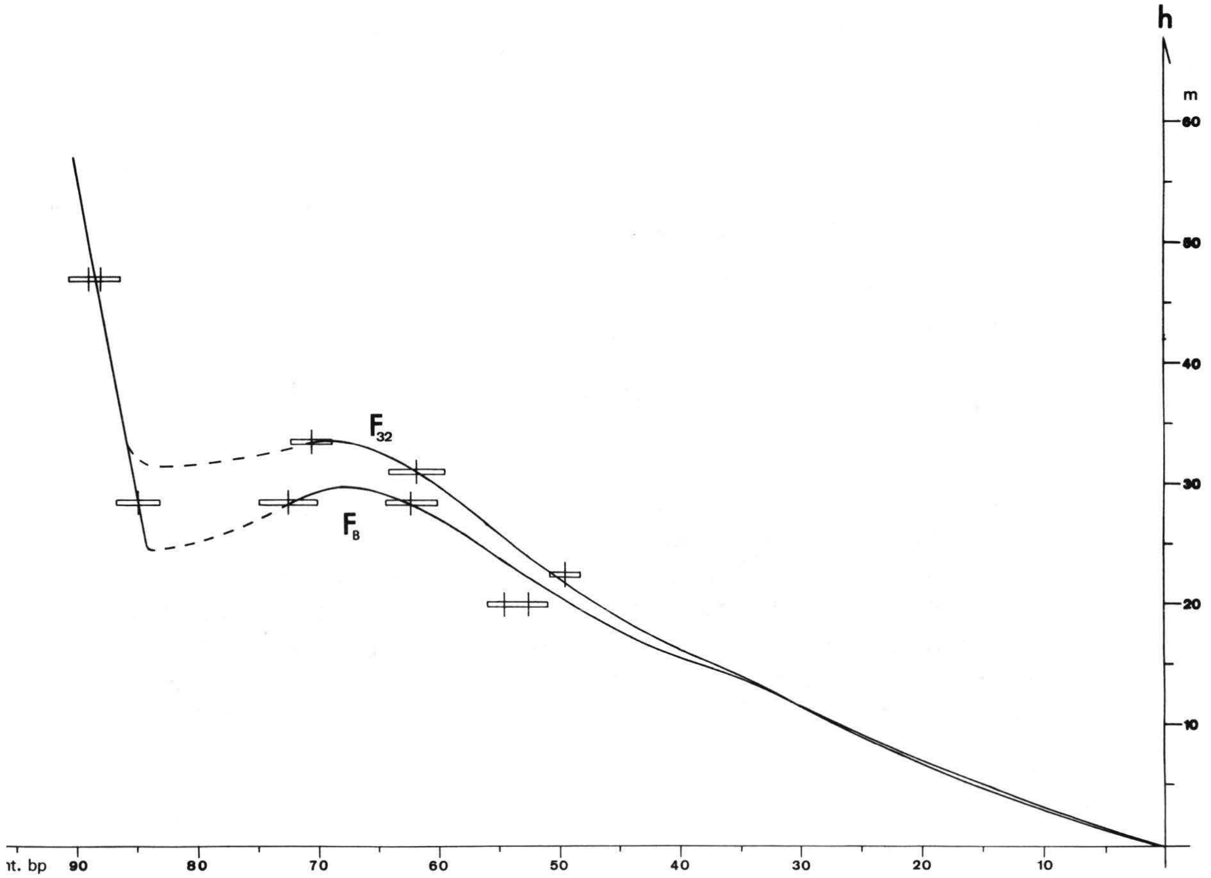

Fig. 5. The shoreline displacement at Bastuberg (F_B) and the 3.2 mm/yr. isobase. The local radiocarbon dates used to derive the curves (Table 1 n. 17–23) and to test them (Table 1 no. 24–26) have been included.

reached by the Baltic at both Bastuberg and Gallträsket between the Ancylus and Litorina transgression peaks, it is possible to trace a schematic path for $F_B(t)$ and $F_{32}(t)$ within t = 85–70 cent. bp.

According to ERONEN's (1974) calculations based on dates from north Ostrobothnian basins, a slow-down of the regressive displacement of the water level must have occurred sometime between 8400 and 7600 bp as a consequence of the connection with the rising ocean. Although ERONEN (1974) dates this event to c. 8300 bp, he (1976a) later places it within the period 8500–8000 bp, stating that it has never been accurately defined. BERGLUND (1964), on the other hand, estimates the beginning of the Mastogloia phase at Blekinge at c. 8500 bp. However, regression seems to have been still taking place at Bastuberg around 8500 bp (ERONEN 1974). Thus, an arbitrary date of c. 8400 for the minimum in the study area seems a fair choice, the difference in the rates of uplift within the study area being too small to matter for our purpose.

We know that the minimum at Gallträsket was slightly over the 31 m treshold (HYYPPÄ 1935, 1937, 1950; ALHONEN 1972; ERONEN 1974) and, setting this minimum to be 31.5 m, we can arrive at a rough approximation for the corresponding minimum at Bastuberg. Recalling:

$$(5)\quad \begin{aligned} F_s(t) &= F_{Bl}(t) + U_s(t), \text{ and} \\ F_B(t) &= F_{Bl}(t) + U_B(t) \\ F_{32}(t) &= F_{Bl}(t) + U_{32}(t). \end{aligned}$$

Then rearranging and substituting for all values:

$$\begin{aligned} F_B(t) &= F_{32}(t) - (U_{32}(t) - U_B(t)), \text{ and} \\ F_B(84) &= 31.5 - (0.0015(84)^2 - 0.0456(84)) = 24.7 \text{ m} \end{aligned}$$

The figure of c. 24.5 m above present sea level for the minimum at Bastuberg should be regarded only as a rough approximation. It is a couple of metres lower than ERONEN's (1974 p. 126–127) estimate but the actual figure may be even lower, judging by the corresponding minimum of c. 27 m reported from the Suurisuo bog in Askola (VIRKKALA 1953). Precision is not required from this region of the curves because the sites cannot be accurately dated due to the nature of the shoreline displacement during the period. $F_B(t)$ and $F_{32}(t)$ within the interval t = 90–0 cent. bp have been plotted in fig. 5.

Knowing the shoreline displacement at both the centrally located Bastuberg bog ($F_b(t)$) and the periphery of the study area ($F_{32}(t)$) the waterside dwelling site can be easily dated. The dating is done on the basis of the already mentioned correlation between the horizontal and vertical distances from Bastuberg to other sites within the study area (see fig. 2), making use of the proportions:

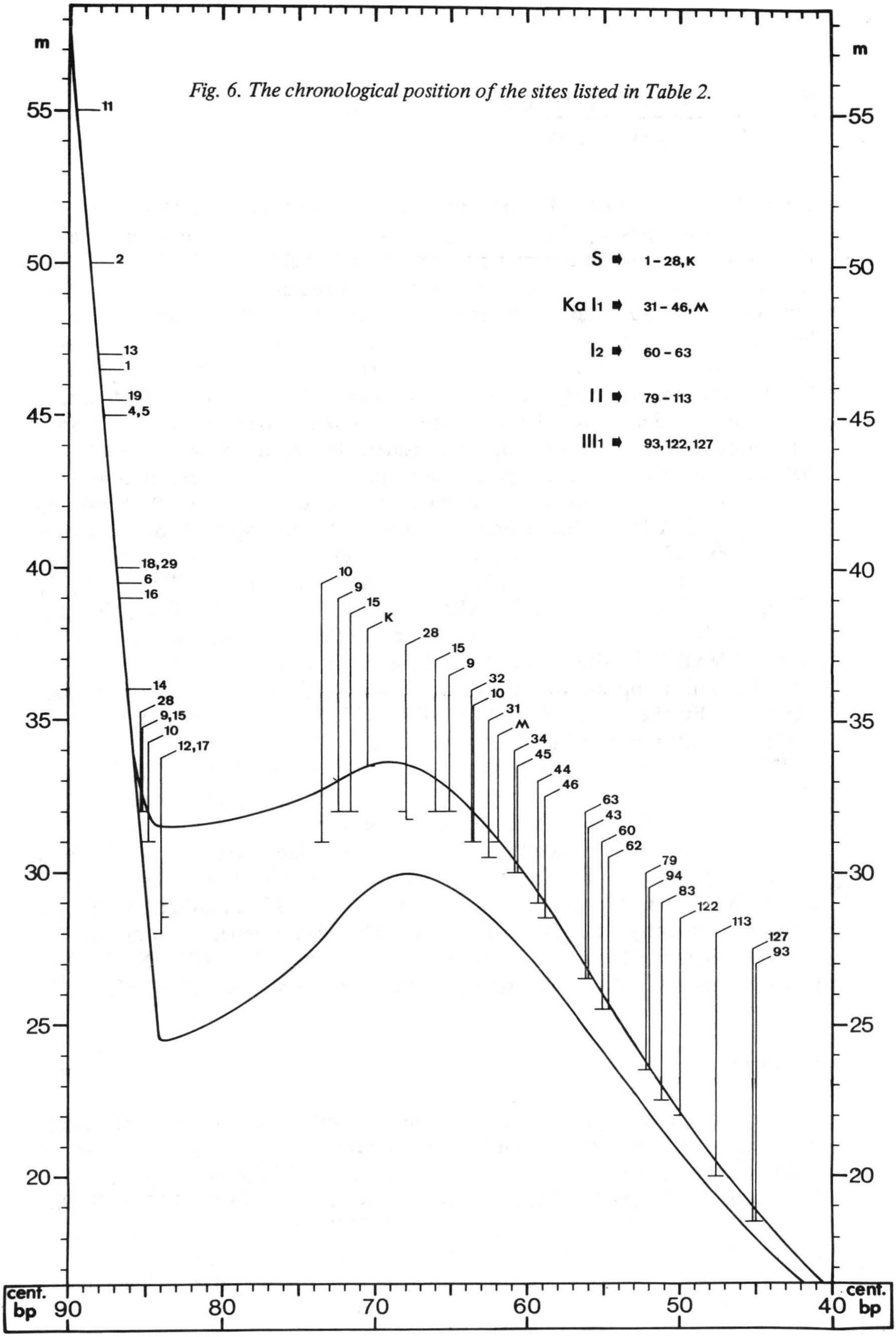

Fig. 6. The chronological position of the sites listed in Table 2.

$$\frac{\vec{d}}{D} = \frac{\vec{h}}{H} = \frac{F_S(t) - F_B(t)}{F_{32}(t) - F_B(t)},$$

where d is the horizontal distance from a site s to Bastuberg and D is the length of the "radius" passing through s. The sites can, of corse, be very easily dated by a relatively simple mathematical calculation, but this may also be done with the help of fig. 6. The procedure can be summarized as follows: A site situated, for example, at 30 m above the present sea level and half way between Bastuberg and the 3.2 mm/yr. isobase, i.e. D = 2d, is plotted in the diagram at a point on the 30 m ordinate half way the vertical distance between $F_{32}(t)$ and $F_b(t)$. The chronological position of the site can be then read from the t-axis.

The sites dated must be as carefully as possible tied to their contemporary shorelines. Since this requires a considerable amount of work both in the field and the archives, in this preliminary study the sites used are those recently studied and, consequently, checked by SIIRIÄINEN (1969). However, some of SIIRIÄINEN's listed sites from the study area were left out. The preceramic site of Jönsas because more recent research has shown that the lower limit of the preceramic occupation is difficult to define (PURHONEN 1971, 1972, 1973; PAJARI 1974; PAJARI & OJONEN 1975; OJONEN 1976). Instead the Ka I1 occupation at the same locality (Mätäoja) has been used on the basis of VÄKEVÄINEN's (1972, 1973) excavation reports. The site of Kopinkallio which appears to be a quartz quarry and not necessarily a dwelling site laying by the shore (cf. SIIRIÄINEN 1969, 1973). On the site of Antasbacken the altitude of which has been measured on the basis of the carving of "1872 30 M" found on the Heimåsberget rock, interpreted by LEPPÄAHO (1932, 1934) to represent a mark made by the cartographers meaning 30 m above sea level. But according to the Topographic Office there is no record of such a mark and, consequently, its value as a fixed point is questionable. The carving may have been made by the Russian Army during the last century, hence 1872, of may represent the date May 30th 1872 in either Swedish or Russian. Incidently, it is possible that the altitudes assigned to some of the other Lapinjärvi sites may be erroneously too low (cf. SIIRIÄINEN 1969 p. 70, footnotes 3, 4, 6). The sites plotted in fig. 6 have been listed in Table 2.

Discussion

Several curves representing the shoreline displacement somewhere within the study area have been drawn by various authors on the basis of geological and/or archaeological data (e.g. HYYPPÄ 1937; SAURAMO 1940, 1955; DONNER 1952, 1964, 1965, 1969b; TYNNI 1966; OKKO 1967; SIIRIÄINEN 1972; ERONEN 1974, 1976a, b; NUÑEZ 1978a, 1978b). The curves presented here are closesto to the most recent ones (1974–1978).

The results obtained are in accordance with the available archaeological and geological data from the area: The Ancylus limit at Askola is close to

60 m according to TYNNI (1966) and the figure obtained for t = 90 cent. BP, which is roughly the date of the Ancylus transgression peak (ERONEN 1976a), was c. 57.5 m. The altitude of 33.6 m for the Litorina transgression peak at the 3.2 mm/yr. isobase corresponds to the estimates for the Kauniainen-Espoo area, which is situated by this isobase (HYYPPÄ 1935, 1937, 1950; ERONEN 1974). The 30 m Litorina peak at Bastuberg can be equated to ERONEN's (1974 p. 141) "... a couple of metres beyond the treshold" (c. 28.5 m). The dating of the dwelling sites presented in fig. 6 is in agreement with the radiocarbon dates of the cultural phases (MEINANDER 1971, SIIRIÄINEN 1973). Furthermore, keeping in mind that the present work only involves a limited number of sites within a relatively small area, the dates obtained for the sites correlate well with SIIRIÄINEN's (1973) proposed chronology. Table 3 is provided to facilitate comparisons.

Nevertheless the dates for the boundaries between consecutive cultural phases differ in some cases from those of SIIRIÄINEN's boundaries, but the differences fall well within the margins of error associated with the dating systems.

SIIRIÄINEN (1969, 1972) gives a reasonable estimate of ± 0.5 m for errors due to levelling in the determination of the altitude of dwelling sites. However, this figure should be taken as a minimum since there seems to be other sources of error affecting the archaeological and geological data. The different criteria employed to determine the contemporary shoreline of sites may lead to greater inaccuracy. The contemporary shoreline is sometimes determined on geomorphological grounds, and in these cases the error depends upon the morphological feature itself. Another criterium is the lowest limit of the cultural layer, but the one most commonly used is the so-called lower limit of finds. The lower limit of finds tends to fall somewhat below the lowest limit of the cultural layer, though the difference is probably not too great in most sites (cf. ÄYRÄPÄÄ 1929 p. 28). On the other hand, judging by the excavation reports, the concepts of cultural layer and lower limit of finds seem to vary from one excavator to another. This may in some cases lead to major differences in the results. In any event, since an allowance of ± 1 m is generally made for the determination of thresholds of basins in geological research, such a margin of error should be more appropriate in the present model.

Provided that the assumptions made in the development of the model were correct, in dates from the diagram of fig. 6 the error along the t-axis should fall within the standard deviation of the radiocarbon dates on which the curves have been based, and along the h-axis within ± 1 m. However, the degree of precision varies for different regions of the curves: For t = 90–85 cent. bp the error limit is determined by the corresponding radiocarbon dates (Table 1 no. 21–23). The error for the interval t = 85–70 cent. bp cannot be estimated because this region of the curves is the product of rather rough calculations based only on stratigraphical data. The interval t = 70–62 cent. bp is probably the most accurate portion of the curves, but sites falling within the interval t = 82–86 cent. bp are difficult to date. The nearly stationary sea level around the peak of the Litorina transgression causes the ± 1 m error associated with the altitude of the sites to correspond to a considerable interval along the t-axis; and the nature of the shoreline displacement during the period makes it possible for sites of certain altitudes to be assigned to differently dated shores. In most cases such sites can only be dated to the period 8600–6200 bp. The precision of the curves at around t = 62 cent. bp is again relatable to the corresponding radiocarbon dates (Table 1 no. 18, 19). The closer the idealized model represented by the curves is to the actual shoreline displacement, the more the margins of error should decrease as t goes from 62 cent. bp to zero. For instance the deviation of ± 230 years at t = 62 cent. bp would decrease to about ± 165 years at t = 45 cent. bp.

A rough test for the reliability of the curve can be made by comparing the radiocarbon dates (Table 1 no. 24–26) of hearths from the sites of Holmgård (113) and Liljendal (83) with the corresponding dates obtained from the present model. The radiocarbon-dated hearth from Holmgård yielded ages of c. 5450 and 5250 bp whereas the date obtained from the curves was c. 4750 bp. The difference is just within the acceptable marginal error but, on the other hand, Holmgård seems to be a rather large site (SARKAMO 1956) and the dated hearth needs not belong to the last occupation of the site, which is actually the one dated by the present model. Moreover, there are comparable radiocarbon dates from the same cultural phase (see Table 3). The radiocarbon date from Liljendal, c. 4950 bp, is closer to that obtained from the diagram, c. 5100 bp, and well wihtin the expected margin of error. Thus, although only a very crude test, it suggests that the path of the curves is fairly correct. The position of the Holmgård and Liljendal radiocarbon dates with respect to the curves can be seen in fig. 5.

As it was mentioned earlier, the dates from fig. 6 are in good agreement with both the geological and archaeological data. The date of c. 9000 bp obtained for the highest site in the area, Ketturinmäki (11), agrees with the radiocarbon date of c. 9230 bp (Table 1 n. 29) yielded by the Antrea float and with the Ancylus Lake affinities of this find and those of Heinola and Kirkkonummi (LINDBERG 1916, 1920; HYYPPÄ 1933; AARIO 1934, 1935c; SAURAMO 1951). Moreover the early Mesolithic settlement of Askola has been recently dated to be period of the Ancylus regression (SIIRIÄINEN 1969, 1973; NUÑEZ 1978b). Incidently, according to its altitude, Ketturinmäki could also be assigned to either the Yoldia regression or the Ancylus transgression shores (see TYNNI 1966 p. 90) but there seems to be no reason to consider this site to be considerably older than the rest of the preceramic sites belonging to the Ancylus regression period.

Similarly, due to the nature of the shoreline displacement, several preceramic sites may date either to the Ancylus regression, the Litorina transgression or the Litorina regression shores. In these cases certain somewhat arbitrary decisions were made. For instance all ceramic sites were considered to be younger than the Litorina transgression maximum, since it was reasoned that an older date would imply the adoption of pottery in Finland considerably earlier than in the surroinding territories.

This sets the date of the highest ceramic site of the area, Siltapellonhaka (32), at c. 6350 bp which is some 200 years but not significantly different from SIIRIÄINEN's (1973) date of c. 6150 bp for the Meso/Neolithic boundary. However, the criterium used by SIIRIÄINEN to draw his boundaries is the latest and not, as conventionally done, the earliest manifestation of each cultural phase. In that case the date for the S/Ka boundary would be given by the lowest preceramic sites (Mattila (12) and Siltapellonhaka (17) both at c. 28 m a.p.s.k.) which according to their altitude may be dated to either the period between the Ancylus and Litorina transgression peaks when the water level had receded to a minimum around 8400 bp (see p. 28) or to a Litorina regression shore around 5850 bp. The first possibility sets the sites well within the preceramic period and the S/Ka boundary is then marked by the site of Jusla (10) at around 6350 bp, which is the same date obtained for the earliest ceramic site in the area. The second possibility also provides a date comparable to SIIRIÄINEN's 6150 bp but it would imply an overlap of c. 500 years between the Suomusjärvi culture and the earliest Comb Ceramics phase, Ka Il.

The lowest preceramic sites from Askola (12, 17) present an interesting problem because they occur some 2 m below the highest local ceramic sites (31, 31). This problem has been discussed by LUHO (1957, 1967) and more recently by SIIRIÄINEN (1969, 1972, 1973). The difference in altitude has been generally explained as the result of a transgression though it has not been clear which one. The problem has been simplified by ERONEN's (1974) recent research which indicates that there was only one transgressiove event in the area during the Litorina period. Although the younger date is also possible, there are according to LUHO (1957, 1967) certain features at these two preceramic sites which suggest the washing of the cultural layer (cf. SIIRIÄINEN 1973). Moreover, when the S gradient for the coastal region is calculated on the basis of the Jusla site the result (17.2 cm/Km) is much closer to the corresponding gradient for the Päijänne district (17.5 cm/Km) than the gradient obtained on the basis of the Siltapellonhaka site, 18.2 cm/Km (cf. SIIRIÄINEN 1970, 1971, 1972, 1973). Therefore, the lowest preceramic sites at Askola (12, 17) were dated to c. 8400 bp.

The placing of these two sites in fig. 6 does present some problems: Their low altitude does not quite fit the expected proportion between radii and altitudes, but on the other hand the curves are not very accurate within the interval t = 85–70 cent. bp (see p. 34) and, furthermore, the water level did recede to a low position of c. 27 m a.p.s.l. in the Askola area (VIRKKALA 1953). Nevertheless, if the margin of ± 1 m is taken into account the proportion also holds for these sites.

The dates of the boundaries do not differ significantly from those proposed by SIIRIÄINEN (1973), perhaps with the exception of the KA II/III boundary. If SIIRIÄINEN's (1969) data is used the Ka II/III boundary is set by the site of Honkaniemi (93) at around 4500 bp, some 250 years later than the date proposed by him (1973). The young date obtained for this site is due to its low altitude, on the basis of which a local irregularity of the land uplift has been claimed (ÄYRÄPÄÄ 1929; SIIRIÄINEN 1969, 1972, 1973).

On the other hand a reappraisal of the evidence allows an alternate interpretation: Honkaniemi is generally regarded as a late Typical Combed ware (Ka 112) site (ÄYRÄPÄÄ 1929; LUHO 1948; SIIRIÄINEN 1969) on the basis of the dominance of sherds belonging to this particular cultural phase, but the site has also yielded a considerable amount of Uskela type (Ka III1) sherds (ÄYRÄPÄÄ 1929 p. 28). According to ÄYRÄPÄÄ (1929 p. 24) the Ka II2 sherds were dominant throughout the site, but he bases this statement on surface finds and not on excavated material. The excavation area amounted to a total of only 106 m^2 (ibid. p. 16, 18) which is less than 5 % of the site's extension (ibid. p. 17). Considering that the site lies within a modern cultivation field (ibid. p. 15–24) we can allow for the spread of sherds through plowing. Now, if the site had been intensively occupated during the Ka II2 phase, a fact supported by the wealth of flint and Ka II2 sherds, and later to a minor extent during phase Ka III1, we can expect a dominance of Ka II2 sherds among the mixed plow-spread surface finds. On this basis ÄYRÄPÄÄ's (1929) lower limit of finds at Honkaniemi could be ascribed to the Ka III1 phase instead of the Ka 112 phase. Incidentally, the plow may also have been responsible for a slightly lower position of the limit of finds.

If the altitude of 18.5 m a.p.s.l. given to Honkaniemi is taken to represent that of the later Ka III1 occupation, then the Ka II/III boundary is set by the site of Holmgård (113) at around 4760 bp which is the same as SIIRIÄINEN's (1973) estimate of 4750 bp. Furthermore, the above interpretation would make the later occupation of Honkaniemi contemporaneous with the nearby (c. 6 Km) Ka III1 site of Vävarsbacka (127), a not at all unreasonable prospect. These two sites in turn would mark the Ka III1/2 boundary at c. 4500 bp, which is for all purposes the same as SIIRIÄINEN's date of c. 4550 bp.

The date of c. 4750 bp implies an overlap of about 230 years between the Ka II and the Ka III1 phases, provided the data employed were correct. However, the overlap may be at least partly due to an erroneous lower limit of finds for the site of Pitäjänmäki (122) which was determined on the basis of a single 50 cm wide test trench, the central part of the site having been apparently destroyed by quarrying (WARIS 1962). On the other hand, the possible overlap of styles is not so difficult to explain satisfactorily. Style III1 may certainly have originated as a distinct stylistic trend already during the Ka II phase, but not become dominant until a later period, the one we identify as the Ka III1 phase. This would explain the common occurrence of Ka II and Ka III1 sherds at the same sites; though it could also be the result of a slowed-down rate of the regressing sea level during this time (cf. SIIRIÄINEN 1969, 1972, 1973). In any event, contemporary distinct styles have been reported from Combed ware Finland; a classical example being the Jäkärlä group in the south-western part of the country (EDGREN 1966; see also SIIRIÄINEN 1973 p. 18).

Although the dates of cultural boundaries yielded by the present model are based on a limited number of sites and, consequently, cannot be as representative as those obtained from SIIRIÄINEN's model which deals with a far greater number of sites from all over Finland, the differences observed between the dates from the two systems are rather small (see Tables 3 and 4). Most of the boundary dates presented here are slightly older than the corresponding dates given by SIIRIÄINEN. This may be due to the fact that the present model has been based on uncorrected radiocarbon dates whereas SIIRIÄINEN seems to have made slight corrections to his dates to make up for the "old wood" effect of charcoal dates (cf. ERONEN 1974 p. 122). There may be, however, other reasons for this feature: It may be connected with a possible trend observable from Table 4 which suggests that SIIRIÄINEN's boundary dates become older with respect to the corresponding dates from this model as we move from older to younger cultural voundaries. It is impossible to tell at this point whether this is merely a coincidal feature caused by the ranfom distribution of the sites' altitudes or whether it constitutes a true trend. Such a trend could be explained as a difference of some 200 years at around t = 60 cent. bp, perhaps resulting from the above mentioned corrections made by SIIRIÄINEN, a difference that would decrease as t goes from 60 to 0 cent. bp.

In case all these comparisons might have over-emphasized the differences, it should be made clear that they fall well within the estimated margins of errors (see p. 37) and, above all, stressed that the similarities between the dates from the two systems are in fact striking.

The results from both archaeological and Quaternary research suggest that the uplift has been fairly regular at either side of a hinge zone which seems to run from the northern shores of Lake Ladoga across southeastern Finland continuing into the Gulf of Finland (DONNER 1966, 1969a, 1970; SIIRIÄINEN 1969, 1972, 1973; SAARNISTO & SIIRIÄINEN 1970; SAARNISTO 1973). SIIRIÄINEN (1972) locates the hinge between KÄÄRIÄINEN,s (1963, 1966) 2 and 3 mm/yr. isobases, pointing out the possible existence of a regional or local uplift irregularity in the Porvoo-Askola-Lapinjärvi area. Since the study area is situated between these two isobases and, on the basis of the results presented here, it seems to have undergone a regular upheaval, it is possible to regard the Porvoo-Askola-Lapinjärvi anomaly as part of the zone of lesser uplift considered to exist south of the hinge line. This implies that the shape of the hinge is not as regular as it has been graphically represented (DONNER 1969a, 1970; SIIRIÄINEN 1969) but, on the other hand, a zig-zag pattern is not unlikely considering the possible *en bloc* mode of uplift (cf. HÄRME 1961, 1963, 1966; TUOMINEN wt al. 1973).

In any event, the possibility of a local uplift irregularity within the study area cannot be yet discarded. The study area seems to concide with a zone of negative residual uplift relatable to a prominent triangular fault block (TUOMINEN et al. 1973). The perfectly acceptable results obtained by assuming a regular uplift suggest, on the other hand, the validity of this assumption. It is possible, however, to reconcile this assumption with the notion of crustal block movement by the idea of the study area forming part of a single crustal block. A single block would certainly maintain consistent gradients within the study area, thus explaining the acceptable dates presented here. It is also possible that the differential movement of crustal blocks may be somewhat compensated when the resultant of the uplift over a period of several millenia is taken into account.

Concluding remarks

1. The diagram of fig. 6. provides an excellent base for the drawing of palaeogeographical maps which, after all, were the main reason for developing the present model. The maps and their archaeological interpretation will be published in a forthcoming paper.
2. Apart from reinterpreting the lower limit of finds at Honkaniemi to represent the Ka III1 occupation, there are no further new archaeological implications. The results obtained here corroborate those of SIIRIÄINEN's.
3. According to the present study the approximate chronology of the study area is the following:
   - c. 9000 bp – early preceramic occupation
   - c. 6350 bp – S/Ka boundary
   - c. 5600 bp – KaI1/2 boundary
   - c. 5450 bp – KaI1/II voundary
   - c. 4750 bp – KaII/III boundary
   - c. 4500 bp – KaIII1/III2 boundary
4. Judging by the results obtained from both SIIRIÄINEN's and the present models, it seems that with the exception of the hinge a regular uplift can be assumed at least for archaeological purposes.
5. The development and comparison of similar shoreline displacement models from other areas present an exciting prospect for the study of settlement patterns. However, this requires a far greater number of both geological and archaeological radiometric dates (C-14 and TL).

TABLE 1. List of radiocarbon dates mentioned in the text.

no.	denomination	date		(bp)	shoreline m a.s.l.	reference
1	Lu-315	6910	±	90	4.0	BERGLUND 1971
2	Lu-314	6710	±	90	4.0	– " –
3	St-1332	7105	±	90	4.5	– " –
4	St-1331	6950	±	90	4.5	– " –
5	Lu-325	6780	±	85	5.6	– " –
6	Lu-324	6720	±	80	5.6	– " –
7	Lu-341	6890	±	80	6.0	– " –
8	Lu-342	6850	±	80	6.0	– " –
9	Lu-349	5260	±	65	6.0	– " –
10	Lu-320	5420	±	75	5.6	– " –
11	Lu-319	4970	±	75	5.6	– " –
12	Lu-313	3820	±	65	5.2	– " –
13	St-1406	3545	±	65	4.8	– " –
14	St-1405	3145	±	65	4.8	– " –
15	Lu-187	4110	±	100	4.0	– " –
16	Lu-147	3370	±	100	4.0	– " –
17	Hel-392	7250	±	240	28.5	ERONEN 1974
18	Hel-391	6230	±	220	28.5	– " –
19	Hel-350	6180	±	230	31.0	– " –
20	Hel-599	7050	±	170	33.5	VÄKEVÄINEN 1975
21	Hel-394	8480	±	190	28.5	ERONEN 1974
22	Hel-664	8780	±	160	47.0	ERONEN 1976a
23	Hel-660	8870	±	170	47.0	– " –
24	Hel-19	5460	±	150	20.0	MEINANDER 1971
25	Hel-11	5260	±	145	20.0	– " –
26	Hel-310	4950	±	130	22.5	
27	Hel-269	9230	±	210	–	SIIRIÄINEN 1973
28	Hel-799	5190	±	140	–	
29	Hel-800	5340	±	150	–	
30	Hel-832	4890	±	150	–	TORVINEN 1979

TABLE 2. List of sites plotted in fig. 6. The numbers are those used by SIIRIÄINEN (1969).

Site parish/locality	symbol	h m	d Km	d/D	Phase
Askola/FILPOTTI	1	46.5	23.6	0.75	S
Askola/HOPEANPELTO	2	50.0	23.2	0.73	S
Askola/RIIHIMÄENPELTO	4	45.0	22.4	0.71	S
Askola/RUOKSMAA	5	45.5	25.0	0.79	S
Askola/VANHAPELTO	6	39.5	23.4	0.76	S
Askola/HAITI	9	32.0	24.2	0.77	S
Askola/JUSLA	10	31.0	20.8	0.66	S
Askola/KETTURINMÄKI	11	55.0	23.2	0.73	S
Askola/MATTILA	12	28.0	18.6	0.59	S
Askola/RAHKAISSUO	13	47.0	23.6	0.75	S
Askola/REVÄSMÄKI	14	36.0	23.4	0.66	S
Askola/ROKKI	15	32.0	23.6	0.75	S
Askola/SILTALA	16	39.0	23.4	0.76	S
Askola/SILTAPELLONHAKA	17	28.0	20.2	0.64	S
Askola/TOPPINEN	18	40.0	21.0	0.68	S
Askola/VANHA-KLEMETTI	19	45.5	20.6	0.65	S
Porvoo/HENTTALA	28	32.0	14.2	0.47	S
Pukkila/YLI-HYRYLÄ	29	40.0	32.6	1.00	S
Helsinki (Vantaa)/KILTERI	K	33.5	52.8	0.97	S
Askola/MATTILA	31	30.5	18.6	0.59	Ka I1
Askola/SILTAPELLONHAKA	32	31.0	20.2	0.64	Ka I1
Helsinki (Vantaa)/KAARELA	34	30.0	50.8	0.87	Ka I1
Lapinjärvi/FÄLLISMALM	43	26.5	41.4	0.88	Ka I1
Lapinjärvi/GAMMELBY	44	29.0	38.2	0.88	Ka I1
Lapinjärvi/HEIMBACKEN	45	30.0	41.6	0.91	Ka I1
Lapinjärvi/HEIMÄNGEN	46	28.5	38.4	0.87	Ka I1
Helsinki (Vantaa)/MÄTÄOJA	M	31.0	52.0	0.96	Ka I1
Helsinki (Vantaa)/STORSKOGEN	60	25.5	40.6	0.77	Ka I2
Lapinjärvi/FÄLLISMALM	62	25.5	41.4	0.88	Ka I2
Liljendal/KVARNBACKEN	63	26.5	31.0	0.67	Ka I2
Helsinki/PITÄJÄNMÄKI	79	23.5	50.8	0.86	Ka II1
Liljendal/KVARNBACKEN	83	22.5	31.0	0.67	Ka II1
Askola/HONKANIEMI	93	18.5	18.6	0.55	Ka III1
Helsinki/PITÄJÄNMÄKI	94	23.5	23.5	0.86	Ka II2
Ruotsinpyhtää/HOLMGÅRD	113	20.0	31.4	0.58	Ka II2
Helsinki/PITÄJÄNMÄKI	122	22.0	50.8	0.86	Ka III1
Porvoo/VÄVARSBACKA	127	18.5	13.2	0.42	Ka III1

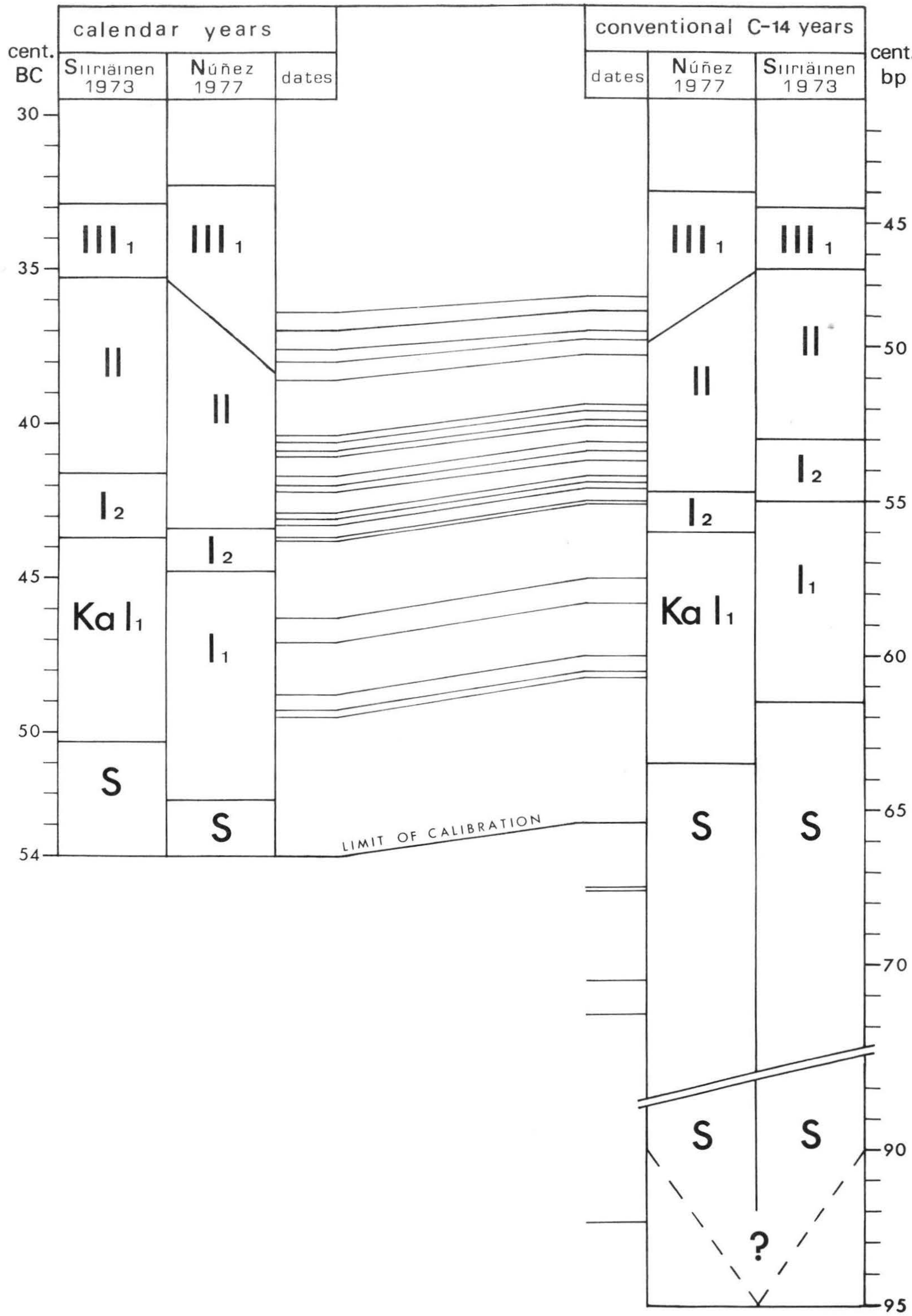

TABLE 3. Comparison of the results of fig. 6 to SIIRIÄINEN's chronology. The dates are given in both conventional radiocarbon years (right $t_{1/2} = 5568$ years) and calendar years (left, calibrated according to DAMON 1972). Dates compiled from MEINANDER (1971), SIIRIÄINEN (1973) and other sources (Table 1).

TABLE 4. Differences between the boundary dates obtained from the two systems. Note the proximity of the dates.

Boudary	Siiriäinen 1973 (bp)	Nuñez 1978 (bp)	difference
S/Ka	6150	6350	– 200
Ka I1/2	5500	5600	– 100
Ka I2/II	5300	5470	– 170
Ka II/III1	4750	4760	– 10
Ka III1/2	4550	4500	+ 50

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Abbreviations

AAONBA = Archives of the Archaeological Office of the National Board of Antiquites (Museovirasto).
FM = Finskt Museum
SM = Suomen Museo
SMYA = Suomen Muinaismuistoyhdistyksen Aikakauskirja

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