DENDROCHRONOLOGY IN SWEDEN

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Modern dendrochronology has existed for more than 10 years in Sweden and is currently practiced at four different localities:

1) The Department of Quaternary Geology, Lund
2) The Department of Quaternary Geology, Uppsala
3) The Royal College of Forestry, Umeå
4) By a private person, Trollhättan

During this period the laboratory in Lund has investigated more than 10,000 samples of oak (Quercus sp.) and Scots pine (Pinus silvestris L.), in all over one million tree rings, in order to test the basic methodology and to build the necessary standard chronologies. This paper reports on the results and conclusions drawn from this material.

The great majority of samples originated from archeological excavations or as the subjects of interdisciplinary cooperation with scientists who wished to use dendrochronological datings in their own research. The results of these investigations are shown in figure 1, which gives the lengths and physical range of existing chronologies.

The oak chronology is applicable over most of Sweden where oak naturally occurs. The series is constructed primarily of excavated samples from early medieval Lund (Bartholin 1976, 1981). A local chronology has been collected from samples from the southwestern part of Skåne and stretches in its full length back to 578 A.D. Using this chronology good oak material from other localities can be dated and then assembled separately to form other local series, such as the chronology for the Stockholm—Uppsala region that covers the period 828—1380 A.D. Yet another local oak chronology from the island of Gotland (895—1127 A.D.) has proved to be a good standard for dating objects from the island of Öland, and from the eastern coast of the Swedish mainland.

The method used in Lund for dating oak is in general use throughout Europe (Eckstein, 1969; Eckstein et al., 1984). This same method has also been employed on pine in Sweden, a species that occurs naturally over nearly the entire country. The initial research on this species was carried out in the following regions, which were themselves selected in accordance with particular scientific questions and interests:

A) *Northern Lapland* (1, fig. 5). This chronology has been built from more than 500 samples from living trees and subterrestrial stems from the area around Lake Torneträsk. Each single year of the over 1500-year long mean curve is covered by an average of 42 separate samples. Yet that is barely half the originally collected material, the greater part of which was rejected because of missing rings (Bartholin and Karlén, 1983). The main purpose of this project is to provide data for dendrochronological in-

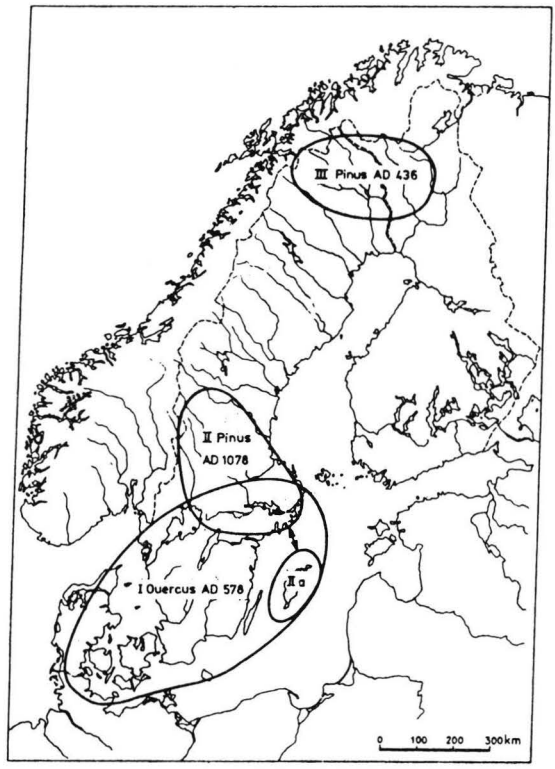

Fig. 1. Time and space range of the dendrochronological mean curves calculated by the laboratory in Lund.

terpretations (Aniol and Eckstein, 1984). Ongoing investigation of sub-aquatic stems from the same region and from other parts of Lapland may eventually enable the chronology to be extended several thousands of years back in time.

This chronology can even be used for datings in Finnish Lapland (Bartholin and Karlén, 1983).

B) The province of *Dalarna* (12, fig. 5) is very rich in old timber houses that until recently have only been dated typologically. In this project the intention is to dendrochronologically date at least 100 old houses, 85 of which have already undergone investigations resulting in 81 datings (Bartholin and Landström, 1983 A; Bartholin; 1984). This chronology is cross-dateable on a chronology from Småland published by Löfstrand (1983). A correlation with a Norwegian series from the Trondheim area published by Thun (1984) can also be demonstrated.

C) The province of *Härjedalen* (6, fig. 5) has been investigated, and one living forest stand and five old houses gave material for chronologies for the periods 1088—1342 A.D. and 1352—1980 A.D. This work will provide the basis for datings in the province of Jämtland, which is also very rich in old timber houses (Bartholin and Landström, 1983 B).

D) Based on the study of more than 1500 samples from the archeological excavation of Helgeandsholmen in *Stockholm* and on churches in the region (16, fig. 5) a series has been constructed that goes back to 1338 A.D. A smaller chronology for the 12th—14th centuries also exists for this area.

E) The island of *Gotland* (24, fig. 5) has a very important position in the cultural

history of Northern Europe, and a good chronology for this island is therefore of the highest priority. At present only the periods 1412—1711 A.D. and 1689—1981 A.D. are covered by well-dated samples. Series from Gotland can, however, be dated on the chronology from the mainland (Bartholin, 1983).

The work of building up a base chronology for Gotland is made more difficult because of the occurrence of the most common and greatest problem in applying dendrochronology to pine, missing rings. When the effort was first begun on Gotland with an investigation of living trees this phenomenon was not seen at all in material covering the last 200 years, although nearly 100 samples were examined (Bartholin, 1983). When the work was continued to extend the curve back in time the problem suddenly appeared, especially in samples that had been growing during the 17th century.

The 17th century is also problematic for the same reason, missing rings, in Lapland, in Dalarna, and at Helgeandsholmen in Stockholm. From this latter site 118 samples were investigated in an attempt to date the so-called 'Finnish Church' from 1671, of which 116 could be dated but only 20 of which were of suitable quality for use in a mean curve. The remainder had one or more missing rings.

Missing rings are very often the reason that an object of pine can not be dated. It is therefore very important to collect as many samples as possible from each site in order to allow localization of those positions where rings are missing. A minimum of 10 samples seems to be necessary to properly document a building or construction.

Just how crucial this problem really is to an investigation can be demonstrated by curves from the roof timbers over the nave of Fleringe Church on Gotland, which gave six different datings ranging from 1677 to 1684 (see fig. 2). The construction itself was very uniform, and there was no evidence that the timber had been cut down on more than one occasion. In this particular case the missing rings occurred at the end of the curves, and the growth in the beginning was more or less normal. Something radical apparently happened in the year 1665. Forest fires and insect attacks are reported in historic documents for this period on the island, and the same phenomenon is seen during the same period in the timbers from other churches in the vicinity of Fleringe. Unfortunately the problem of missing rings is not limited to just the 17th century.

A possible explanation for why difficulties are also encountered in constructing series for the 13th century in all the investigated areas, with the sole exception of Lapland (but including both the pine *and* oak chronologies for the other regions), is not just missing rings but a lack of sufficient material for examination, perhaps a result of a severely reduced building rate during this time. In 1985 the efforts of the laboratory in Lund will be concentrated on the difficult periods in order to complete the chronologies on local material for the entire historical era.

The geographical ranges of the various pine series have been mentioned earlier in the article, such as the correlation between Småland and Dalarna, and that between Gotland and the mainland. Experience indicates that objects even from other parts of the country that have not yet been directly covered by the existing chronologies can in fact be dated. Good support for this conclusion is found in the investigation on recent pine done by the Forestry College in Umeå (Jonsson, 1972). 7203 trees from 27 regions were sampled and mean curves were made for each region based on the annual ring indices for the period 1911 to 1968. At the laboratory in Lund these indices were made into dendrochronological curves, and were then compared both visually and with the statistical method for calculating the 'Percentage of Agreement' (or percentage of parallel variation) (Eckstein and Bauch, 1969). The results of these comparisons are shown in figure 3. If the values of agreement exceed 71 % there is a 99.9 % or greater theoretical probability that the result does not occur by chance for the given length (overlapping)

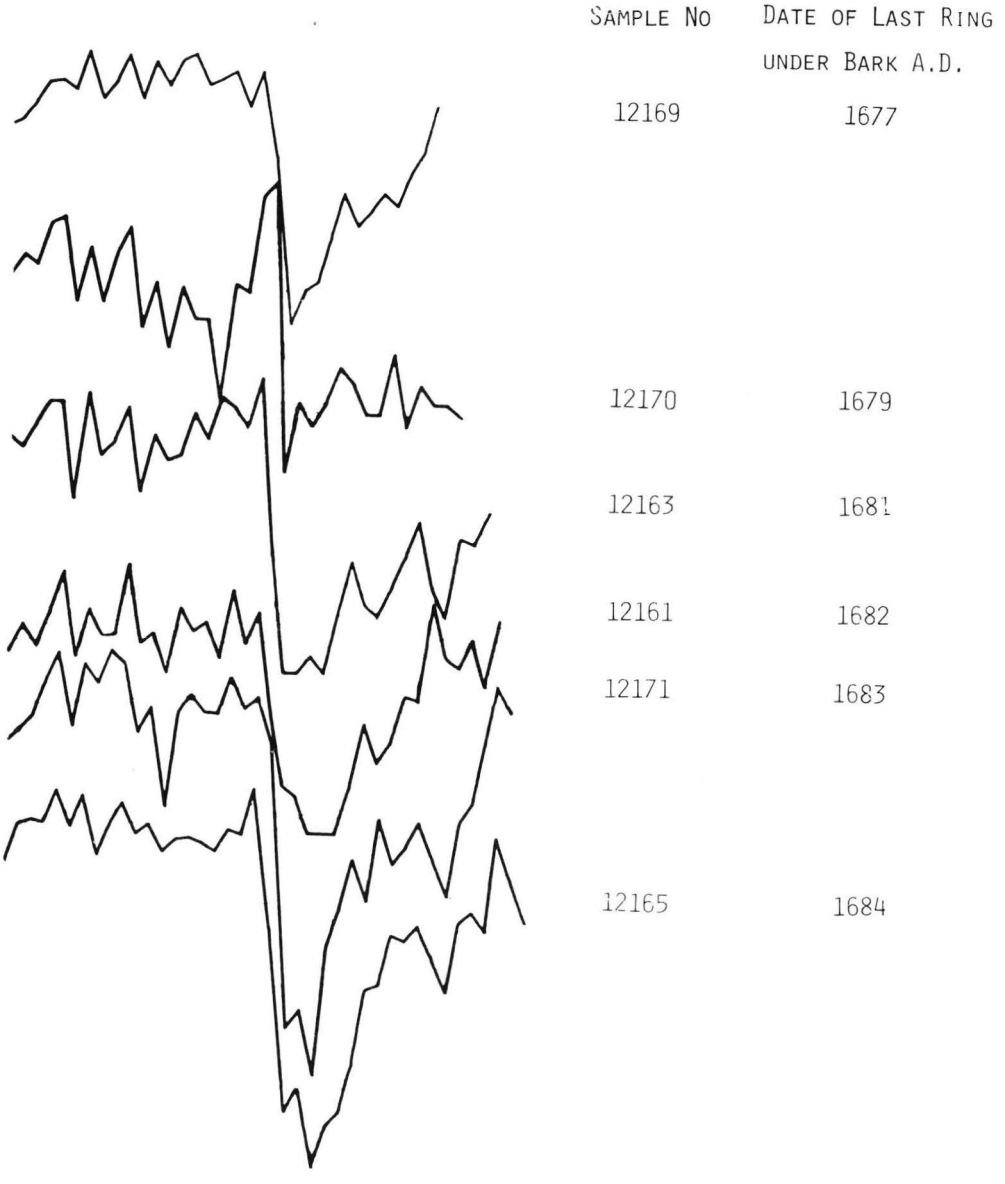

Fig. 2. Example of the problem of missing tree rings in pine.

of 58 years (1911—1968) of the two curves, i.e. the probability that the two curves are 'synchronous' in that position. The values of agreement 65 % and 61 % give a probability of 99 % and 95 %, respectively. Under 61 % agreement there is hardly any similarity at all between the curves, but, conversely, if the values exceed 80 % the cur-

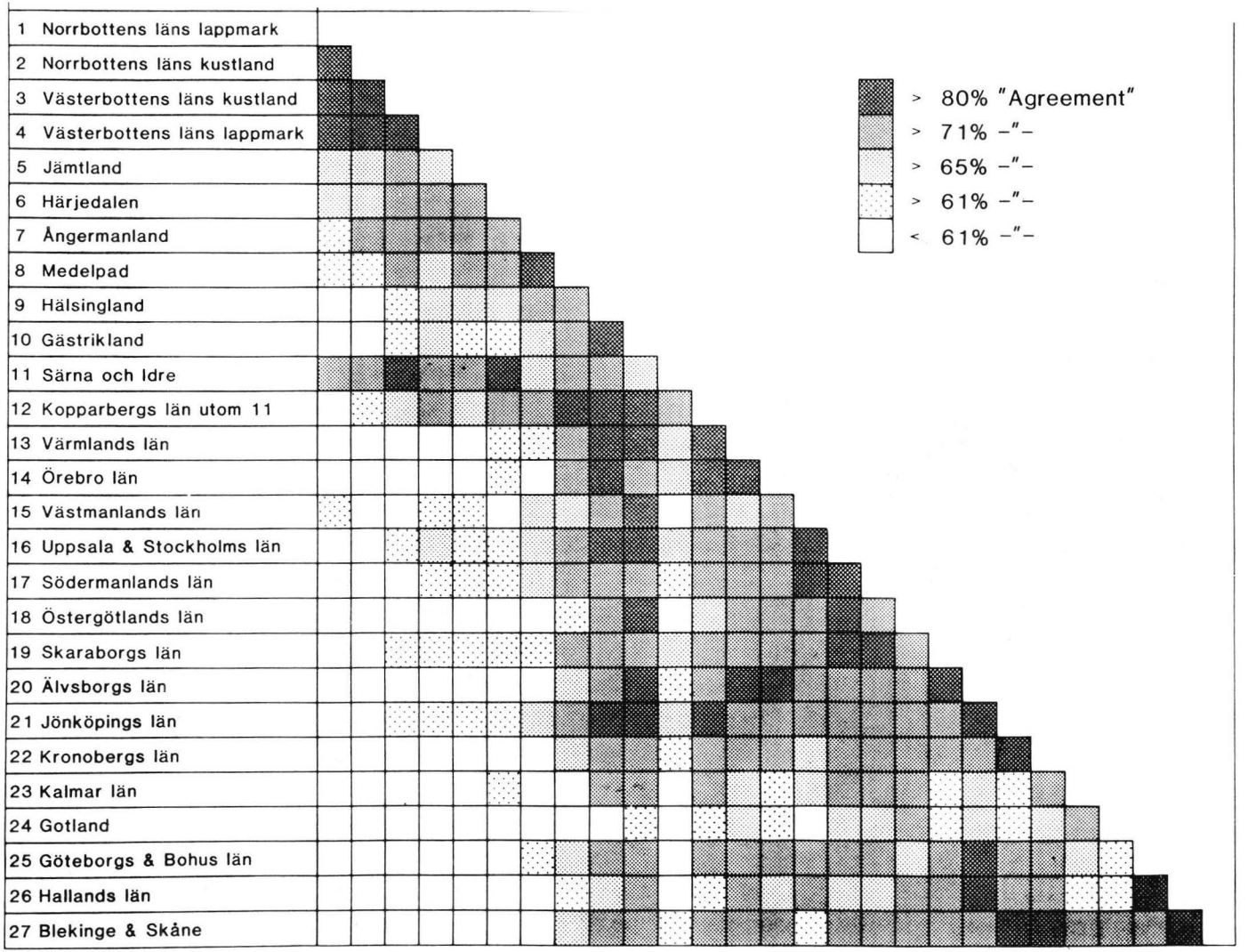

Fig. 3. Dendrochronological correlation as percentage of agreement for the period 1911—1968 as calculated by the laboratory in Lund on the pine chronologies from 27 different localities in Sweden assembled by Jonsson (1972).

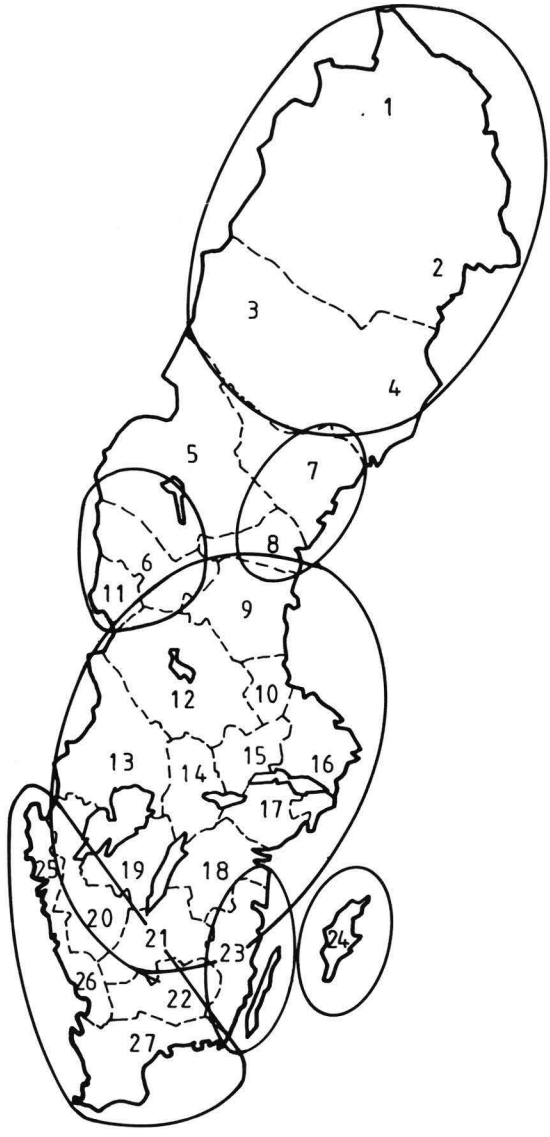

Fig. 4. Dendrochronologically homogeneous regions according to the percentage of agreement between indices from investigations on living pines conducted by Jonsson (1972) and evaluated in Lund.

ves are almost identical. This high value was chosen to underline the homogeneity in the material. Any good statistical correspondence between two samples is afterwards verified by a visual control of the curves.

According to these figures the country can be divided into dendrochronologically homogeneous regions for pine (fig. 4). This model corresponds to the 'natural conditions' in the country. The homogeneity of the large Central-Swedish region is confirmed by practical dendrochronological experience, which even indicates that good correspondence exists with Gotland and the Trondheim area in Norway. Experience also indicates that there should be good possibilities for extending the chronology of

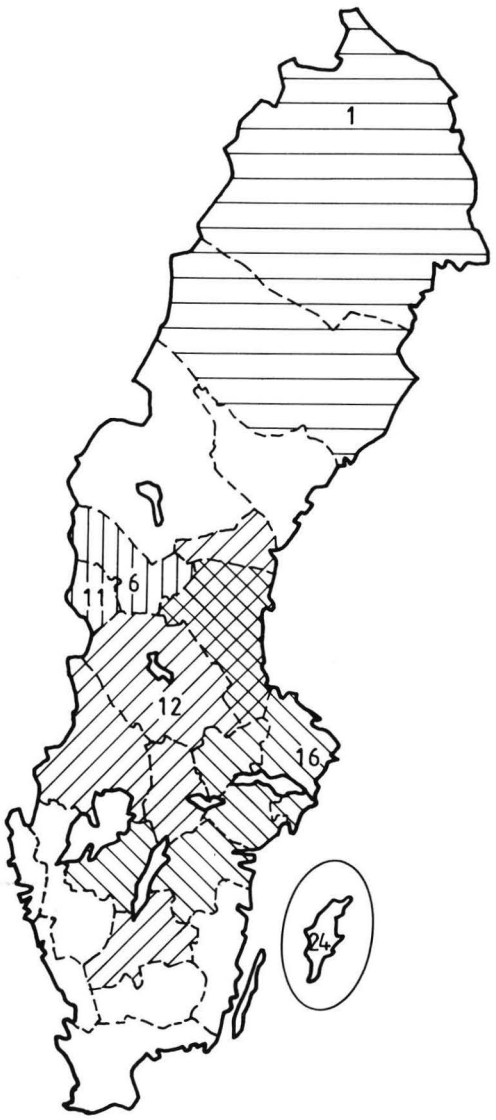

Fig. 5. Estimated physical range of existing pine chronologies of the laboratory in Lund based upon evaluation of the base data from Jonsson's investigations on living pine (1972).

Härjedalen (6, fig. 5) into the province of Jämtland (5, fig. 4), which otherwise seems to be dendrochronologically unstable and thus problematic.

The values from the investigation of the living pines can also be used to estimate the expected physical range of the existing chronologies. This is illustrated on the map, figure 5. Here the numeral represents the dendrochronological investigated base area (as per fig. 3). The shading highlights all the areas of that geographical region that have a correlation with the base area exceeding 80 % agreement, that is to say an area where the dendrochronological conditions are almost identical, as indicated by a high value of agreement, so that any object from the region should be dateable on the existing

mean curve.

A) The curve from *Lapland* (1) is valid for datings for the whole of Norrbotten and Västerbotten

B) The curve from *Dalarna* (12) is valid for datings in Dalarna, Medelpad, Hälsingland, Gästrikland, Värmlands län, Örebro län, and in Jönköping län (= the Småland highland).

C) The curve from *Härjedalen* (6), including the Särna and Idre areas (11), is expected to be valid in Jämtland.

D) The curve from the *Stockholm* area (Helgeandsholmen, 16) is valid for datings in Hälsingland, Gästrikland, Västmanlands län, Stockholms län, Uppsala län, Södermanlands län, and Östergötlands län.

E) A special curve for *Gotland* (24) is considered necessary in spite of correspondence with the mainland due to the special local conditions prevailing on the island.

A conservative evaluation of the situation leads to the conclusion that most of the country will be covered by the presently existing mean curves when they, as planned, are completed for the historical period during 1985.

Based on practical experience and the results of the correlation experiments it seems that suitable dendrochronological material from yet 'uncovered' regions should be dateable on already existing series. But practical experience also proves the importance of a dense network of local chronologies recording local variances, such as that used by the Forestry College (Jonsson 1972). Thanks to modern computer technique local series can be maintained easily and continuously in response to the availability of material from local sources.

As a result of the last 10 years' research the dendrochronological method is now applicable in Sweden on both pine and oak, and most of the country is covered by dendrochronological standard chronologies for the historical period. Dendrochronological research can in the future be concentrated on methodological studies and improvements, and on interdisciplinary projects where the method can serve as a tool for quick and reliable datings of wood.

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