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Measurement of Environmental Radiation at the Ancient Hill-Fort Lingsberg, Vallentuna, Uppland, Sweden

Risø National Laboratory, DK-4000 Roskilde, Denmark
November 1986

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A SURVEY OF ARCHAEOLOGICAL SAMPLES DATED IN 1985

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Abstract: A survey is given of archaeological samples received for dating in 1985 at the Nordic Laboratory for Thermoluminescence Dating. A total of 66 samples were dated, 42 of which were burnt stones. All results were corrected for short-term fading as measured for samples stored at room temperature for four weeks. The beta dose from potassium and rubidium in feldspar and the alpha dose from uranium and thorium in quartz and feldspar were included assuming alpha efficiency factors of 0.1 for quartz and 0.2 for feldspar.

INIS-DESCRIPTORS: AGE ESTIMATION; ARCHAEOLOGICAL SPECIMENS; DENMARK; FINLAND; SWEDEN; THERMOLUMINESCENCE

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INTRODUCTION

This survey presents TL dating results for archaeological materials received for dating in 1985. The materials included ceramics, bricks, burnt clay and burnt stones. A total of 66 samples are discussed (Table 1). Surveys of archaeological samples dated in 1983 and 1984 are given by Mejdahl (1984, 1985a).

Table 1. Archaeological samples from the Nordic countries dated in 1985 at the Nordic Laboratory for TL dating.

Material	No. of samples	Percent
Ceramics	8	12
Bricks	1	1
Burnt clay	15	23
Burnt stones	42	64
Total	66	100

TL DATING TECHNIQUE

The additive dose method with supralinearity correction (Aitken 1985) was used throughout. The grain size ranged from 0.1 - 1 mm and three groups of minerals: potassium feldspar (12% K), sodium feldspar (5% K) and quartz were separated using the heavy liquid technique. The liquids were aqueous solutions of $3Na_2WO_4.9WO_3.H_2O$, sodium meta-tungstate.

The TL age A for a coarse-grained feldspar is given by

$$A = \frac{AD}{(E + B_{ext} + B_{int} + A_{int})} \quad (1)$$

where

AD is the dose accumulated since firing
E is the annual dose from environmental radiation
B_{ext} is the annual beta dose from the gross sample
B_{int} is the annual beta dose from internal radionuclides
A_{int} is the annual alpha dose from internal radionuclides

AD, E and B_{ext} were determined as described in Bøtter-Jensen and Mejdahl (1983) and Mejdahl (1983, 1985b).

The internal beta emitters in feldspars are potassium, rubidium and, to a smaller extent, uranium and thorium. The K content was determined by the beta counting technique described by Bøtter-Jensen and Mejdahl (1985). The Rb content of 25 samples was measured by neutron activation analysis (Mejdahl 1986a) and from these results the following relation between the Rb and K contents was derived:

$$Rb\ (ppm) = -9.17 + 38.13\ K\ (\%) \quad (2)$$

The K:Rb ratio was about 270:1 which may be compared with the ratio 200:1 stated by Warren (1978). For grains in the 0.1 - 0.3 mm range the corresponding dose ratio is 3.4:1, that is the contribution from Rb is about 30% of that from K for this grain size. The Rb content of the samples described in the present report was calculated from equation (2).

The internal alpha emitters in quartz and feldspar grains are uranium and thorium. The U content of all samples was measured by the delayed neutron counting technique (Kunzendorf et al. 1980). The Th content of 15 samples was determined by neutron activation analysis (Mejdahl

1986a) and based on these results a relation between the U and Th contents was derived:

$$Th\ (ppm) = 0.826 + 0.763\ U\ (ppm) \qquad (3)$$

The Th content of the samples discussed in the present report was calculated from equation (3).

One contribution to the error in determining the internal alpha dose was the effect of the presence of red coloured grains in some samples. Such grains appeared to contain more U and Th than light grains and have lower luminescence efficiences because of reduced transparency. The internal alpha dose would therefore be overestimated for samples containing both red and light grains. In such cases we have used U and Th contents obtained for similar samples containing no red grains.

All dating results have been corrected for short-term fading. The fading was estimated by comparing the TL signal from two sets of samples that were given doses of 20 Gy in addition to their natural doses with a four-week interval and measured immediately after the irraditiation of the second set. In most cases the fading did not exceed 15%.

Tables with beta and gamma (including cosmic-ray) doses and the U content of grains are given. The beta doses are infinite-matrix values usually measured on dry samples for pottery and clay and wet samples for stones. The average beta dose to a grain will depend on grain size and potassium and rubidium contents. Attenuation factors and absorbed fractions were taken from Mejdahl (1979).

The total uncertainty including random and systematic errors at the 1 σ level is stated for all samples. The calculation was described by Mejdahl (1986b).

TL DATING RESULTS, DENMARK

A total of 35 samples from eight Danish sites dated in 1985 are discussed below.

1. Mellemholmen, Søborg

From 1981 onwards extensive excavations were carried out at Mellemholmen under the direction of Robert Egevang from the Danish National Museum and Søren Frandsen, Gilleleje Museum. Samples from several features including two brick kilns, a cemetery and a habitation area have been dated earlier by radiocarbon and TL (Mejdahl 1984). The samples described below are burnt stones from pits or fireplaces located in a habitation area in the eastern part close to a Viking Age rampart. Two fireplaces (nos. 847 and 861) were located within the frames of houses with postholes. Five radiocarbon dates of charcoal found in connection with two houses located just in front of the rampart were in the interval 1020-1220 AD with Stuiver's calibration (Stuiver 1982).

The environmental radiation was measured at two places in the area, but not directly in the pits. The results were 0.94 and 0.89 mGy/a. Very similar results were obtained, however, in fireplaces in the cemetery (Mejdahl 1984); the mean value 0.91 mGy/a was, therefore, taken to be representative. A total of ten burnt stones from five pits or fireplaces were dated on the basis of K- and Na-feldspars extracted from the stones. Infinite-matrix beta doses, internal U contents and fading over four weeks are listed in Table 2. The TL dates are given in Table 3. The TL dates are somewhat older than the five radiocarbon dates mentioned above, but they are not unrealistic and except for pit

no. WO, 851, results obtained for two samples from the same pit are in fairly good agreement. A direct comparisón with radiocarbon results was possible only for fireplace SY, but in this case the radiocarbon age was much older, 945 BC (calibrated).

Table 2 Infinite-matrix beta dose rates, internal U-contents in feldspars and fading over four weeks for samples of burnt stones from Mellemholmen, Søborg. The environmental radiation was 0.91 mGy/a.

Risø TL no.	Pit no.	Beta dose rate (mGy/a)	U-content (ppm)	Fading, four weeks
R-840503	YT, 847	4.52	0.20	0.80
R-840504	"	4.54	0.08	0.85
R-840505	WQ, 848	4.16	0.21	0.76
R-840506	"	4.59	0.10	0.79
R-840510	YH, 850	3.58	0.07	0.73
R-840512	"	5.12	0.40	0.69
R-840515	WO, 851	4.10	0.04	0.83
R-840516	"	3.62	0.06	0.84
R-840518	SY, 861	3.55	0.10	0.80
R-840519	"	3.96	0.08	0.74

Table 3 TL dates for burnt stones from pits and fireplaces at Mellemholmen, Søborg.

Risø TL no.	Pit no.	TL age (a)	TL date
R-840503	YT, 847	1282	690 AD +/- 70 a
R-840504	"	1317	
R-840505	WQ, 848	1615	470 AD +/- 100 a
R-840506	"	1425	
R-840510	YH, 850	1144	760 AD +/- 70 a
R-840512	"	1314	
R-840515	WO, 851	1915	70 AD +/- 100 a
R-840516	"	1470	510 AD +/- 100 a
R-840518	SY, 861	1298	630 AD +/- 80 a
R-840519	"	1411	

2. Saunte Nørregård

The site, comprising three Iron Age houses and several large mounds of burnt stones, was excavated in 1983 by Carsten Paludan-Müller, Gilleleje Museum. The position of the postholes indicated that the houses might represent three phases of the same farm. Two burnt stones from one of the mounds and three samples of burnt clay from postholes were dated. The environmental radiation was measured during the excavation by scintillation counting. Gamma + cosmic and infinite-matrix beta dose rates, U content of the grains and fading over four weeks are given in Table 4 and the TL dates obtained are listed in Table 5. The

results for the mound indicate that it dates to the Viking Age; this is in contradiction with the find of ceramics that could be dated stylistically to the transition between Preroman and Roman Iron Age (around AD 1). The results for the three houses indicate that they were almost contemporaneous and yield a mean TL age of 10 BC, in accordance with the archaeological evidence.

Table 4. Gamma + cosmic and infinite-matrix beta dose rates (natural water content), U content of grains and fading of feldspars over four weeks for samples of stones and burnt clay from Saunte Nørregård. F= feldspar, FK = potassium feldspar, FN = sodium feldspar, Q = quartz

Risø TL no.	Feature	Material	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-831501	Mound 30,B	Stone	0.89	4.82	FK 0.08 FN 0.19	FK 0.82 FN 0.98
R-831506	Mound 30,C	Stone	1.03	4.54	FN 0.09 FN 0.33	0.80
R-831507	House A	Clay	0.98	1.78	Q 0.16 F 0.28	0.89
R-831508	House B	Clay	0.98	2.12	F 0.28 F 0.27	0.90
R-831509	House C	Clay	0.98	2.16	Q 0.15 F 0.25	0.93

Table 5. TL-dates for burnt stones and burnt clay from Saunte Nørregård. The measurement on burnt stones were based on feldspars and those on clay were based on quartz and feldspar.

Risø TL no.	Feature	Material	TL age (a)	TL date
R-831501	Mound 30, B	Stone	1353	780 AD +/- 150 a
R-831506	Mound 30, C	Stone	1061	
R-831507	House A	Clay	2180	10 BC +/- 150 a
R-831508	House B	Clay	1993	
R-831509	House C	Clay	1814	

3. Veldbæk near Esbjerg

This site is an Iron Age settlement excavated in 1983 by Palle Siemen, Esbjerg Museum. The types of ceramics found on the site as well as the shape of the houses indicate that the site is from the Younger Germanic Iron Age, 600-800 AD.

The environmental radiation was measured by scintillation counting during the excavation. Two burnt stones from a shallow pit, a burnt stone and two ceramic samples from postholes were dated. Environmental gamma + cosmic and infinite-matrix beta dose rates together with the U content of grains and the fading over four weeks are listed in Table 6. The TL dating results are given in Table 7.

The TL dates for the pit indicate Bronze Age rather than Iron Age as expected on archaeological grounds. Because there were no finds in the pit, the age estimate was based primarily on its position in an Iron Age house. A Bronze Age date can, therefore, not be excluded. On the other hand, the rather large difference between the two TL results in Table 7 (R-832008 and R-832009) is somewhat puzzling. TL dating of quartz from the samples will now be attempted.

The TL results for the two ceramic samples are in good agreement with the archaeological estimate while the result for R-832010, a burnt stone, is slightly more recent than expected. Because of the small fading value (0.95), the reason can hardly be fading. The possibility of dating quartz from the sample is being studied.

Table 6. Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading over four weeks for samples from Veldbæk. S = stone, C = ceramics

Risø TL no.	Material	Feature	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-832008	S	Pit	0.81	7.00	0.98	0.91
R-832009	S	"	0.81	5.70	0.30	0.97
R-832010	S	House 13 TL11	0.61	4.34	0.32	0.95
R-832013	C	House 11, TL15	0.61	3.13	0.11	0.74
R-832014	C	House 13, ØBII	0.61	2.98	0.32	0.93

Table 7. TL dates for burnt stones and ceramics from Veldbæk. Results for burnt stones are based on feldspars and those for ceramics on quartz and feldspar. S = stone, C = ceramics. F = feldspars, Q = quartz.

Risø TL no.	Material	Feature	Mineral	TL date
R-832008	S	Pit	F	640 BC +/- 180 a
R-832009	S	"	F	1270 BC +/- 180 a
R-832010	S	House 13, TL 11	F	1010 AD +/- 70 a
R-832013	C	House 11, TL 15	F	670 AD +/- 150 a
R-832014	C	House 13, ØB II	Q	720 AD +/- 100 a

4. Sejlflod near Aalborg

Since 1979 Aalborg Historical Museum has carried out extensive excavations at Sejlflod (Fig. 1) under the direction of Jens N. Nielsen (Nielsen and Rasmussen 1986). The finds include a large cemetery with more than 300 graves from the period 300-500 AD and a village comprising more than 100 houses. 80 of these span the period 400 - 1100 AD. A number of samples for TL-dating, mainly burnt stones, have been taken over the years and some results were described by Mejdahl (1984).

The present series consists of five burnt stones and a sample of burnt clay from houses estimated to be from the early medieval period. The environmental radiation was measured by scintillation counting during the excavation in 1983. Gamma + cosmic and infinite-matrix beta dose rate, uranium content of the grains and fading over four weeks are given in Table 8 and the TL dates are listed in Table 9.

Three of the results (R-832908, R-832909 and R-832919) are in good agreement with the archaeological estimate whereas the other three are somewhat older than expected. They are not unreasonable, however, because there have been activities on the locality in the periods indicated.

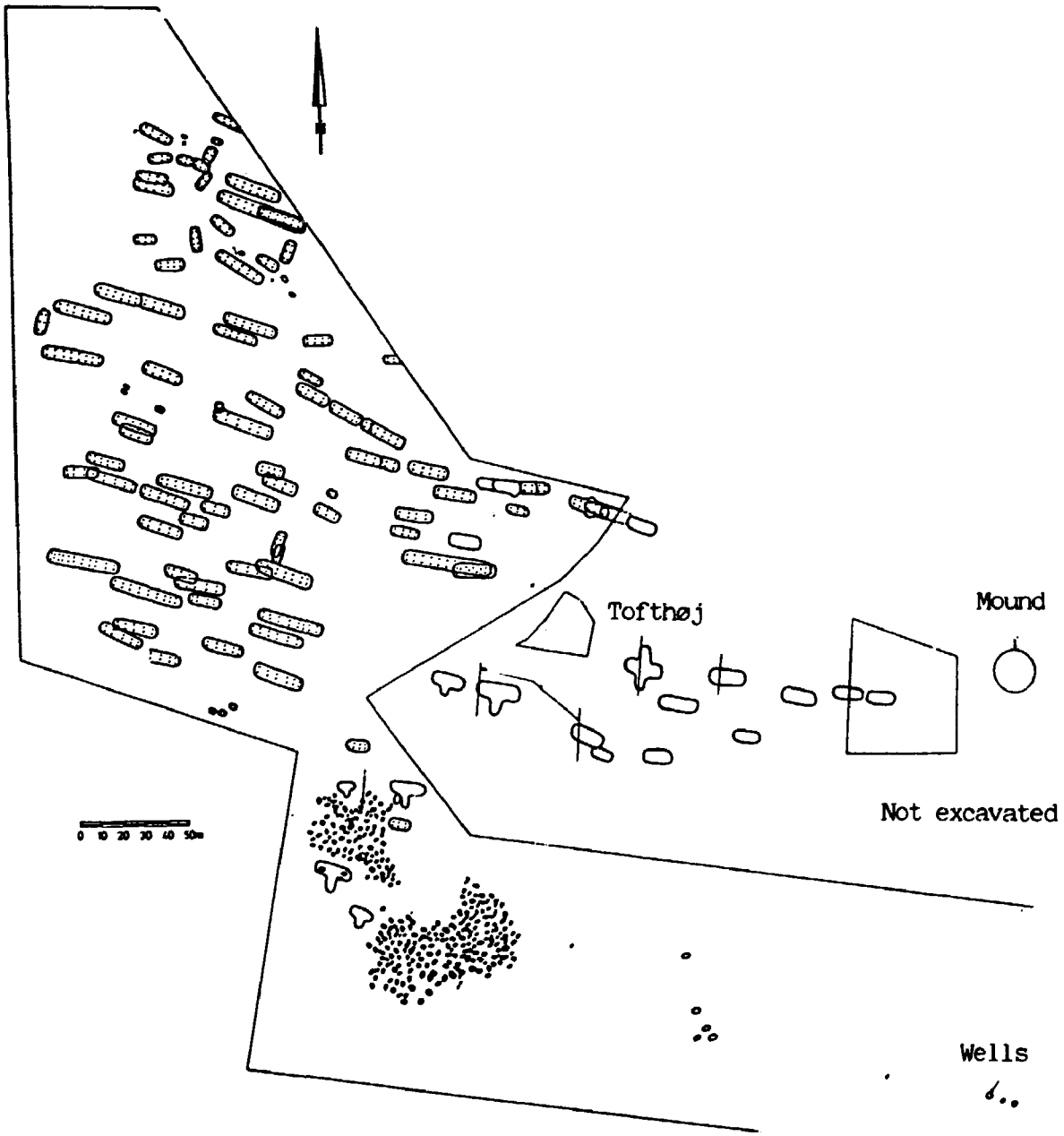

Fig. 1. Plan of the excavation at Sejlflod. House dug into the ground, Surface house, Pithouse, Inhumation grave, x Cremation burial. From Nielsen and Rasmussen (1986).

Table 8. Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading of feldspars over four weeks. The samples were collected in 1983. One sample (R-832907) was burnt clay, the others were burnt stones. Feldspars were used for all samples except R-832912 which was based on quartz. FK = potassium feldspar, FN = sodium feldspar.

Risø TL no.	Arch. no.	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-832903	AOR, 8405	0.66	4.55	0.31	0.94
R-832907	AOT, 8403	0.61	1.58	0.31	0.96
R-832908	Fireplace 8404	0.69	4.77	0.19	0.89
R-832909	"	0.69	5.05	0.10	0.90
R-832912	ANY, 8398	0.68	0.93	0.14	1.01
R-832919	APG, 8406	0.64	5.34	FK 0.07 FN 0.23	0.82

Table 9. TL-dating results for samples from Sejlflod. R-832907 was burnt clay, the others were burnt stones. R-832912 was based on quartz and the others were based on feldspars.

Risø TL no.	Arch. no.	TL age (a)	TL date
R-832903	AOR, 8405	1832	150 AD +/- 100 a
R-832907	AOT, 8403	1453	530 AD +/- 200 a
R-832908	Fireplace 8404	853	1050 AD +/- 100 a
R-832909	"	1025	
R-832912	ANY, 8398	1410	580 AD +/- 100 a
R-832919	APG, 8406	882	1100 AD +/- 60 a

5. Nr. Snede

The site, an Iron Age village, was excavated in the period 1980-86 by Vejle Museum and the excavation in 1983 when the samples were taken was directed by Torben Egeberg Hansen (Egeberg Hansen 1982, 1983, 1985). A number of burnt stones were collected for dating from a shallow pit dug in an area with remains of houses and fences. Its position indicated that it was younger than a house dated archaeologically to the period around 400 AD.

The environmental radiation was measured by scintillation counting during the excavation. Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading over four weeks are given in Table 10. Most of the stones collected turned out to be unsuitable for dating, but an attempt was made to date one of them. The results are given in Table 11. The large discrepancy between the results for quartz and feldspar indicates that also this stone is not so well suited. The result for quartz appears reasonable, whereas the feldspar date is much younger than expected. Because the feldspar showed a rather large fading at room temperature (0.78), the fading at 100 °C was studied over this period and resulted in a residual value of 0.58. The implication is that the feldspar from the sample is unsuited for dating because of fading.

Table 10 Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading over four weeks for a burnt stone from Nr. Snede.

Risø TL no.	Arch no.	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-831203	AX 183	0.83	5.11	0.19	0.78

Table 11. TL dates for quartz and feldspar extracted from a burnt stone from Nr. Snede. F = feldspar, Q = quartz.

Risø TL no.	Arch no.	Mineral	TL date
R-831203	Ax 183	(F	1330 AD +/- 100 a)
		Q	470 AD +/- 100 a

6. Grønholt

The excavation, carried out in 1984 by Birgit Als Hansen from the Danish National Museum, comprised a brick kiln of an unusual type with permanent firing facilities in the form of arches of bricks (Fig. 2). The format of the stones indicated a medieval date. The kiln has been described by Als Hansen (1984, 1985). The environmental radiation was measured by scintillation counting during the excavation. The result together with the infinite-matrix dose rate, the U content of the grains and the fading over four weeks are given in Table 12. The TL dating result is given in Table 13. The result in Table 13, 1320 AD +/- 50 a, may be compared with two radiocarbon dates obtained from charcoal from the fire pit. On being calibrated according to Stuiver (1982) these were:

K-4531 : 1235 - 1260 AD
K-4532: 1215 AD +/- 50 a

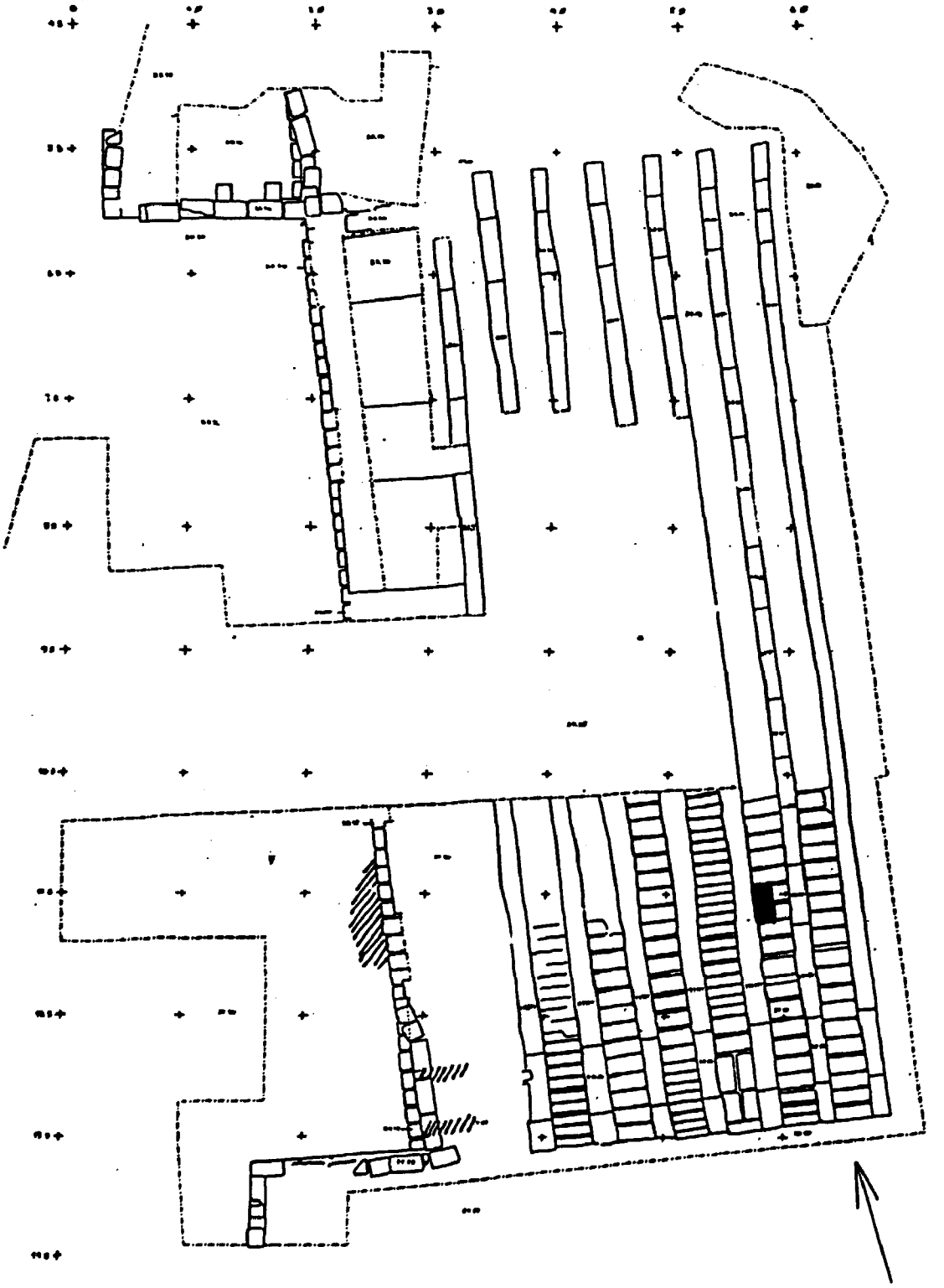

Fig. 2. The brick kiln at Grønholt. ▨ Charcoal taken for radiocarbon dating. ■ Bricks taken for TL dating. Scale 1:50. By courtesy of Birgit Als Hansen, The Danish National Museum.

If one considers that the radiocarbon dates refer to the growth of tree rings in the wood, an event that antedates the application in the kiln, the agreement between the TL and C-14 results is regarded as excellent.

Table 12. Gamma + cosmic and infinite-matrix beta dose rates and the fading over four weeks for a brick from the brick kiln at Grønholt. The U content was not measured, but an alpha dose rate of 0.15 Gy/a was assumed.

Risø TL no.	Dose rate (mGy/a) Gamma + cosmic	Beta	Fading 4 weeks
R-840520	1.20	2.6	0.85

Table 13. TL dating result for a brick from the tile kiln at Grønholt.

Risø TL no.	TL date
R-840520	1320 AD +/- 50 a

7. Farvergade 7, Næstved

The excavation was carried out in 1981 and directed by Per Bugge Vegger, Næstved Museum. Several cultural layers, a kiln and a pit with burnt stones were unearthed (Vegger et al. 1982). Palle Birk Hansen has since submitted two burnt stones from the pit (one of which was insufficiently heated) and ceramics from the lower cultural layer BE, estimated to be Viking Age (Birk Hansen 1986). Results for these samples and from additional measurements on two stones (R-812604 and R-812605) dated earlier are given in Tables 14 and 15. The results are identical within the uncertainty and give a mean TL date of 610 AD.

Table 14. Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading of feldspars over four weeks for samples from Farvergade 7, Næstved. C = ceramics, S = stones, FK = potassium feldspar, FN = sedium feldspar.

Risø TL no.	Feature	Material	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-842601	Layer BE	C	0.70	3.73	0.36	0.91
R-842603	Pit	S	0.75	5.37	0.42	0.88
R-812604	"	S	0.75	4.72	0.61	0.96
R-812605	"	S	0.75	6.16	0.61	0.90

Table 15. TL dating results for ceramics and burnt stones from Farvergade 7, Næstved. C = ceramics, S = stones.

Risø TL no.	Feature	Material	TL age (a)	TL date
R-842601	Layer BE	C	1458	530 AD +/- 90 a
R-842603	Pit	S	1341	640 AD +/- 90 a
R-812604	"	S	1429	560 AD +/- 90 a
R-812605	"	S	1253	730 AD +/- 90 a
Mean value:			1370 +/- 50 x) a	
Mean TL date:			610 AD +/- 50 x) a	+/- 90 a

x) Statistial mean error.

8. Egeskovgård near Tåstrup

The excavation, comprising an Iron Age longhouse and an adjacent smaller house interpreted as an outhouse (Fig. 3), was carried out in 1984 under the direction of Eliza Fonnesbech-Sandberg, Søllerød Museum (Fonnesbech-Sandberg 1984). TL dating was made on two samples of burnt clay from five postholes in the longhouse and one from the smaller house. The results are given in Tables 16 and 17. The result for R-843906 was based on quartz only because the sample contained too little feldspar; the others were based on quartz and feldspar. The three TL ages are identical within the uncertainty and thus support the interpretation of the small house as an outhouse of the longhouse.

The mean TL date is 10 BC, in excellent agreement with a calibrated radiocarbon date of 1 AD (K-4479) made on charcoal from postholes in the longhouse.

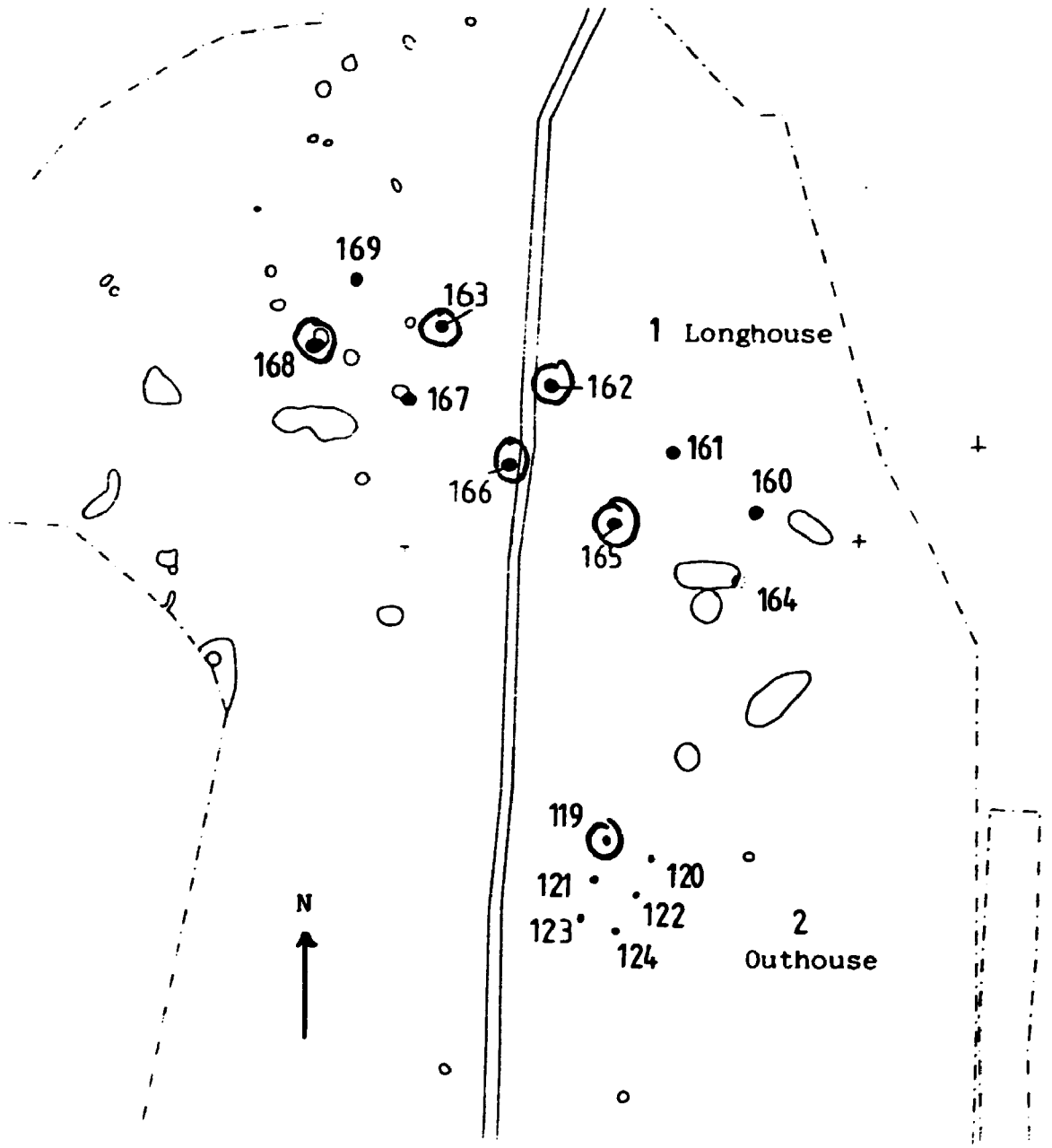

Fig. 3. Plan of the excavation at Egeskovgård, Høje Tåstrup. Scale 1:200. From Fonnesbech-Sandberg (1984).

Table 16. Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading over four weeks for samples of burnt clay from Egeskovgård. The U content was estimated to be 0.45 ppm.

Risø TL no.	House	Sample no	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-843901,02,05	Longhouse	162,163,168	1.07	2.04	0.45	0.95
R-843903,04	"	165,166	1.00	1.82	0.45	0.98
R-843906	Outhouse	119	1.06	1.65		0.99

Table 17. TL dating results for samples of burnt clay from Egeskovgård. R-843906 was based on quartz and the others were based on quartz and feldspar.

Risø TL no.	House	TL age (a)	TL date
R-843901, 02, 05	Longhouse	1943	40 AD +/- 170 a
R-843903, 04	"	1898	90 AD +/- 150 a
R-843906	Outhouse	2135	150 BC +/- 170 a
Mean TL age		1992 +/- 70 a	
Mean TL date		10 BC +/- 70 a	+/- 150 a

TL DATING RESULTS, SWEDEN

A total of 25 samples from five sites were dated and the results are described below.

1. Bandlundeviken, Gotland.

A Viking Age village or trading place excavated in the period 1983-85 by the Institute of Archaeology, Stockholm University under the direction of Göran Burenholt and Bengt Brandt (Brandt 1986; Burenholt 1987). The environmental radiation was measured by scintillation counting during a visit in 1986. Two samples of ceramics were submitted for dating and the results are given in Tables 18 and 19. The results for the two samples are identical and agree well with the archaeological estimate.

Table 18. Environmental and infinite-matrix beta dose rates, U content of grains and fading over four weeks for samples of ceramics from Bandlundeviken. The water uptake was 13% of the dry weight. F = feldspar, Q = quartz.

Risø TL no.	Feature	Arch.no.	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-850601	VIII: 6	933	0.60	3.97	F 0.26 Q 0.17	1.00
R-850602	IX: 5	1029+ 1050	0.60	3.99	F 0.26 Q 0.17	1.00

Table 19. TL dates for samples of ceramics from Bandlundeviken.

Risø TL no.	Feature	Arch.no.	TL age (a)	TL date
R-850601	VIII:6	933	1041	930 AD +/- 70 a
R-850602	IX: 5	1092+1051	1060	

2. Anneberg and Sandviken

Anneberg and Sandviken are two of a number of sites in Central Uppland. Anneberg is situated in the Bälinge bogs and Sandviken a few miles east of the bogs. The sites are under study by Ann Segerberg, Gustavianum, Uppsala (Segerberg 1978, 1984). Excavations were carried out at Anneberg in 1983-1986 and at Sandviken some years earlier. The finds at Anneberg showed that it was a neolithic settlement whereas the site at Sandviken was estimated to be Bronze Age. The environmental radiation was measured and samples of burnt stones collected for TL dating in 1985. The dating results are given in Tables 20 and 21.

The TL dates are very consistent, results from the same feature being the same within the uncertainty of dating. Mean TL dates have, therefore, been calculated for each feature. The results for stones from the first feature at Anneberg (hole near road) agree well with the archaeological evidence and with a radiocarbon date of about 3200 BC obtained with the accelerator at Uppsala. However, the samples from the potato field and the garage yielded TL ages that are considerably younger than expected. The results have been corrected for a rather

large fading, and the question arises as to whether or not the fading corrections should be higher. Fading tests on samples stored at elevated temperatures are in progress and TL dating based on quartz will be attempted. On the other hand, the consistency of the results indicate that the dates are not seriously in error. Also the results for Sandviken are younger than expected, but there are no obvious reasons why they should be in error.

Table 20. Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading over four weeks for burnt stones from Anneberg and Sandviken. FK = potassium feldspar, FN = sodium feldspar.

Risø TL no.	Locality	Feature	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-853601	Anneberg	Hole near road	1.30	5.01	0.90	0.91
R-853604	"	"	1.30	5.30	0.50	0.96
R-853605	"	Potato field	1.30	5.32	FK 0.11 FN 0.21	0.84
R-853607	"	"	1.30	5.45	0.05	0.87
R-853610	"	Garage	1.27	4.41	FN 0.12 FN 0.22	0.78
R-853622	Sandviken	Hole no. 2	1.06	3.56	FK 0.25 FN 0.40	FK 0.86 FN 0.94
R-853623	"	"	1.06	4.02	FK 0.99 FN 1.47	0.83

Table 21. TL dating results for samples of burnt stones from Anneberg and Sandviken.

Risø TL no.	Locality	Feature	TL age (a)	TL date
R-853601	Anneberg	Hole near road	5743	3580 BC +/- 300 a
R-853604	"	"	5382	
R-853605	"	Potato field	4221	
R-853607	"	"	4367	2160 BC +/- 250 a
R-853610	"	Garage	3858	
R-853622	Sandviken	Hole no. 2	1740	80 AD +/- 150 a
R-853623	"	"	2061	

3. Stenby near Eskilstuna.

Stenby (Fig. 4) is an ancient hill-forts (Swedish: fornborg) studied by Olle Lorin (Damell and Lorin 1985; Lorin 1985). The TL dating was made on burnt stones taken from a shaft dug into the hill-fort and from a mound or heap of stones at the southern part of the circumference. The environmental radiation was measured in the shaft and the mound in connection with the sample taking. TL dating results are given in Tables 22 and 23.

The result for the shaft is in excellent agreement with a radiocarbon date of 445 +/- 75 AD made on charcoal from the shaft (St-9329, uncalibrated). The sample from the southern mound appears to be slightly more recent. There was no other dating evidence at this locality.

Fig. 4. The ancient hill-fort Stenby near Eskilstuna.

Table 22. Gamma + cosmic and infinite-matrix beta dose rates, U content of grains and fading over four weeks for burnt stones from Stenby.

Risø II no.	Feature	Dose rate (mGy/a) Gamma + cosmic	Beta	U content (ppm)	Fading 4 weeks
R-853101	Shaft, north	1.70	5.02	0.32	0.92
R-853103	"	1.79	6.07	0.51	0.82
R-833105	Mound, south	1.89	5.75	0.35	1.00

Table 23. TL dating results for burnt stones from Stenby.

Risø TL no.	Feature	TL age (a)	TL date
R-853101	Shaft, north	1479	500 AD +/- 80 a
R-853103	"	1487	
R-853105	Mound, south	1217	770 AD +/- 100 a

4. Lingsberg and Rävsta.

These are two ancient hill-forts situated in the Angarnsjö area north of Stockholm. They were excavated in 1985 by Michael Olausson from the Institute of Archaeology, Stockholm University. TL dating was made on burnt stones from the hill-forts and burnt clay from a kiln near Lingsberg. The environmental radiation was measured in connection with sample taking (Fig. 5). The TL dating results are given in Tables 24 and 25. The results are in good agreement with expected ages.

Fig. 5. Measurement of environmental radiation at the ancient hillfort Ringsberg, Västergötland, Sweden.

Table 24. Gamma + cosmic and internal-external beta dose rates, U content of grains and fading over 4 weeks for samples from Ringsberg and Rävsten. R-854407 was burnt clay; the others were burnt stones. FK = potassium feldspar, PL = plagioclase feldspar.

Risø II no.	Locality	Feature	Dose rate (Gamma + cosmic)	Beta	U content ppm	Fading 4 weeks
R-854401	Ringsberg	South	1.41	4.90	0.22	1.00
R-854402	"	"	1.41	5.18	0.24	1.00
R-854404	"	[illegible]	1.[illegible]	4.71	0.24	0.97
R-854405	"	Pit	1.[illegible]	4.90	0.22	1.00
R-854406	Rävsten		1.[illegible]	4.71	0.27	0.98
R-854408	"		1.[illegible]	4.44	0.20	1.00

Table 25. TL dates for samples from Lingsberg and Rävsta. R-854405 was burnt clay; the others were burnt stones.

Risø TL no.	Locality	Feature	TL age (a)	TL date
R-854401	Lingsberg	Shaft 2	1953	180 AD +/- 110 a
R-854402	"	"	1682	
R-854404	"	Shaft 3	1783	
R-854405	"	Kiln	1856	130 AD +/- 150 a
R-854406	Rävsta		1804	140 AD +/- 130 a
R-854408	"		1895	

5. Söder Sallerup near Malmö

The excavation comprising a number of Iron Age settlements (Fig. 6) was carried out in 1984 by Liselotte Israelson and Jan Persson, Malmö Museum (Wihlborg 1985). The environmental radiation was measured by scintillation counting during the excavation, and samples of burnt stones and burnt clay were taken for dating. The stones were all from postholes while the clay came from a trough-shaped pit.

Results for six samples have been published previously (Mejdahl 1985a). Seven additional samples of ceramics, burnt clay and burnt stones from postholes were received in 1985. Results for these are given in Tables 26 and 27. Dating of feature no.700 and house III to the Roman Iron Age is in agreement with the archaeological estimate based on ceramics found in the postholes. The results for no. 600 and house I are more recent than the archaeological estimate which was late Viking Age. Feature no. 1605 in house I is a posthole that belonged to a small group that did not fit into those of the house and were supposed to belong to an older phase; this is confirmed by the TL date.

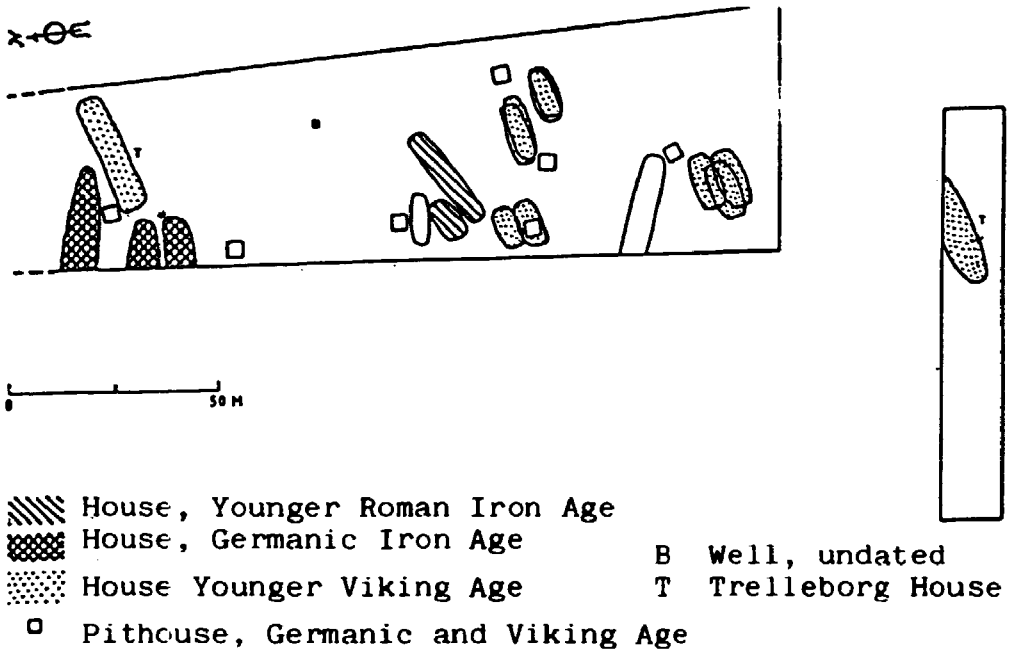

Fig. 6. Plan of the excavation at Söder Sallerup near Malmö. From Wihlborg (1985). By courtesy of Liselotte Israelsson.

Table 26. Water uptake (wet/dry weight), infinite-matrix beta dose rates, U content of grains and fading over four weeks for samples from Söder Sallerup. C = ceramics, L = burnt clay, S = stone. A gamma + cosmic dose rate of 1.02 mGy/a was assumed on the basis of earlier measurements.

Risø TL no.	Feature	Material	Water uptake	Beta dose rate (mGy/a)	U content (ppm)	Fading 4 weeks
R-852301	House, no 700	C	1.14	3.84	0.15	1.00
R-852302	House, no 700	L	1.19	3.35	0.26	0.94
R-852303	House, no 600	L	1.17	3.19	0.26	0.98
R-852304	House I, no 859	S	1.03	5.22	0.24	1.00
R-852305	House I, no 865	S	1.03	4.02	0.17	0.82
R-852306	House I, no 1605	S	1.03	5.99	0.51	0.95
R-852307	House III, no 899	L	1.16	2.93	0.22	0.93

Table 27. TL dates for ceramics, burnt clay and burnt stones from Söder Sallerup. C = ceramics, L = clay, S = stone.

Risø TL no.	Feature	Material	TL age (a)	TL date
R-852301	House, no 700	C	1823	130 AD +/- 120 a
R-852302	House, no 700	L	1880	
R-852303	House, no 600	L	823	1160 AD +/- 50 a
R-852304	House I, no 859	S	599	1320 AD +/- 50 a
R-852305	House I, no 865	S	739	
R-852306	House I, no 1605	S	1394	590 AD +/- 100 a
R-852307	House III, no 899	L	1775	210 AD +/- 120 a

TL DATING RESULTS, FINLAND

Samples from two sites, Nousiainen, Koivumäki and Pieksämäki, Vemmellahti, are discussed. In addition, samples of tiles from nine churches were received, but the dating of these is as yet incomplete.

1. Nousiainen, Koivumäki

The site was excavated in the beginning of the 1970s by Torsten Edgren, Museiverket, Helsinki. Two horizons, Middle Neolithic and Preroman Iron Age, were found. The TL dating was made on ceramics and burnt clay from the latter phase. The site is of particular interest because there were signs of iron smelting activities and the clay may partly originate from kilns used for iron smelting. The environmental radia-

tion has not yet been measured, but a value of 1.50 mGy/a +/- 0.20 mGy/a was assumed. The TL dating results are given in Tables 28 and 29. Because the samples were very small (see Table 28), the U content of grains and fading could not be measured for all of them. Values obtained for R-851305 have, therefore, been assumed for all samples. Because of the small sample sizes, the TL ages in Table 29 show considerable scatter. A weighted mean TL age was calculated using the relative number of AD determinations for each sample as weight factor. The resulting TL date, 40 BC, agrees well with the archaeological estimate.

Table 28. Sample weight (dry), water uptake (wet/dry weight), infinite-matrix beta dose rate (dry samples), U content of grains and fading over four weeks for samples from Nousiainen. A gamma + cosmic dose rate of 1.50 mGy/a was assumed. C = ceramics, L = clay.

Risø TL no.	Arch no.	Material	Dry sample weight (g)	Water uptake	Beta dose rate (mGy/a)	U content[x] (ppm)	Fading[x] 4 weeks
R-851301	219	L	41	1.16	4.15	0.30	0.95
R-851302	237	L	48	1.23	4.18	0.30	0.95
R-851303	250	L	37	1.22	4.40	0.30	0.95
R-851304	263	L	50	1.22	4.45	0.30	0.95
R-851305		C	80	1.11	3.95	0.30	0.95
R-851307		C	37	1.11	4.18	0.30	0.95

x) Because the samples were very small, the U content and fading could be measured only for R-851305. The same values were assumed for the other samples.

Table 29. TL dating results for samples of ceramics and burnt clay from Nousiainen. C = ceramics, L = clay, N = number of AD determinations, F = feldspar, Q = quartz.

Risø TL no.	Arch.no.	Material	N	Mineral	TL age (a)
R-851301	219	L	1	F	1525
R-851302	237	L	6	F + Q	2237
R-851303	250	L	6	F + Q	2081
R-851304	263	L	1	F	1565
R-851305		C	6	F + Q	2040
R-851307		C	2	F	1665

Weighted[x)] mean TL age 2025 a

Mean TL date 40 BC +/- 200 a

x) Using the relative number of AD determinations as weight factor.

2. Pieksämäki, Vemmellahti

This site was excavated by Timo Jussila and the estimated age based on typology of ceramics is 600-1000 a. The environmental radiation was measured by Högne Jungner and was 1.70 mGy/a. The TL dating was made on ceramics and the results are given in Tables 30 and 31. A U content of 0.30 ppm for feldspar was assumed. The dating was based on feldspar only because the quartz was unsuitable. The result, 1030 AD, agrees well with the archaeological estimate.

Table 30. Sample weight (dry sample), water uptake (wet/dry weight) infinite-matrix beta dose rate (dry sample) and fading over four weeks for ceramics from Pieksämäki.

Risø TL no.	Sample weight (g)	Water uptake	Beta dose rate (mGy/a)	Fading 4 weeks
R-851306	50	1.12	4.57	0.99

Table 31. TL date for a sample of ceramics from Pieksämäki. N = number of AD determinations, F = feldspar.

Risø TL no.	N	Mineral	TL age (a)	TL date
R-851306	2	F	995	1030 AD +/- 100 a

CONCLUSION

The latest improvement in our TL dating technique, namely inclusion of the dose contribution from inherent U, Th and Rb in the grains used for dating, has resulted in a greater consistency in results from samples originating from the same feature. For four sites, Grønholt, Egeskovgård, Stenby, and Anneberg, comparisons with radiocarbon dates were possible and in all cases the agreement was excellent. In general

the TL results were in agreement with archaeological estimates, but cases of disagreement did occur. In those cases where the TL dates were more recent than expected, the reason could be insufficient correction for short-term fading. The fading can be accelerated by storing samples at elevated temperatures (e. g. 100°C, (Templer 1986), and fading studies of such samples are in progress.

The procedures used for estimating the dose from internal radionuclides appear to work well, but need a firmer basis. Equations (2) and (3) used for calculating the Rb and Th contents must be confirmed by measuring a larger number of samples by neutron activation analysis and the alpha efficiency factor for feldspars must be more firmly established.

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Abstract (Max. 2000 char.)

A survey is given of archaeological samples received for dating in 1985 at the Nordic Laboratory for Thermoluminescence Dating. A total of 66 samples were dated, 42 of which were burnt stones. All results were corrected for short-term fading as measured for samples stored at room temperature for four weeks. The beta dose from potassium and rubidium in feldspar and the alpha dose from uranium and thorium in quartz and feldspar were included assuming alpha efficiency factors of 0.1 for quartz and 0.2 for feldspar.

Descriptors

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