THERMOLUMINESCENCE DATING OF POTTERY AND BURNT STONES FROM SCANDINAVIAN ARCHAEOLOGICAL SITES

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Abstract

While methods for dating pottery by thermoluminescence (TL) were established more than a decade ago, burnt stones, in particular granites, turned out to be a more difficult material to respond to this method because of the nonuniform distribution of their radioactive constituents as well as the minerals present in their matrix.

By using large grains (0.1—5 mm) of feldspars we have succeeded in developing a method that allows TL dating of burnt stones as well as pottery. The method has been used extensively during the last few years for dating material from archaeological excavations in the Nordic countries. Current progress in the method is reported and a number of dating results are presented and discussed.

The Nordic Laboratory for Thermoluminescence Dating

The Nordic Laboratory for Thermoluminescence (TL) Dating was established from January 1st, 1983. It replaced a project called The Research Councils' Archaeometry Project which was started in 1977 on the initiative of the Danish Research Councils for Natural Science and the Humanities. In 1981 and 1982 the project also received support from the other Nordic countries.

The Nordic Laboratory is financed by the Nordic Research Councils, in the form of grants given to customers of the Laboratory, and the Nordic Council of Ministers. The Laboratory receives samples from archaeologists and geologists in the Nordic countries. The dating capacity is about 100 archaeological and 60 geological samples per year. Archaeological samples can usually be dated with an accuracy of 5—7 %. A survey of archaeological samples dated in 1983 and the first six months of 1984 is given in Table 1.

Table 1. Archaeological samples dated in 1983 and the first six months of 1984.

Material	No. of samples		%
Ceramics	25	(1)	17
Clay	16		11
Bricks	8	(3)	5
Burnt stones	99	(5)	67
Total	148	(9)	100

Note: The numbers in brackets represent results that deviated from known ages or other TL ages of a series of samples.

The majority of the samples dated were burnt stones (granites), and this material is found to be well suited for dating. A few results, indicated in brackets, deviate from known age or TL ages of other samples in a series. The three deviating results for bricks are for bricks from Kronborg Castle which is dated historically to about AD 1400. The TL results yield an age close to AD 1650.

Progress in dating technique

The principle of TL dating has been outlined by Aitken et al. (1985) and our dating method has been described by Mejdahl (1982, 1983). Our method is based on quartz and feldspar grains larger than 0.1 mm. Separation of minerals is acomplished by means of heavy liquids (Fig. 1).

Light minerals move to the left in the figure and heavy minerals to the right. In addition to quartz two fractions of feldspar are obtained: Potassium feldspar with a K content of about 12 % and sodium feldspar with a K content of about 5 %. Plagioclase feldspar cannot be separated from quartz by this technique but a pure quartz fraction can be obtained by treating the mixture with concentrated hydrofluoric acid. Large grains of potassium feldspar are preferred for dating because a large proportion of the radiation dose will then be delivered by beta from the potassium in the mineral lattice.

The TL age for a feldspar sample is given by the following equation

$$A = \frac{AD}{(E + B_S + B_K + D_U)}$$

where

A is the age since firing
AD is the dose accumulated since firing
E is annual dose from environmental radiation
B_S is annual beta dose from the gross sample
B_K is internal annual dose from potassium in feldspars
D_U is annual alpha and beta doses from uranium in feldspars

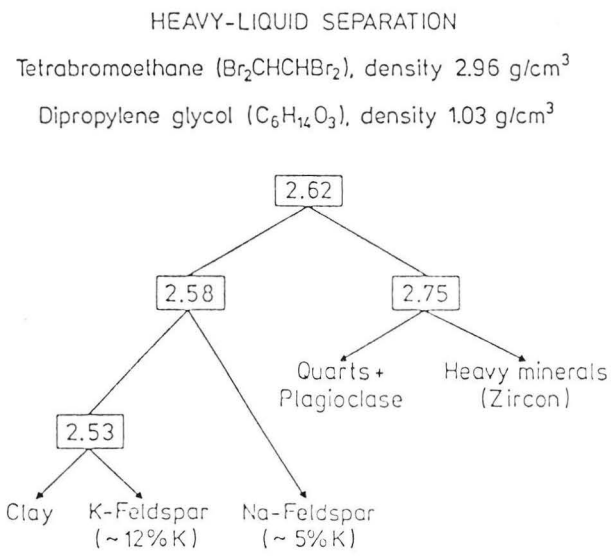

Fig. 1. Separation of minerals using heavy liquids. The two liquids are mixed to give the densities indicated.

The methods used for measuring AD, E and B_S were as described in Bøtter-Jensen et al. (1983), Bøtter-Jensen and Mejdahl (1983) and Mejdahl (1982, 1983). Calculation of B_K requires a determination of the potassium content in the feldspar grains and this was done by beta counting using a multicounter system described by Bøtter-Jensen and Mejdahl (1985). The uranium content in the feldspar grains, used for calculating D_U, was determined by delayed neutron counting (Kunzendorf et al., 1980).

In the following, TL dating results obtained for a number of Danish and Swedish archaeological sites are presented and discussed. For some of the Danish sites the TL results could be compared with radiocarbon dates.

TL dating results, Denmark

Hellum, Himmerland

A special type of pottery kiln built around a big stone was excavated in 1983 by Jan Kock, Ålborg Historical Museum (Kock 1984). The kiln was filled with wasters from the last firing, and the remains of about 70 vessels could be distinguished. Based on the ceramics, the kiln was estimated to date from about 1200 AD.

The TL dating was based on two ceramic samples, each weighing about 200 g. The results are given in Table 2.

Table 2. TL dates of potsherds from a pottery kiln found at Hellum, Himmerland. The dating was based on feldspars, and a 5 % correction for fading was applied.

Risø TL No.	Arch. No.	TL date
832901	1399	1270 AD ± 50 a
832902	1399	1250 AD ± 50 a
Mean value	1260 AD ± 50 a	

Three samples of charcoal from the kiln were dated by radiocarbon (K-4220, K-4221 and K-4222). Calibrated according to Stuiver (1982) the three dates give a range 1030—1150 AD in which each date is equally probable. The age range define the mean age of formation of the annual rings of the samples dated, and the application of the wood in the kiln must have taken place some years later. The TL date is apparently somewhat more recent than the radiocarbon results, but taking into account the uncertainty of about ± 50 years of each method it cannot be stated with certainty that there is a discrepancy. It can be concluded that an age of about 1200 AD for the kiln, as estimated by the excavator, must be close to the true age.

Mellemholmen, Søborg, North Zealand

During an excavation in 1982, directed by Robert Egevang, The National Museum, and Søren Frandsen, Gilleleje Museum, several interesting features were found of which two, a tile kiln complex and a cemetery will be discussed.

The kiln complex comprised two kilns I and II where I represented a restoration and expansion of II, which, therefore, must be the older. The kilns were excavated by Birgit Als Hansen from the National Museum. Four samples of bricks and joint were taken for TL dating and the results for three of these are given in Table 3.

Table 3. TL results for samples from the kiln complex 1982 found at Mellemholmen, Søborg. The dating was based on quartz and feldspar grains.

Risø TL No.	Material	Kiln No.	TL age (a)
820521	Brick	I	419
820522	Brick	I	488
820523	Joint	II	489
Mean value	465 ± 25 a (mean error)		
TL date	1520 AD ± 25[1] a ± 40[2] a		

[1] Statistical mean error
[2] Total error

Since the TL results did not show an age difference between the two kilns, the mean value, 1520 AD, was taken as the best estimate of the TL date for the kiln complex.

Three samples of charcoal from the kilns were dated by radiocarbon one from kiln I (K-4198) and two from kiln II (K-4196 and K-4197). The calibrated results (Stuiver 1982) were 1415, 1410 and 1420 AD, this means no age difference between the two kilns can be detected by radiocarbon. As in the previous example there is an apparent difference between TL and C-14 results, but using the same arguments as before it can be concluded that the difference is hardly significant.

The second feature was a cemetery called Bodil's cemetery. The graves had walls and roofs of bricks, and several contained well-preserved skeletons. Scattered across the cemetery were fireplaces or pits filled with burnt stones. Presumably, the cemetery was in use before the church at Søborg was built, and it was estimated to date to the interval 1150—1200 AD. The relation of the pits to the cemetery could not be decided on archaeological grounds.

A numbers of samples for TL dating were taken from the graves and pits. Four of these have been dated and the results are given in Table 4.

The dating of bricks posed some problems because there was very little feldspar and the quartz was not well-suited to dating. Feldspar from one of the stones, R-820510, showed an unusually large fading of 21 % in four weeks while feldspars from the other samples faded by 8 % in four weeks. All results have been corrected for fading. Because of these difficulties the results are regarded as preliminary.

The TL results for the tombs can be compared with radiocarbon dates of bones from three other tombs (K-3993, K-3994 and K-3995). The calibrated (Stuiver 1982) mean value of these was 1200 AD. Again, the TL date appears to be more recent, but the difference is hardly significant. The TL dates for the pit indicate that it might be slightly older than the tombs but does belong to the same period.

Table 4. TL dates for samples from Bodil's cemetery, Mellemholmen, Søborg.

Risø TL No.	Feature	Material	TL dates
820505	Tomb, 852	Brick	1300 AD ± 70 a
820536	Tomb, 846	»	1330 AD ± 70 a
820509	Pit, 856	Stone	1140 AD ± 80 a
820510	Pit, 856	»	1060 AD ± 80 a

Table 5. TL dates of burnt stones from Moesgaard, Vindinge near Roskilde. The dating was based on feldspars.

Risø TL No.	Hearth No.	TL age (a)
821703	55	(1660)
821704	55	1135
821708	54	1145
821709	102	1125
821712	102	920
Mean value (4 samples)	1080 ± 55 a	
TL date (4 samples)	900 AD ± 55[1] a ± 80[2] a	

[1] Statistical mean error.
[2] Total error.

Farvergade 7, Næstved

An excavation in 1981 directed by Per Bugge Vegger (Vegger et al., 1982) revealed a kiln complex that had been used for firing glazed tiles. Ceramics found in the layers indicated the period 1250—1350 AD; however, coins from the time of King Erik Menved (1286—1319) found under the kilns pointed to the first half of the 14th century. Two samples of fired clay from the kilns (R-812601 and R-812602) have been dated by TL. The mean value was 1295 AD ± 50 a, in good agreement with the archaeological estimate.

Moesgaard, Vindinge

The excavation at Moesgaard took place in 1982 and was directed by Tom Christensen, Roskilde Museum (Christensen 1983). The excavation included two houses estimated to be built during the Viking Age. The houses were adjacent, but at a right angle to each other and were interpreted as a farm. Burnt stones for TL dating were collected from three hearths found inside the houses. The results are given in Table 5.

The age for R-821703 is somewhat greater than those of the other samples. At present, I have no explanation for the deviation, but have omitted the result. The results for the other samples are consistent and give a mean TL date of 900 AD, that is, late Viking Age.

TL dating results, Sweden

Lapphyttan, Västmanland

The excavation, directed by Åke Hyenstrand and Gert Magnusson, Riksantikvarieämbetet, Stockholm, concerned an iron smelting furnace, a so-called »masugn» in Swedish. In 1982 samples of burnt stones for TL dating were taken from the shaft, the filling around the shaft, a slag pile and a fireplace in a house.

The dating of these samples proved difficult because their content of feldspar was very low. Dating based on quartz was attempted, but without success. It is a general experience that quartz from burnt stones is not well-suited for dating. The predose method was also tried, but the samples appeared to be too old for this method. Eventually, the dating was based on the small feldspar samples. Results for seven samples are presented in Table 6.

The age of a sample taken from the bottom of the slag pile was somewhat younger

Table 6. TL dates for burnt stones from an iron smelting furnace at Lapphyttan, Västmanland. The dating was based on feldspars.

Risø TL No	Feature	TL age (a)
824201	Shaft of furnace	645
824203	Slagg pile, bottom	(501)
824206	» , middle	628
824208	» , top	589
824209	Filling around shaft	542
824210	»	673
824211	Hearth in house	592
Mean value (6 samples)	612 ± 20 a (mean error)	
TL date (6 samples)	1370 AD ± 60 a (total error)	

Table 7. TL dates of burnt stones from Torsburgen and Gothemshammar, Gotland. The dating was based on feldspar.

Risø TL No.	Locality	TL date
823601	Torsburgen, Ala Luke	1190 AD ± 80 a
823602	»	1110 AD ± 80 a
823604	Gothemshammar	1270 AD ± 80 a
823605	»	1160 AD ± 80 a

Note: The total uncertainty is stated.

than the others; this was puzzling, but the other six samples gave consistent ages with a statistical mean error of only ± 20 a. The resulting TL date is 1370 AD ± 60 a (total error). Radiocarbon dates have indicated two horizons: 985—1270 AD and 1240—1430 AD. The TL date is in good agreement with the most recent of these.

Gotland

In 1982, samples of burnt stones were taken from two defence systems, Torsburgen and Gothemshammar, in connection with an archaeological investigation carried out by Johan Engström, Gustavianum, Uppsala (Engström 1984). Two samples from each locality could be dated and the results are given in Table 7.

The two sets of samples thus date to the early Medieval period. The first sample, R-823601, contained no alkali feldspar; therefore, the dating was based on a mixture of quartz and plagioclase feldspar where the plagioclase TL signal would be dominant. The result for this sample was corrected for fading by 14 %; the other samples showed no fading in four weeks.

It should be stressed that the TL dates cannot be assumed to pertain to the construction of the defence walls; they must reflect later activities. For Torsburgen a considerable number of radiocarbon dates have been obtained, which extend back to the birth of Christ. A series taken at Ala Luke covers the period 600—1100 AD, but cannot be compared with the TL results because of different stratigraphy of the samples. Wright (1979) obtained a predose TL date of 30 AD for quartz extracted from burnt limestone.

Bronze Age mounds, Södermanland

In connection with a study of Bronze Age centra in Södermanland carried out by Sonja

Table 8. TL dates of burnt stones from Bronze Age mounds in Södermanland.

Locality	No of samples	TL date
Vagnhärad, central	6	910 BC ± 40 a ± 180 a
Vagnhärad, outer	3	1250 BC ± 130 a ± 200 a
Lindö	5	890 BC ± 50 a ± 200 a
Lindholm	8	1170 BC ± 80 a ± 200 a

Note: Statistical mean errors and total errors are stated.

Wigren, Riksantikvarieämbetet, Stockholm (Wigren 1985) burnt stones for TL dating were collected from assemblies of mounds at three localities: Vagnhärad, Lindö and Lindholm. At Vagnhärad a central area comprising the most conspicuous mounds could be distinguished from the peripheral area some 500 m away. The mounds were not excavated, but stones were taken at depths of 30—50 cm, and the gamma radiation was measured in the holes that remained.

A total of 26 samples representing 14 mounds were dated, but 4 results were discarded because they deviated by about 1000 years from the other results; two were younger and two older. The results for the remaining 22 samples are summarized in Table 8.

It can be seen that all mounds date to the same Bronze Age period, around 1000 BC. The mounds in the peripheral area at Vagnhärad appear to be older than those in the centre, but it should be stressed that the date of the outer area is based on only three samples. Vagnhärad, central and Lindö are contemporaneous whereas Lindholm appears to be slightly older. Except for Vagnhärad, outer, the dating precision is high, with statistical mean errors ranging from 40 to 80 years. This indicates that is should be possible to differentiate between Bronze Age localities having age differences as small as 100 years.

Conclusion

A TL technique utilizing large grains of alkali feldspars has been developed during the last few years. The results presented illustrate the application of the method to a variety of archaeological materials.

In cases where TL and radiocarbon results could be compared, the TL ages were generally younger than those obtained by radiocarbon. This is to be expected because the two methods usually do not date the same event. A real discrepancy between results obtained by the two methods was not found.

The possibility of dating burnt stones is a particularly attractive feature of our TL method. The results for burnt stones from Swedish Bronze Age mounds demonstrates that a high precision can be achieved, which is useful for relative dating. The absolute uncertainty, that also includes systematic errors, is 5—7 %.

Acknowledgements

It is a pleasure to thank Dr. H. Tauber and the excavation directors for useful discussions concerning the dating results. I am grateful to members of the staff of the TL laboratory: Ms. L. Farina, K. Larsen, H. Vehl and U. Wilhelmsen for skilful assistance.

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