TL-DATING OF VITRIFIED RAMPARTS: DID BIRNAM WOOD GO TO DUNSINANE HILL IN A.D. 455?

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Abstract

As a contribution to the general interpretation of "vitrified forts" a major dating project was started with samples from Northern Europe. To increase the unsatisfying rate of success which could be achieved by standard TL-techniques, the pre-dose method was reconsidered to which an essential novelty was added consisting in a normalisation of the archaeological doses from individual samples to sensitivity.

The TL-results extent over approx. 2000 years with a distinct clustering at about 500 A.D. The date obtained for Dunsinane Hill (ref. Shakespeare's *Macbeth*) indicates that TL-ages need not necessarily be concordant with historical or C-14 dates. Methodological limitations arise not only from high firing temperatures, but also from low firing temperatures. Intensive sampling can rule out systematic errors.

Vitrified forts have been defined as prehistoric fortifications where the building stones of the rampart are bound together by vitreos material formed in situ by the action of heat (Christison, 1898). The 230 sites that are known in Europe until now have attracted the phantasy of archaeologists for more than 200 years, but despite the engagement of scientists a comprehensive understanding of how these vitrifications have been accomplished has not been obtained. At least for some of the materials used in building ramparts the investigations have revealed the conditions which are needed to fuse rocks (Kresten et al., 1993). For quite a number of hill-forts these results lend support to the constructive theory. The contradiction between the sophisticated methods that would be needed to vitrify sizeable ramparts and the traditional time-setting of the forts into prehistoric periods have stimulated the following investigations.

As some elucidation was expected from the age of the fortifications, first attempts to date hill-forts were undertaken already in the early days of thermoluminescence dating, most remarkably by the pre-dose technique (Wright, 1979). Recent attempts towards this goal have been made by Sanderson et al. (1985, 1988) and Strickertsson and Placido (1988). Their approach was focused on Scottish hill-forts, the most frequent occurrence of this kind of fortification. Ten TL-dates, spanning from 723 A.D. to 2160 B.C., have been evaluated altogether, four of which in fair agreement to C-14 dates.

A collection of samples from Sweden, Scotland, Ireland, Wales, France and Germany (collected by P. Kresten in recent years) allows to extend dating studies over a wider geographical area and thus permits setting the phenomenon into a more general context. It will thus be possible to decide whether or not the method of vitrifying ramparts is a pure Celtic habit, as it is accepted still today.

Dating Methods

By selecting techniques and minerals for TL-dating a compromise had to be found that would be suitable to cover all the different materials from the various hill-forts and equally be able to date quartz, as this is the prevailing mineral in sandstone. Among the standard methods which were tried first, the quartz inclusion method is the method at hand, but it proved unsuitable due to the high degree of supralinearity which most of the samples exhibited. This observation is in close agreement to Sanderson's experiences (1988).

For the major part of the samples the fine-grain technique of thermoluminescence dating yielded the most promising results with the added disadvantage of a low amount of fine-grain material in granitic and gneissic rocks. The technique is well known and described elsewhere (see Aitken, 1985). Alpha-counting and potassium analysis was used here for the evaluation of the internal dose. Most remarkably, supralinearity was not observed in the fine grain fraction (1–11 µm).

However, dates for only half of the sites could be obtained, while the other half proved undatable by this method, as TL-emission on laboratory irradiation differs severely from natural TL-emission. This is obviously the result of an extremely high firing temperature, as can be deduced from the mineral composition. X-ray diffraction patterns show high temperature modifications of quartz and correspondingly high temperature modifications of feldspars, even sillimanite (Al_2SiO_5) was detected. Confirming a long known fact in TL-dating firm relations between diffraction patterns and datability cannot be established, and hence the suitability of a sample for fine-grain dating cannot be predicted on the basis of its mineral composition.

The unsatisfying rate of success of only 50% led us reconsider the pre-dose dating method, because this method has several advantages over high-temperature methods. In particular, exclusively quartz contributes to the TL-signal, there are no limitations arising from fading and exposure to light. Therefore, also rocks are datable which have been exposed to light for some time. Severe limitations arise, however, from the fact that some electronic levels (luminescence and reservoir levels) which are involved in the transport of electronic charge, are easily saturated by even small doses. The applicability of the technique is thus restricted to comparatively young samples of less 2 ka. In view of these limitations it was expected that only the historic hill-forts would be datable.

A review of the pre-dose effect was recently given by Bailiff (1994), practical operating instructions can be learned from fall-out dosimetry studies made by Haskell et al. (1994).

In the pre-dose technique the sensitivity increase of the low energy TL-peak of quartz at 100°C is recorded after successive heating and dosing. As the sensitivity increase depends on the previously acquired dose, named the archaeological dose, the method can be used as a dating tool (Fleming, 1973). A first estimate of this archaeological dose is obtained by multiple activation (i.e. dosing and heating) of the same sample, and is therefore called the MA-archaeological dose (multiple activated archaeological dose, see Fig. 1).

However, the MA-archaeological dose is not the final value which would yield correct ages, it still depends on experimental quantities, especially on the laboratory dose. The true archaeological dose is obtained when the pre-dose experiments are performed with a laboratory dose equal to the expected archaeological dose.

A better approach to this true archaeological dose is obtained from a so-called R-characteristic (Fig. 2) in which the MA-archaeological doses are plotted against the laboratory doses (Haskell et al., 1988). The point in the graph where the ratio of the

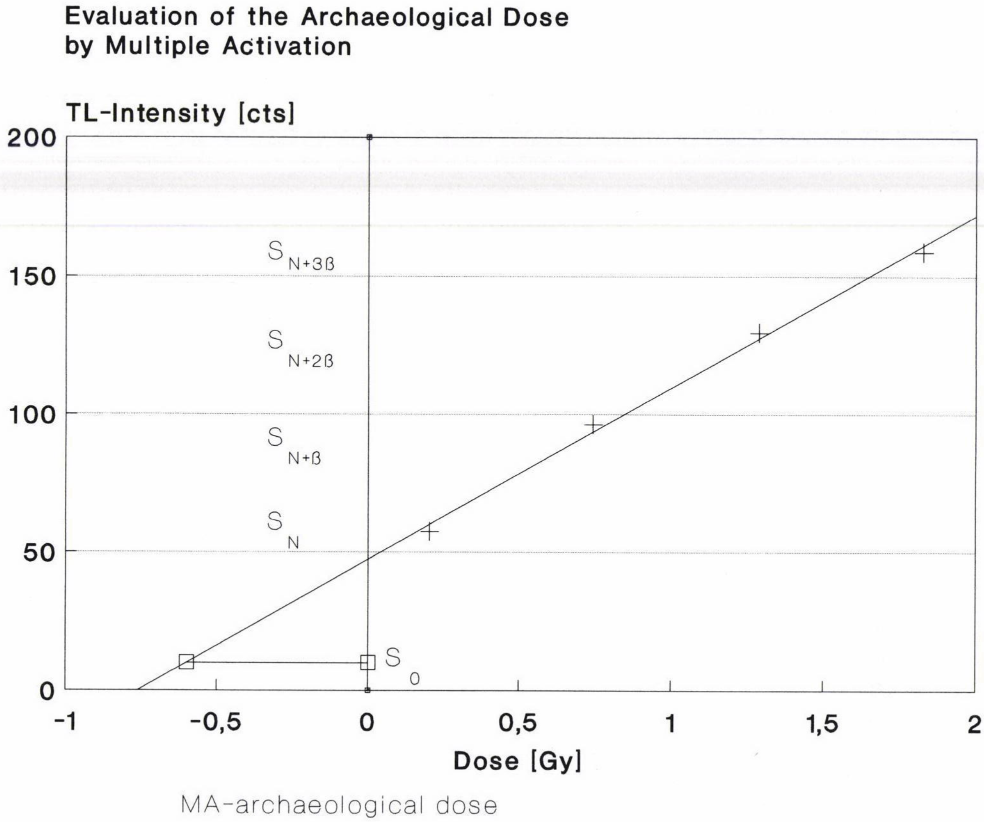

Fig. 1. Evaluation of the archaeological dose by multiple activation. The dose accumulated after archaeological storage is obtained by back-extrapolation of the regression line to the dose axes taking into account that all intensity measurements are made above the background-level S_0. The dose is called the MA-archaeological dose, it is only a first step in the evaluation of the true archaeological dose.

two doses is unity, yields the so-called RC-archaeological dose forming the base for age calculations (Haskell et al., 1994).

The high degree of scatter in this type of graph (Haskell et al., 1988) usually precludes the pre-dose technique from dating applications, because even a great number of data does not yield reproducible results. As the data in Fig. 2 are from individual samples, we attribute the scatter to a missing interralation of the samples and thus suggest to normalize samples for better comparison.

It was mentioned above that the sensitivity increase depends on the accumulated archaeological dose. As the experiments aim at the determination of this dose, it is a logical consequence to normalize the MA-archaeological doses from the individual samples to sensitivity. A suitable mathematical expression is the ratio S_N/S_o (first sensitivity over background) which is a measure for the effectiveness of the thermal activation of holes from the reservoir to the luminescence level. The ratio is constant for samples having received equal doses and having been stored under equal storage conditions. For samples which have received radioactive doses in addition to their natu-

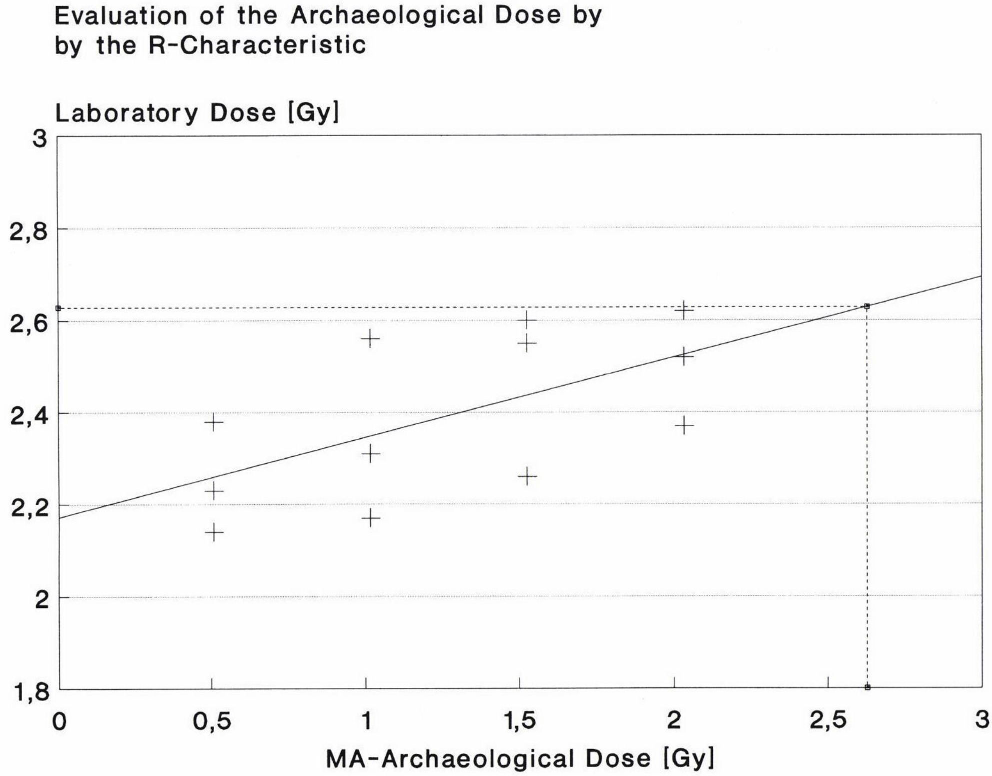

Fig. 2. Evaluation of the RC-archaeological dose from the R-characteristic which is a plot of the MA-archaeological doses vs. the laboratory dose. The RC-archaeological dose is obtained at 2.63 Gy where the ratio of the two doses is unity. The reliability of this value is limited, as the regression line can only be extended over a comparatively short range of laboratory doses which is due to the risk of saturating the luminescence level of quartz.

ral dose, the values S_N/S_o are expected to form a straight line, because additional doses affect only the value of S_N.[1]

The normalisation is performed in the following way:
For the different portions of the sample, carrying the doses natl. TL, natl. TL+1 beta dose, natl. TL+2 beta dose etc., the MA-archaeological doses are evaluated using at least four different laboratory doses per portion (i.e. each portion is subdivided into 12 sub-portions and the MA-archaeological doses are evaluated using one constant laboratory dose on three sub-portions). The MA-archaeological doses are then plotted over their S_N/S_o-values (see Fig. 3). The normalisation consists virtually in a selection

[1] In TL-dating additive dose techniques are usually the preferred techniques for dose evaluation; ie. the accumulated doses are evaluated for different portions of a sample which have received radioactive doses in addition to their natural dose. The total accumulated dose is evaluated from a backextrapolation to the dose axis. This technique has been applied also here.

Table 1. TL single-dates for vitrified hill-forts.

Germany							
Bremerberg	BRE04	639	A.D.	± 136	cg	470 B.C.	dendro[a]
		487	A.D.	± 151	cg		
		368	A.D.	± 165	pd		
Marialskopf	Mar04	311	A.D.	± 127	fg		
	Mar01	305	A.D.	± 105	fg		
France							
Hartmanns-willerkopf	HWK02	33	B.C.	± 122	fg		
		607	B.C.	± 173	fg		
Camp de Péran	CDP07	1014	A.D.	± 62	fg	1030 ± 60	BP[b]
		1118	A.D.	± 72	fg		
Puy de Gaudy	PDG02	1145	A.D.	± 53	fg		
		1082	A.D.	± 58	fg		
		999	A.D.	± 89	pd		
Scotland							
Finavon	FIN01	581	A.D.	± 94	fg	640 A.D.	TL
		303	B.C.	± 163	fg	2540 ± 70	BP[c]
Mote o'Mark	MOM05	1112	A.D.	± 58	fg	750 A.D.	TL
						459 ± 42 A.D.	
						380 ± 60 A.D.	
						425 ± 50 A.D.	
						355 ± 50 A.D.[d]	
Rubh Aird Ghamsgail	RAG12	307	A.D.	± 130	fg		
Dunearn	DEA01	814	A.D.	± 88	fg		
Dunsinane	DUN02	455	A.D.	± 120	fg		
Tap o'Noth	TON02	456	A.D.	± 105	fg	2160 B.C.	TL
Craig Phadrig	CRP06	1424	A.D.	± 46	fg	130 B.C.	TL
		1005	A.D.	± 99	pd	2280 ± 100	BP[e]
Doune of Relugas	DOR01	146	B.C.	± 114	fg		
Cairnton	CTN01	1424	B.C.	± 226	fg		
Ireland							
Banagher Glebe	BAG01	511	A.D.	± 137	fg		
Wales							
Caer Euni	EUN05	332	B.C.	± 121	fg		
	EUN06	227	B.C.	± 138	fg		
Sweden							
Broborg	BRO01	368	A.D.	± 150	fg	740 A.D.	TL
						1505 ± 55	BP
						1595 ± 55	BP[f]

a) Hollstein, E. (1973) Jahrringkurven der Hallstattzeit. *Trierer Zeitschrift* 36, 37–55.
b) Nicolardot, J.-P., Jaubert, A.N. and Wimmers, W.H. (undated) Quelques nouvelles données des fuoilles au Camp de Péran. – Association des Amis du Camp de Péran. Pledran, 23 pp.
c) MacKie, E.W. (1969) Radiocarbon dates and the Scottish Iron Age. *Antiquity* 43, 15–26.
d) Longley, D. (1982) The date of Mote of Mark. *Antiquity* LVI, 132–134.
e) Cunliffe, B. (1994) Iron Age Communities in Britain. – Routledge, London and New York.
f) (Ua-3065) and (Ua-3066)

cg = coarse grain technique
fg = fine grain technique
pd = pre-dose technique
BP = uncalibrated C-14 date

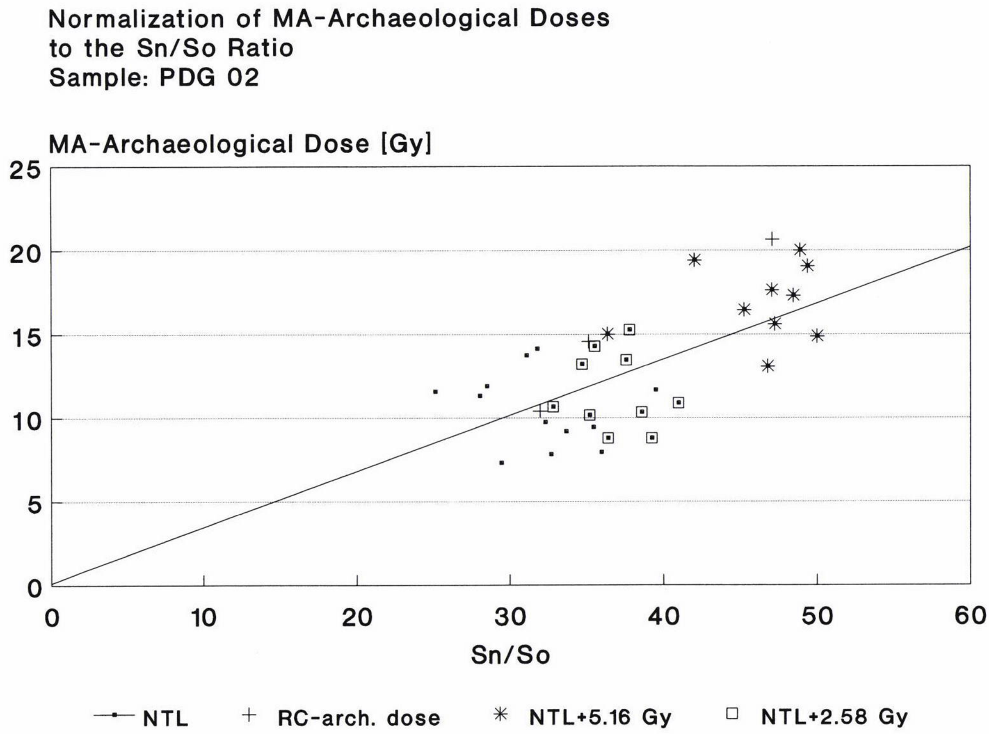

Fig. 3. Normalization of MA-archaeological doses to sensitivity. The normalization aims at the construction of a linear regression which runs through zero. This is achieved by not only omitting obvious outliers, but also by proper selection of data. The plot yields information whether doses given in addition to the natural dose saturate electronic traps (reservoir traps).

of data with the aim to reduce the intercept of the regression line to zero. The necessity to run through zero results simply from the fact that no sensitization can occur without a dose. With the remaining data the RC-archaeological doses are calculated as mentioned above (Fig. 2) and are plotted as a function of the added dose. The true archaeological dose, from which the age is finally calculated, is taken as the intercept of the regression line to the dose axis (Fig. 4).

Discussion

Samples from 10 sites for which fine grain data have already been evaluated were tried with the pre-dose method, but for only three consistent results were obtained. For the majority of samples the activation temperature was beyond the range of our instrumentation, in two other samples a high TL-signal which we attribute to Cristobalite, overlapped the 100°C peak and thus prohibited the evaluation of the signal. Both effects indicate a firing temperature beyond 1200°C and neither TL-technique, coarse-grain, fine-grain or pre-dose would be applicable.

Saturation of the hole reservoir indicating a high age, was the reason for failure for only three samples.

The ages in Tab. 1 extent over a period of more than 2000 years, but with a distinct

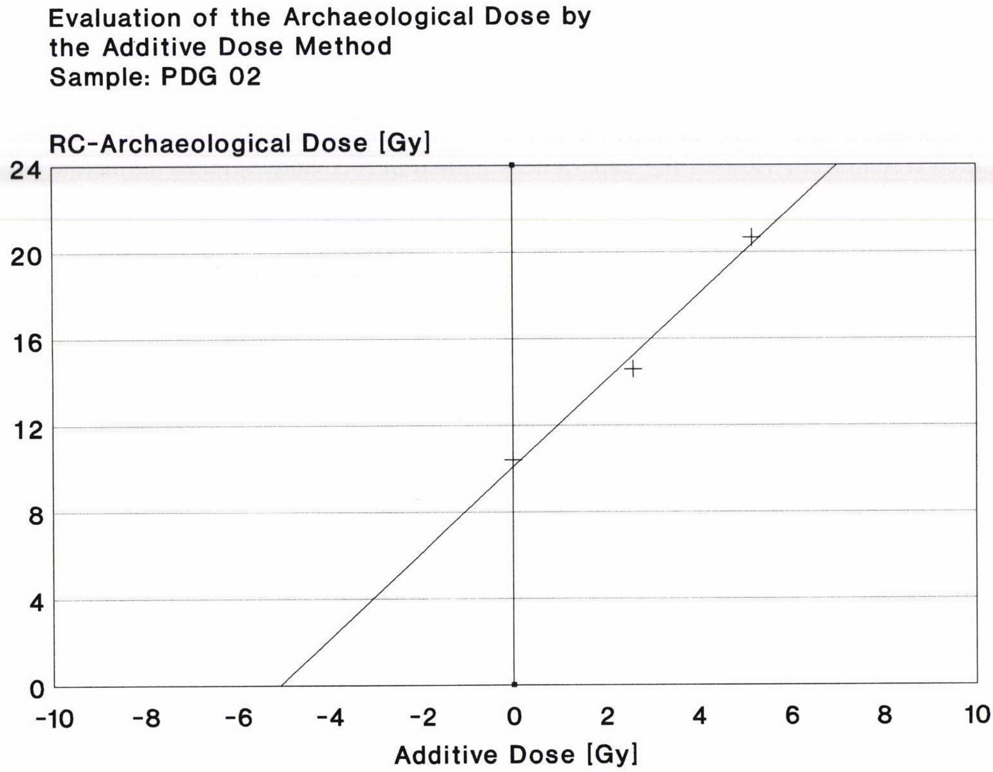

Fig. 4. According to standard additive dose procedures the final archaeological dose is obtained by back-extrapolating the linear fit of the normalized RC-archaeological doses to the axes of additive doses.

clustering around 500 A.D. which shifts the phenomenon towards historic rather than prehistoric times.

Regarding the numerous deviations between TL-dates and reference dates in Tab. 1, it must be remembered that TL dates the last heating over 500°C and therefore is a record of either the construction or the destruction date, it may not be associated with the settlement of the site. Dunsinane Hill is an example for the fact that the known historic event which, following Shakespeare's Macbeth, took place around A.D. 1000, does not coincide with the TL-date. Obviously this site has been occupied many centuries after the ramparts had been vitrified. In general, as the two methods date different events, an agreement between TL and C-14 dates cannot be expected. TL is always expected to yield a younger age as, for example, a large time span may elapse between the falling of the tree used to build the rampart and its destruction. Deviations of this kind may have occurred in the samples of Bremerberg and Mote o'Mark, both of which show considerable higher C-14 dates than TL-dates.

Another type of disagreement concerning the deviation between TL-dates obtained in this and former work reveals a specific problem of dating fused rocks. Whereas too high a firing temperature is recognized in course of the dating procedure, too low a firing temperature is less easily detected. In this latter case a remnant geological TL-component gives rise to a high TL age. This possibility has to be taken into account for the TL-dates of Tap o'Noth and Craig Phadrig, as it is unlikely that two laboratories would obtain so far differing results. These differing results are an excellent justification for the common practice of TL-dating which averages the results of individual samples rather than to average the repeated results from the same sample to gain a context date.

Results in Tab. 1 may be thus regarded as a reasonable starting point for more detailed research. In view of the experiences gained in this study a more deliberate selection of samples has to take place which should include not only a larger number of well defined samples from the same site, but also exclude samples of obviously exceeding firing temperatures which has been seen as the main cause of difficulties in this study.

Acknowledgements

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