

Ancient TL Date List

In AnTL 3(i) we announced plans to launch an International TL Date List and, after discussion amongst members of the Editorial Board, a specimen list containing several entries has been prepared. Readers are invited to send their comments regarding the format of the Date List and interested laboratories should submit pre-applications (see below) for the 1st edition of the list, reaching the Editor **no later than 31st January 1987**, to enable publication by mid-1987. It is likely that two lists will be published during 1987 if a large number of submissions are received, and it is envisaged that the date list will become an annual publication. The TL Specialist Seminar will provide an opportune time to discuss matters concerning the list. Those laboratories that have already sent details of their recent TL dates to Ancient TL will shortly receive advice from Durham concerning the new list. In arriving at a structure for the Date List, we have considered a number of previously published ideas concerning TL date presentation and we hope that readers will consider that the proposed structure, by incorporating the best of these, fulfills the current needs of TL and archaeological researchers. We look forward to receiving your responses.

Editor

Date List Structure

1. The list will include dates for fired materials of archaeological interest. Sediment TL ages will not be included at this stage.
2. The list is intended to contain TL dates for which sufficient information has been supplied that is consistent with the date and associated errors given by the laboratory. It is not intended to be an "authorised" list.
3. Each entry is divided into two sections. The first (Part I) is a non-technical specification of the date and provides basic information concerning the date and associated error, and the archaeological context of the sample. The second (Part II) is a compacted technical specification, the format of which is intended to be sufficiently comprehensive to provide information of interest to TL researchers. Its format is flexible and will permit subsequent additions and alterations where necessary. By providing a split entry in this way we aim to interest archaeologists, for whom basic information concerning the date and associated error and the archaeological context of the sample should be easily accessible. The Reports section in Part I gives access to further detailed information.
4. In this issue we have provided specimen TL dates for single samples, but the format can be easily adapted to accommodate a number of dates from the same site.
5. Dates within the archaeological periods ranging from the Mesolithic to the historic are given AD/BC to reinforce the absolute basis of TL dates. Palaeolithic dates are to be given as TL ages in ka, and the last two digits of the test year are included in the laboratory reference code, as shown below. One error, the overall error, has been adopted in the single date entry for Part 1 and the precision may also be given in the technical specification. An average date derived from a number of single dates will be given with two errors, as presently advocated.

6. In order to compact the information, a number of abbreviated terms and forms of expression of data have been adopted, the details of which are given in the Single Date Entry Specification. The information to be provided is indicated by a description in italics within squared brackets, or, for some numerical data, is illustrated by open boxes. The Specification should be read in conjunction with the Notes and Key sections. A full explanation of the structure of the Date List and abbreviations will be given in each publication of the Date List.
7. Three example date entries (AnTLDL#1-#3) are given on p 43-45 for;
- i) a palaeolithic sample , dated using the inclusion and fine-grain techniques,
 - ii) a pottery sample dated using a multi-mineral inclusion technique of the Risø Laboratory, &
 - iii) a pottery sample dated using the pre-dose technique.

The examples are intended to demonstrate the potential flexibility of the technical specification, to which additions may be made in the future, and which will serve as the basis for specifying the results obtained using other techniques.

Procedure for Date List Entry Submission

- * Send to Durham by **31st January 1987**, a list of the dates you wish to be considered for inclusion using Part I specification only. This list should not exceed 50 single dates per laboratory.
- * The Editorial Board will examine the entries from all the laboratories and select the contents of the first list. Laboratories will then be invited to supply further details, including Part II. By this time we will have been able to consider any revisions to the Entry in the light of comments from AnTL readers. It is likely that a form will be issued to obtain the data required for Parts I and II. The Editorial Board will again examine the complete entries to ensure that all relevant information has been supplied; submitted entries failing to meet these requirements will not be included.

ANTL SINGLE DATE ENTRY SPECIFICATION

The specification for a single date entry is suitable for inclusion and fine-grain results. The variations in specification for dates obtained using the pre-dose technique and the multi-mineral techniques, where tabulation is necessary, are detailed under the section 'Variations'. It can be seen that the form of tabulation used for the latter is also suitable for providing details of a series of dates from the same site. The form of TL age quotation for Palaeolithic samples is also specified in this section.

Date List Entry

PART I DATE SPECIFICATION

Site: [*name, regional location, country*]

TL Date : [] [] [] [] ± [] [] **A.D./B.C.** ([*lab.Abb.*] [] [] **TL** [*technique*])

Lab. Sample Ref.:

Material: [*eg pottery, burnt clay, stone or flint, and brick*]

Archaeological Ref.: [*sample ref, as assigned by archaeologist*]

Archaeological evidence: [*brief description of context*]

Site Director: [*name, institution, and country*]

Reports: [*details of laboratory and excavation reports*]

PART II

TECHNICAL SPECIFICATION

A. 1.min.([*mineral*]) **tech.**([*technique*] ; [*grain size range*])

2. P = [] [] ± se Gy **2a. I / P** = [] [] [] **3. Slopes** [2nd/1st: [] [] ± se]

4. Plateau [± [] [] % ; [$T_1 - T_2$]] **4a. Peak** [[] [] [] [] °C ; [*heating rate*] °/s ;
[*pre-heat details if applicable*]]

5. Stability [[$T_1 - T_2$] ; [*period*] ; [*storage T °C*] ; [*result*] ; [] [] ± [] [] %]

6. a value = [] [] or **b value** = [] []

B. 1. Total. Effective.Dose-rate = [] [] [] ± s.e. [α = [] [] % [*method*] ; β = [] [] %
[*method*] ; γ = [] [] % [*method*] ; cos. = [] [] % [*method*]]

2. Radon [+/- [] [] % [*method*]]

3. Water [Sample ([] [] ± [] %) ; Environment ([] [] ± [] %)]

C. Error [[*procedure* : eA76 or specify other]]

D. Age = [] [] [] [] [] **a** [± [*precision*] ; ± [*overall accuracy*]]

Special Remarks:

VARIATIONS

1. SINGLE DATE ENTRY FOR THE PALAEO-LITHIC

Part I: TL Age = [] [] . [] [] ± [] [] ka [*lab. Abbr.* [] [] TL [*technique*]]

Part II: D. Age = [] [] . [] [] ka [± [*precision*] ; ± [*overall accuracy*]]

2. SINGLE DATE ENTRY : PRE-DOSE TECHNIQUE

Part II :

A 2. P = [] [] ± [] [] Gy ([*pre-dose procedures*])

3. Initial. Sensitivity. [] [] %S_N; [] % (of S_N) UV reversible; Sb = [] [] %S₀

4. TAC [[*temp. region of max. sensitization*] ; [*heating rate*] °/s]

5. Stability. [[*result of stability measurement*]]

3. SINGLE DATE ENTRY : MULTI-MINERAL INCLUSION TECHNIQUE

Part II

A. 1. mins. [*minerals*] **tech.** [mmi; gsr (μm) -1 ([] [] [] - [] [] []), n ([] [] [] - [] [] [])]

Table	[<i>mineral</i>] (gsr·)	[<i>mineral</i>] (gsr·)	
2. P	[] [] ± [] []	[] [] ± [] []	Gy
2a. I/P	[] [] []	[] [] []	
3. Slopes	[] [] ± [] []	[] [] ± [] []	
4. dPlat	± []	± []	%
4a. Peak	([] [] [] - [] [] []) [] [] [] @ [] °/s; [<i>pre-heat details if applic.</i>]	([] [] [] - [] [] []) [] [] []	°C °C

5. Stab [[*mineral*] (gsr ([]), [T₁ - T₂] ; [*period*] ; [*storage T ° C*] ; [*result* [] [] ± [] [] %]]

Table	Method	[min. []] ([gsr []])	[min. []] ([gsr []])	
B 1. Tot.Eff.Dr	 Total effective dose-rate		mGy/a
1a. Ext%tot		[β dose-rate from external sources as % of total]		%
β		[γ + cos. " "]		%
γ + cos		[dose-rate from internal sources as % of total]		%
1b. Int%tot. ([isotopes])				

KEY

STANDARD METHODS/TECHNIQUES/PROCEDURES

i	INCLUSION	aPlat	AGE PLATEAU	pd	PRE-DOSE
fg	FINE-GRAIN	dPlat	DOSE PLATEAU	MA	MULTIPLE ACTIVATION
mmi	MULTI-MINERAL INCLUSION	sPlat	TL SIGNAL PLATEAU	AD	ADDITIVE DOSE PROC.
				Sb	SENSITIVITY BASELINE

KEY contd

α -c	ALPHA COUNTING	NAA	NEUTRON ACTIVATION ANALYSIS
AAS	ATOMIC ABSORPTION	PXE	PIXIE
β -c	BETA COUNTING	SPEC	SPECTROMETER
CAP	CAPSULE	TLD	TL DOSIMETRY
FPh	FLAME PHOTOMETRY	XRF	X-RAY FLUORESCENCE

NON-STANDARD

AutoR	AUTO REGENERATION	PTTL	PHOTO-TRANSFERRED TL
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MINERALS & ETC

cal	CALCITE	p	POLYMINERAL	*	OTHER
ft	FLINT	por	PORCELAIN	-	NOT APPLICABLE
f	FELDSPAR	q	QUARTZ	e	EQUIVALENT TO (USED AS PREFIX)
Af	UNSEP. ALKALI FELDSPAR	z	ZIRCON	a	YEAR
Kf	POTASSIUM FELDSPAR				
Nf	SODIUM FELDSPAR				

Terms: I, P, a, b, A, S_N, S_O, TAC: as defined in the literature.

NOTES**GENERAL**

1. It is strongly recommended that, in addition to laboratory reports, reference to an excavation report is included since this will be of particular importance for archaeologists. If a non-standard technique has been used, reference to a full report or paper must be given under Reports or Special Remarks, and a copy included with date list applications if not published in a recognized journal.
2. Part II presently comprises four sections A-D. It can be seen that they include the following measurement details, A; TL, B; Dose-rate, C; Error and D; Age, each of which contains numbered summaries of particular data. In section B, the total effective dose-rate (Tot.Eff.Dr.) is broken down into percentage contributions for each radiation type.
3. Grain sizes are given in μm . Errors are standard errors given at the 68% level of confidence

SPECIFIC DATA ENTRIES

- A1. The mineral type(s), TL technique, and grain size range(s) are specified using the standard abbreviations given in the key. For a technique employing a number of grain size ranges (gsr's), as in the multi-mineral inclusion (mmi) technique used at the Risø Laboratory, each gsr is assigned a number which, prefixed with the appropriate abbreviated mineral type, is used in the tabulation of measurement details A2 - A4.
- A2. The archaeological or palaeodose, P, is given in Gy with associated standard error, and information concerning the intercept is given in 2a. (I/P).

A2-A5 (Pre-dose)

To be consistent with other techniques, P is used to denote the archaeological dose. S_b, the sensitivity baseline, is the (assumed) sensitivity that would have been measured after firing, expressed as a percentage of S₀. Although stability measurements are not part of the original procedure, it is likely that they will be performed in the future.

- A4. TL signal, TL age or dose plateaux may be specified using the appropriate prefix (s, a or d respectively). The s.e. of the mean value is given (as a percentage) for the indicated temperature interval (T₁-T₂) of the glow curve. If a well-defined TL peak is present in the plateau region, its peak temperature and the heating rate used should be given. This may not be the case for some fine-grain samples.

- A5. The results of TL stability measurements obtained for; the temperature region of the glow curve, the storage period, the storage temperature and the outcome are specified in the order given.
- A6. **a** or **b** value is given.
- B1. The total effective dose-rate, corrected for water uptake, grain size attenuation etc., is given with associated standard error. The percentage contributions of the various radiation types are given with abbreviated name of the method used.
Any correction to the dose-rate (expressed as a percentage of the total) that has been made due to radon emanation should be given, indicating the experimental method used (ie α -c, γ SPEC). In the case of the mmi technique, the external and internal dose-rate contributions for TL grains, expressed as a percentage of the total (Ext%tot. and Int%tot.), are given separately, and the isotope emissions accounted for in assessing the internal dose-rate are listed.
- B3. The average water content and assigned uncertainties for the sample and burial environment are specified.
- C. "eA76" denotes a procedure for error assessment equivalent to that described by Aitken (1976; *Archaeometry*, **18**, 233-238). If another procedure has been used, reference to a report/paper where the methods are described must be given.

EXAMPLES

Entry: Oxford Laboratory

AnTLDL#1

Part I: DATE SPECIFICATION

Site: Maastricht-Belvedere, Holland

TL Age : 238 ± 25 ka (Ox85TLfg&i)
Material: burnt flint

Sample Ref : 712k17
Archaeological Ref : 49/106-2

Arch. Evidence: Flints from layer of fluvial sediment containing the archaeological occupation.

Site Director: W. Roebroeks, Rijkuniversiteit Leiden, NL.

Reports: Huxtable J. and Aitken M. J. (1985) TL dating results for the Palaeolithic site Maastricht-Belvedere. *Mededelingen Rijks Geologische Dienst N.S.* **39**. ISBN 90 12 05231 9. Reprinted in *Analecta Praehistorica Leidensia*, **18**, 41-44. (1985) ISBN 9004.079 068.

Part II: TECHNICAL SPECIFICATION

A.1.min.(ft), tech.(fg & i; 90-125 μ m)

- | | |
|--|--|
| 2. P= 243 ± 15 Gy | 3. Slopes [2 nd /1 st : 0.95 ± 0.05] |
| 4. dPlat [$\pm 2\%$; 300-375 °C] | 4a. Peak [350°C; 5°/s] |
| 5. Stab [300-375 °C; 0.5a; 18°C; $0 \pm 2\%$] | 6. a = 0.102 |

B. 1. Tot.Eff.Dr. = 1.02 ± 0.07 Gy/ka [$\alpha=11\%$ (α -c); $\beta=18\%$ (α -c);

$\gamma = 60\%$ (α -c, α & γ SPEC,CAP) ; cos. = 11% (γ SPEC,TLD)]

2. Radon [*] **3. Water** [Smple($\leq 2\%$) Env.($16 \pm 5\%$)]

C. Error [eA76]

D. A = 238 ka (- ; ± 25 ka)

Special Remarks:

B2. See report for discussion of radon emanation.

Entry: Risø Laboratory

AnTLDL#2

Part I: DATE SPECIFICATION

Site: Bellingegård, Køge, Denmark

TL Age : 530± 100 AD (R85TLmmi)

Sample Ref: R-842201

Material: pottery

Archaeological Ref: House II, No. 35

Arch. evidence: The sherds are from a posthole dug through a pit. The pit can be dated to C4th-5th AD by ceramics and glass beads recovered from it.

Site Director: Svend Åge Tovnbjerg, Køge Museum, DK.

Reports: Mejdahl V. (1985) A survey of archaeological samples dated in 1984. Risø National Laboratory publication M-2541.

Part II: TECHNICAL SPECIFICATION

A. 1. min.[N,K&Af] tech.[mmi; gsr (µm) -1(100-300), -2(300-500), -3(500-800)]

	Nf(gsr3)	Kf(gsr2)	Kf(gsr3)	Af(gsr1)	
2. P	6.96±0.5	7.59±0.9	7.77±0.7	6.15±0.5	Gy
2a. I/P	0.02	0.05	0.04	0.11	
3. Slopes	0.87±0.2	0.96±0.2	0.85±0.2	0.86±0.2	
4. dPlat	±2	±1	±1	±5	%
	(370-400)	(360-420)	(380-490)	(370-400)	°C
4a. Peak	401	410	405	405	°C
	@ 16°/s; pre-heat 290°C for 10min				

5. Stab [Kf(gsr3), - , 360-410°C, 20°C, 96±3%] 6. a [typ] = 0.2

	Method	Nf(gsr3)	Kf(gsr2)	Kf(gsr3)	Af(gsr1)	
B.1. Tot.Eff.Dr		4.52	5.39	5.53	4.95	mGy/a
		±0.3	±0.3	±0.3	±0.3	
1a. Ext%tot						
β	TLD	52	49	43	58	%
γ+cos	SCINT	23	19	19	21	%
1b. Int%tot.		25	32	38	21	%
(U,Th,K&Rb)						

2. Radon [negligible]

3. Water [Smple(19.5±0.5%)]

C. Error [p(*); a(eA76)]

D. A = 1456 a (±60;±100)

Special Remarks:

C. 'p' is the statistical mean error calculated from individual results for the four grain types and sizes.

Entry: Durham Laboratory

AnTLDL#3

Part I: DATE SPECIFICATION

Site: Thorpe Thewles, Cleveland, UK

TL Age : 570 ± 260 BC (Dur84TLpd) **Sample Ref:** TT8

Material: pottery **Archaeological Ref:** TT 81 C 679

Arch. Evidence: Coarse-ware pottery taken from a stratified layer within fill of main structure ditch associated with phase II of a well characterised Iron Age settlement.

Site Director: D Heslop Esq., Cleveland County Archaeology, Middlesborough, Cleveland. UK.

Reports:

Bailliff I.K. (1984) TL dating of Iron Age/early medieval coarse-wares from north Britain. Unpublished TL Laboratory Report No.15, Archaeology Dept., Durham University.

Heslop D. (1986) Excavation of an Iron Age settlement at Thorpe Thewles, Cleveland . CBA Monograph, in press . (Includes TL report).

Part II: TECHNICAL SPECIFICATION

**A. 1.min.(q), tech.(pd; 90-150 μ m) 2. P= 6.96 ± 0.70 Gy (MA & AD)
3. **Init.Sens.**[25% S_N ; 25% UVrev; $S_b = 100\%S_o$] 4. **TAC** [550 -575 $^{\circ}$ C max; 10 $^{\circ}$ /s]
5. **Stab.**[-]**

B.1. Tot. Eff.Dr. = 2.81 ± 0.14 mGy/a [$\beta=63\%$ (TLD); $\gamma + \cos.= 37\%$ (CAP)]
2. **Radon** [0 \pm 5%] 3. **Water** [Smple(10 \pm 2%) Env.(15 \pm 5%)]

C. Error [eA76] **D. A** = 2555 a (± 220 ; ± 260)

Special Remarks:

B1. Dose-rates for burial medium also obtained using α -c, AAS & XRF analysis.

A CAUTION ON LABORATORY ILLUMINATION

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As part of a broad investigation of the bleaching of sedimentary quartz it was proposed to examine the relative bleaching efficiencies of various wavelengths. Preliminaries involved identifying any sources of bias in the experimental design. One possible source considered was the laboratory darkroom illumination.

Lighting at the Adelaide laboratory is provided by white fluorescent tubes converted to safelights. This is cheaply and conveniently done by jacketing the tubes with plastic theatrical colour filters possessing suitable spectral transmission characteristics (Sutton and Zimmerman, 1978; Jensen and Barbetti, 1979).

Given the apparently innocuous nature of yellow light, and the greatly increased operator comfort compared with red light, the Rank Strand Electric filter "Cinemoid" No.1 (yellow) has been used for a number of years, with the standard safelight being one 40W fluorescent tube wrapped in at least two layers of this material.

To ascertain whether this illumination had any effect on quartz TL, two sets of quartz samples were exposed to a safelight for times of up to 72 hours. Both sets were positioned about 1.6m from the centre of the fluorescent tube.

The results are shown in figure 1. Clearly there is considerable disruption of the initial signal. Most notable are the apparent removal of the 325°C peak in (a) and the 25% reduction in peak height at 330°C in (b). In case (a) the bleaching appears strong at the 325°C peak, but the remaining peaks grow, presumably by retrapping. In case (b) the reduction is general, though to differing extents, across the entire glow curve. Both cases illustrate changes of an extent unacceptable in TL work. Mejdahl (pers. comm., 1984) also reports disruption to both quartz and feldspar glow curves by exposure to an unspecified light source (*Ed. note* : VM responds - "... it was a 40W incandescent bulb at ~30cm from the sample.") through two layers of "Cinemoid" No. 1 filter.

Fortunately, the time required for these effects to become prominent is long (>4 hours) compared with normal laboratory operations. Nevertheless, this unexpected susceptibility of quartz TL to bleaching indicated that the safelight spectrum required further restriction, with the transmission cut-off at longer wavelengths. The "Cinemoid" line was no longer readily available, hence a number of possible substitutes were vetted. A range of "Rosco" filters were found to have excellent cut-off properties, but were marred for TL purposes by narrow "windows" of 5-20% transmission in the near UV/blue region.

Further searching revealed an ideal range of filters for safelight use, manufactured by "Chris James and Co.," of 19 New Wharf Road, London, N1 9RT, and available through local agents. The transmission curves of the more suitable filters are shown in figure 2, with a "Cinemoid" No.1 curve for comparison. As a consequence

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of the above, new fluorescent tubes were wrapped in two layers of "Chris James" No. 179 (chrome orange). This provides adequate lighting for normal darkroom operations, combined with significant reduction of <550 nm light relative to "Cinemoid" No.1, and better than 99.99% blockout of the blue/UV wavelengths. Bleaching is less than 5% in 24 hours. Further restriction of "yellow" wavelengths is possible using "Chris James" No. 105 (orange) or No. 158 (deep orange), but is probably unnecessary. The red filters No. 164 (flame red) or No. 106 (primary red) reduce the intensity to a level uncomfortable to the operator after protracted working sessions.

This work was supported by the Australian Research Grants Scheme and the Research Grant of the University of Adelaide.

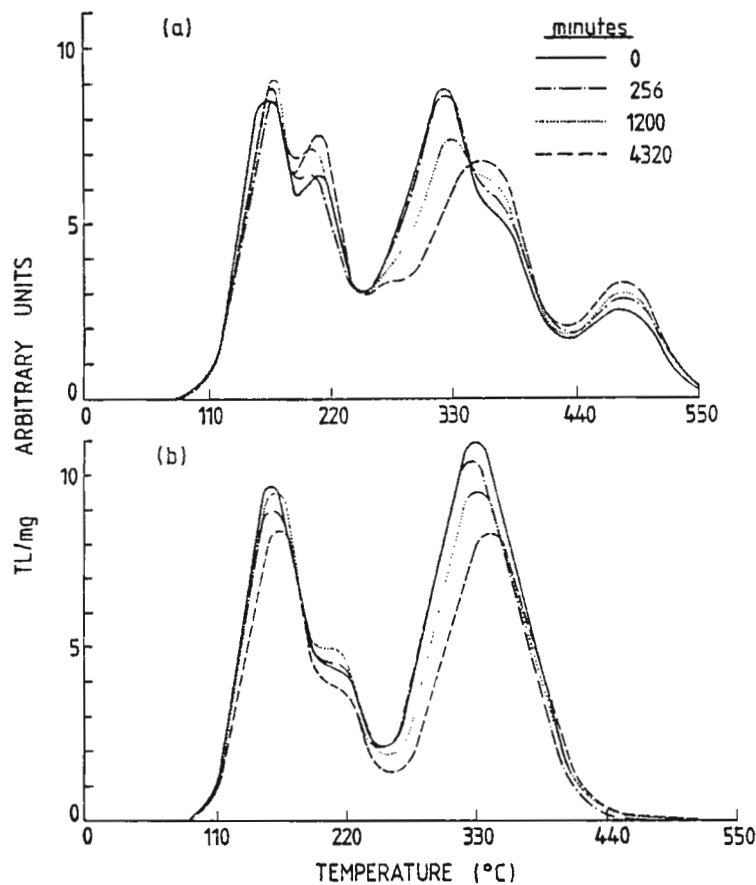


Figure 1.

Shows the bleaching of Lake Woods Quartz from a 40W fluorescent tube wrapped in two layers of "Cinemoid" No. 1 (yellow) filter. The samples were positioned ~ 1.6m from the tube; exposure times as shown.

Treatments:

(a) Lake Woods (S3, TD, 1m) Quartz; pre-heated to 550°C at 5K/s to erase NTL; 74.5 Gy ^{90}Sr - ^{90}Y β irradiation; two days delay before bleaching.

(b) Lake Woods (S3, TD, 1m) Quartz; annealed at 800°C for 24 hours in air; slow cooled; 96 Gy ^{90}Sr - ^{90}Y β irradiation; two days delay before bleaching.

Prior separation steps consisted of HCl digestion, sieving for the 90-125 μm fraction, magnetic separation and a 40 minute etch in 50% HF.

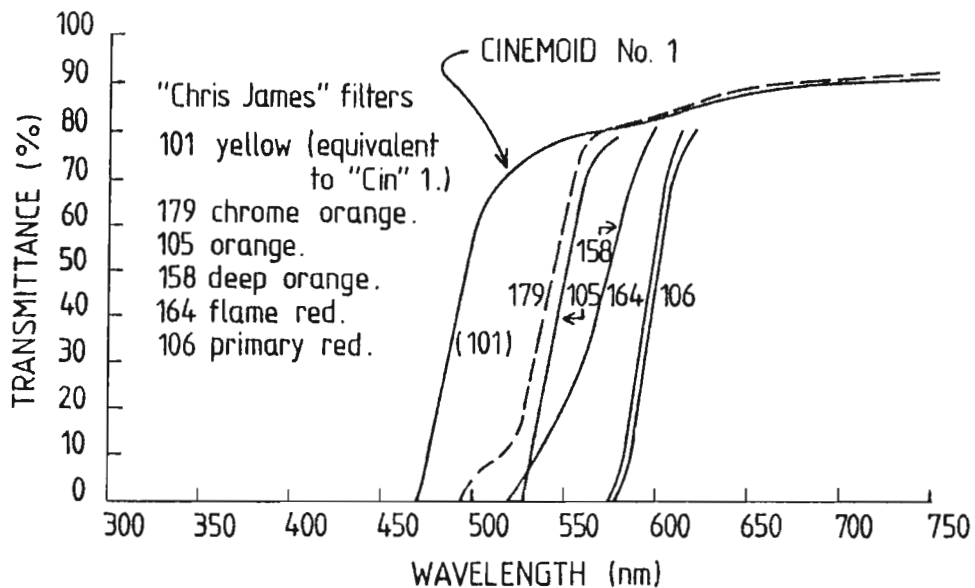


Figure 2. Shows transmittance vs wavelength for a selection of "Chris James" colour filters. "Cinemoid" No. 1. (yellow) is shown for comparison.

REFERENCES

- Jensen, H. and Barbetti, M.(1979). More on filters for laboratory illumination. *Ancient TL* , 7, 10.
- Sutton, S.R. and Zimmerman, D.W. (1978). A blue-uv absorbing filter for laboratory illumination. *Ancient TL* , 5, 5.

[PR] Reviewed by Vagn Mejdahl.

FURTHER NOTES IN RESPONSE TO REVIEWER'S REMARKS.

The sediment from which the quartz was separated was collected from a relic lake-shore dune at the Lake Woods site, Northern Territory, Australia. The quartz had an ED of ~50 Gy. Further details can be found in Hutton, Prescott and Twidale,(1984) *J. Soil Res.* , 22, 15-21, . The samples received only the standard separation procedure, followed by NTL erasure then β irradiation, as outlined in the figure captions.

APPLICATION OF ESR TO THE DATING OF SUBFOSSIL SHELLS FROM MARINE DEPOSITS

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INTRODUCTION

The attempts to use ESR spectroscopy for dating fossil shells by a number of workers (Ikeya and Ohmura, 1981,1984; Hutt et al., 1983, 1985; Molodkov and Hutt, 1985; Katzenberger and Grun, 1985; Radtke et al., 1985; Skinner, 1985) have established the scope of this method. With further development, ESR is expected to become a valuable tool for the dating of biogenic carbonates, especially within the time span 0.3-1 Ma BP which is a period where other methods are limited. In this paper we present the results of our preliminary ESR investigation of shells of different species and age which were collected from the coastal formation of ancient Baltic water bodies and the Polar Basin.

The possibility of cross checking the results of the ESR dating of shells and the TL dating of the same deposits exists for these samples and this is valuable since we may obtain information concerning the conditions associated with the formation of deposits of different genesis.

PROCEDURE

For ESR dating it is necessary, as is the case for TL, to determine the accumulated dose during burial (palaeodose, P) and the annual dose-rate, D. We have found, as in other laboratories, that the main difficulty in ESR dating lies in the estimation of P. This arises from the uncertainty which is associated with the choice of ESR spectral lines suitable for dating, and the significant variation of P evaluations resulting from the use of derivative lines of microwave absorption. An additional problem is the determination of the annual dose-rate in shells; each dose-rate comprises alpha, beta and gamma components of natural radiation from the surrounding deposits and from internal sources. Moreover, the calculation of annual dose-rate and palaeodose differs for the dating of Holocene and Pleistocene shells.

The Age Equation

The ESR age was calculated using the formula

$$A = \frac{P}{D_C + D_{ex,\gamma} + D_{ex,\beta} + kD_{in,\alpha}^{U} + D_{in,\beta}^{U} + D_{in}^{Th}(t)} \quad (1)$$

where, D_C = cosmic ray contribution, calculated according to Yokoyama et al., (1982), $D_{ex,\gamma,\beta}$ = external annual dose-rate, corrected for water content,

determined by means of gamma-spectrometric analysis of sediments and using Bell's data (Bell, 1979), $D_{in\ \alpha,\beta}$ = internal annual dose-rate, and k = efficiency of alpha radiation.

External dose-rate

Since gamma-quanta in shells with wall thicknesses of a few mm are substantially the same as that for the infinite burial volume, the calculation of gamma dose-rate is not a problem.

The external beta dose-rate was determined using the formula of Yokoyama et al., (1982):

$$G_{E\beta} = (1 - e^{-\mu\beta L}) / \mu\beta L \quad (2)$$

where, $G_{E\beta}$ is the attenuation-correction factor for the reduction of beta radiation, L is the thickness of the sample and $\mu\beta$ is the attenuation coefficient of the β -rays.

The external beta dose-rate can also be determined from tables of average beta dose (expressed as a percentage of the infinite matrix dose) for aragonite and calcite (Grun, 1986). The external alpha dose-rate was not considered since the shell surface is removed by etching in dilute HCl.

Internal dose-rate

For Holocene shells, the main source of internal dose, $D_{in\ \alpha,\beta}^U$, is uranium, which is incorporated during crystallization of the shell. Its components were evaluated using the following formulae (Hutt et al., 1985, Molodkov and Hutt, 1985):

$$D_{in,\alpha}^U = C_{\alpha}^U \cdot Q \cdot k \quad (3)$$

$$D_{in,\beta}^U = D_{\beta}^U \cdot Q \cdot (1 - G_{E\beta}) \quad (4)$$

where, $D_{\alpha,\beta}^U$ represents the annual dose-rates for α and β components from U-238 to Th-230, Q is the U-238 concentration in the shell, and k is the efficiency of alpha radiation, for which we adopted a value of 0.15 ± 0.05 .

For Pleistocene shells, the time dependent component of internal dose, $D_{in}^{Th}(t)$, reflects the in-growth of Th-230 with daughters in the shell during its buried state. Correction of the age for Pleistocene shells was achieved using the set of curves shown in figure 1, which have been obtained on the basis of calculation of the increasing internal annual dose-rate due to in-growth of Th-230 and its radioactive daughters with various concentrations of parent uranium in the shell.

Palaeodose

The palaeodose P was determined, using an additional dose method, by extrapolation of the dose response curve to the dose axis.

Pleistocene samples

For Pleistocene samples the area under the absorption curve, obtained by double integration of the first derivative spectra, was used as a measure of the concentration of radiation defects (method S). As a variant of this method,

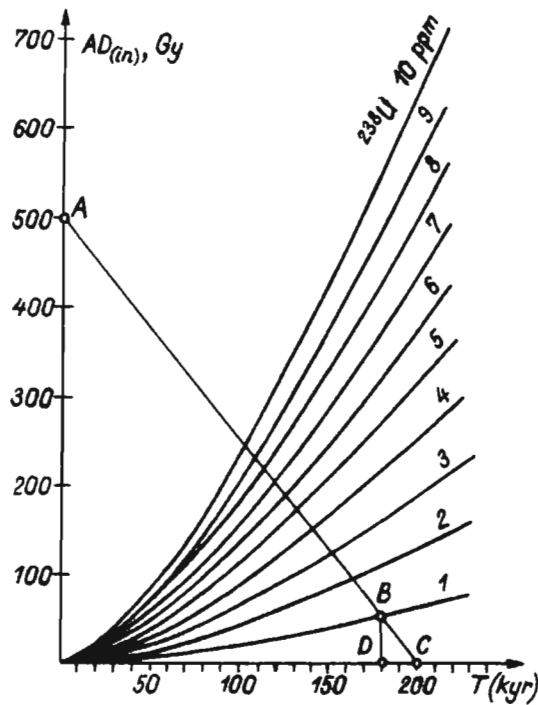


Figure 1. Time dependence of internal palaeodose, P_{in} , for a shell of 0.5 mm wall thickness, vs different U-238 concentrations. Correction for the time-dependent component, $D^{Th}_{in}(t)$, is achieved using the following procedure for a shell containing 1 ppm U-238: Points A and C represent P and $P/(D_c + D_{ex} + D^u_{in})$ respectively, and the linear curve drawn between these two points and curve 1 intersect at point B, the T-coordinate of which provides the true age (point D).

the magnitude of the absorption curve was also used in the region of the magnetic field which produced a good plateau (method A) and the first derivative signal, but with strong (up to 1 mT) overmodulation (method OM, Molodkov and Hutt, 1985). The reproducibility of measurements was better than 3%.

The behaviour of dose-response curves for derivative lines under conditions of artificial or natural irradiation is difficult to predict because of the strong interference of various components of complex ESR spectra. In contrast to this, the dose-response curves obtained by methods S, A and OM, are well represented by the exponential equation of first order kinetics:

$$I = I_{\infty} [1 - e^{-\mu(\gamma + P)}] \quad (5)$$

where, I is the signal intensity for a gamma dose, γ , I_{∞} is the saturation intensity, μ is the sensitivity coefficient, and P can be determined by plotting $-\ln(1 - I/I_{\infty})$ vs γ dose, (Apers et al., 1981).

The values of P obtained using the three methods determine the same quantity, and increased precision was obtained by calculating the mean value, P . For calcite shells, the ESR spectra of which contain intense Mn^{2+} lines, P was determined by subtraction of the background signal of the forbidden Mn^{2+} transition line (the amplitude of which does not change under the artificial irradiation) from the ESR signal of interest.

Holocene Samples

The young (Holocene) shell samples yield a signal of up to 2.5 mT width that is probably associated with an organic protein radical. Because there is uncertainty in the content of this organic radical in shells of different species, age and conditions of burial, we prefer to estimate the palaeodose for Holocene shells by the amplitude of the derivative ESR line. As has been shown previously (Hutt et al., 1985, Molodkov and Hutt, 1985), only the line at $g = 2.0020$ has been found to be suitable for this purpose since the use of other lines resulted in significant higher uncertainty (up to 3 times more) in the evaluation of P.

EXPERIMENTAL

All measurements were made at room temperature using an ESR X-band spectrometer with a microwave power of 2 mW and a modulation amplitude of $4 \mu\text{T}$ at 100 kHz. The samples of shells were carefully washed in water: the remnant sand and clay minerals were removed in an ultrasonic bath. The shells were etched in 0.3N HCl for 3 min in order to remove the α -irradiated surface, and then crushed in an agate mortar. The 75-200 μm fraction was separated and portions of samples of 50-300 mg were irradiated in a Co-60 radiotherapy unit. After irradiation, the samples were either stored for 2-3 weeks or heated at 100°C for 10 min to remove the unstable defects. Sample preparation and experimental measurements were performed in diffuse daylight.

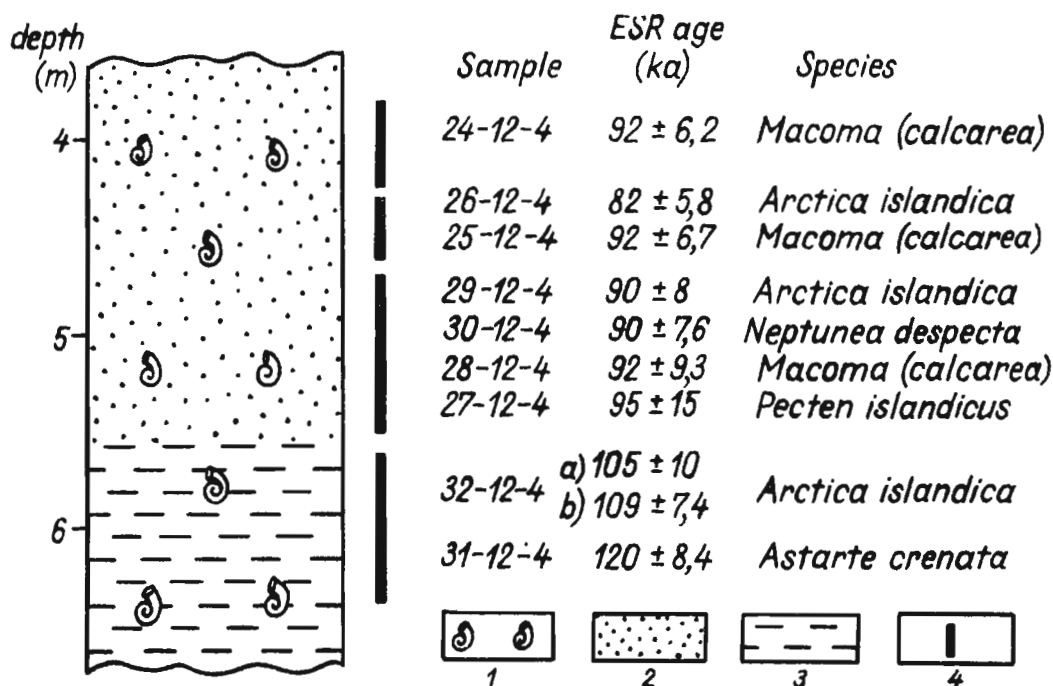


Figure 2. A part of the section from the Arkhangelsk district with the results of the ESR dating of an Eemian formation. 1- shells 2- sand 3- fine sand 4- sampling horizons

RESULTS AND DISCUSSION

The results obtained for Holocene and Pleistocene shells are summarised in table 1 and figure 2. The following conclusions were drawn from them:

- 1) The ESR ages, from the youngest to 300 ka, are in good agreement with the estimated dates, obtained using a number of analytical methods, including palynologic, micro-and macro-faunistic, diatomic, mineralogical, granulometric, radiocarbon and palaeomagnetic techniques.
- 2) For the Pleistocene shells, the best agreement has been obtained when the palaeodose has been determined using methods S, A and OM. In the future, a better method for the determination of P might result from a decomposition of complex ESR spectra and detailed examination of the peculiarities of some of the components.
- 3) Although in some cases the use of lines g3, g4 and g5 of the first derivative signal gave values of P coinciding with expected values (e.g. for samples NN 10-12-4, 14-12-4), there is a serious doubt concerning the reliability of their wide application in dating Pleistocene shells.
- 4) The plateau-test for the circumarctic shells gave good results even for laboratory doses which were close to saturation levels. This suggests that the dominant components of the observed spectra are associated with radiation defects of similar lifetimes and saturation levels of dose. Thus, where these radiation defects have sufficient lifetimes, the procedures of palaeodose determination we have described appear to be suitable for dating shells throughout the Quaternary period.
- 5) The estimation of life-time is usually obtained from an Arrhenius plot. However, thermal annealing in the laboratory may seriously differ from the process of natural relaxation of defects that occurs at ambient temperatures during burial. The results obtained may not reflect the slow processes (e.g. diffusion of defects, its compensators and others) that occur during the burial period. Also, for aragonite shells, the low thermal stability of their structure may complicate the experiments at high temperature. Consequently, the exploration of the extent of the chronological range of the technique (and beginning of thermodynamic equilibrium between decayed and reformed radiation defects) by examining ancient samples from circumarctic regions within the age range 0.3-3 Ma is important because it gives the opportunity to estimate the real geological process of the destruction of defects during long periods.
- 6) The preliminary results show that the ESR dating method is a promising field of investigation. Although there are many unsolved problems, the first step to creating a new and promising tool for studying the history of the Earth has been taken.

Acknowledgments

The author wishes to thank Dr. G. Hutt for fruitful discussions, Dr. H. Kessel and Dr. V. Makeev for useful geological discussions and samples, and also H. Putnik for the donation of shell samples.

Invited Paper: This paper was first presented by the author at a conference "Methodology of TL Dating" held at Tallinn 20-24 April 1986. Two further papers given by Soviet scientists at the same meeting have been invited and we hope to be able to include them in future issues of Ancient TL.

TABLE 1

SAMPLE	ORIGIN	P(Gy) FOR DIFFERENT SIGNALS						P (Gy)	EXPECTED P (Gy)	ESR AGE (ka)	GEOLOG. AGE (ka)
		g3 2.0020	g4 2.0009	g5 1.9976	OM	S	A				
1-12-4	Estonia	15	22.5	12.5	-	-	-	15	14.9-15.8	6.6±0.4	6.5-7.0
2-12-4	" "	20	20	15	-	-	-	20	19.4-21.8	8.3±0.66	8.0-9.0
4-12-4	" "	16.5	22	-	-	-	-	16.5	≤17.3	8.1±0.5	≤8.5
K-IV	" "	15	26	27.5	-	-	-	15	14.8-15.4	6.83±0.57	6.5-7.0
10-12-4	Novosibirsk is.	1075	1075	790	1068	1078	1070	1070	600-1940	550±33	300-1000
11-12-4	Severnaja Zemlya	170	230	335	316	317	316	314	200-500	170±10	110-280
14-12-4	" "	80	80	80	80.1	81	80.5	80.5	68-86	65±8.7	55-70
15-12-4	" "	62	72	56	72	71	72	72	68-86	56±4.2	55-70
18-12-4	" "	194	420	176	270	280	280	280	~276	105±10.5	~100
24-12-4	Arkhangelsk distr.	85	132	110	114	113	114	114	102-130	92±6.2	~100
25-12-4	" "	53	83	113	119	110	113	114	~127	92±6.7	~100
26-12-4	" "	44	97	53	80	85	83	83	~102	82±5.8	~100
31-12-4	" "	66	72	128	121	117	121	120	~100	120±8.4	~100
32-12-4	" "	111	125	155	103	104	103	103	~95	109±7.4	~100

APPLICATION OF ESR TO THE DATING OF SUBFOSSIL SHELLS FROM MARINE DEPOSITS

A Molodkov.

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Errata

Correction to formula 3 on p50:

$$D_{in,\alpha}^U = D_{\alpha}^U \cdot Q \cdot k$$

SOME REMARKS ON FINE-GRAIN SAMPLE PREPARATION FOR TL DATING

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More than one decade has passed since the basic work on the preparation of fine grain TL samples (Zimmerman, 1971), and several aspects concerning the mineralogy of baked clays have not yet been considered in practical dating. For instance, changes in mineral composition occurring on firing, sintering and vitrification have so far not been accounted for. Also, the effect of clay composition on TL properties, such as signal height and the plateau, has received little study. The present report is concerned with three aspects of Zimmerman's early work.

AIMS OF INVESTIGATION

1. The methods of preparing samples of fine grains (1-8 μm) for TL dating follow closely the basic working techniques of clay mineralogy, especially the separation of fine grains by sedimentation which is related to heavy mineral separation using an Attenberg Cylinder. In applying these techniques to fired fabrics, it has been assumed that individual minerals can be isolated by breaking apart the ceramic matrix. We investigated the validity of this assumption and the extent to which firing temperature influences the result of the procedure.
2. For the fine grain technique, the grains to be selected for TL measurement should have received the full infinite matrix dose rate. According to calculations by Bell (1980) of the alpha dose delivered to quartz, attenuation becomes significant in grains larger than 5 μm . A sedimentation technique has been established to ensure that larger particles are not contained in the TL sample. Examination of samples of fired clay using a scanning electron microscope (SEM) has shown the grain size range that is actually achieved using this procedure.
3. Grain size selection is almost always paralleled by mineral selection. This can be shown by comparison of the chemical composition of fine and coarse fractions.

EXPERIMENTAL RESULTS

The effect of firing temperature

Sedimentation experiments were performed using samples of a non-calcareous clay which had been fired at 600, 800, 1000 and 1200°C. Firing was performed following procedures similar to those used in pottery manufacture in order to ensure a similar degree of sintering. The oven temperature was gradually increased by 100°C every half hour, starting from 300°C. The maximum

temperature was held for 30 min and the samples remained in the oven overnight to cool. After crushing in a vice, fine grain samples were obtained by sedimentation in acetone following the standard procedure (Zimmerman, 1971). The sedimented samples were viewed in a SEM, and the images shown in Figure 1 indicate the following:

- The grain-size distribution at a firing temperature of 600°C is substantially homogeneous, the diameter of the largest grains is less than 10 μm , and there are no particles less than 1 μm . The grain size distribution corresponds exactly to the predictions which had been made on the basis of Stoke's law (Zimmerman, 1971).
- The same is still true for the firing temperature of 800°C, but considerable changes occur at higher firing temperatures.
- In the sample fired at 1000°C a noticeable proportion of particles of approx. 2 μm is visible positioned between very large grains. The distribution appears heterogeneous, and there are already vitrified structures detectable that are due to mineral species decomposing at this temperature.
- Fragments of the above type also form the predominant constituent in the 1200°C fired sample. The shape of the grain boundaries and the absence of internal structure of the grains indicate that they are no longer individual mineral grains isolated from the matrix, but fragments of a vitrified continuum. It can be shown that the mean size of fragments at the firing temperature of 1200°C is higher compared with that for lower firing temperatures, although the same sedimentation process has been used.

Maximum grain size

The series of SEM images demonstrates that sedimentation of fine grains in acetone does not guarantee a homogeneous size distribution. Depending on firing temperature and clay composition, a broad distribution may be obtained which contains a proportion of grains with a diameter beyond the critical size. This would not necessarily require a grain size correction (Bell, 1980; Mejdahl, 1979), because not every particle is an individual TL-emitting mineral, but may consist of an agglomerate of very small minerals, each one having received unattenuated dose. However, to exclude errors due to grain size, a narrow distribution of grain sizes would be desirable, preferably with an average grain size of less than 5 μm .

Wet-sifting was used to obtain a narrow grain size distribution independent of firing temperature and clay composition. As before, a suspension of the ceramic material was prepared, filtered through sieves of 10 and 5 μm mesh-width. SEM images of the 5-10 μm fraction revealed a narrower size distribution, and particles of a size less than 3 μm , said to carry spurious light emission, were no longer present. The mean grain size obtained in this procedure was determined by measuring 50 individual particles at a magnification of 2000. The mean diameters obtained for four brick samples #1- #4 of 4.9 μm , 4.4 μm , 4.2 μm and 4.7 μm respectively, are slightly below the low mesh-width, which seems to be due to the particular form of the nylon mesh used.

Quartz enrichment

During the development of fine grain dating the change of composition during sedimentation was studied - in particular, whether the quartz content could be enriched (Zimmerman, 1971). Recent work has shown that quartz can be enriched using magnetic techniques (Janer and Junger, 1982; Kitis and Charalambous, 1985). It is also known from mineralogical techniques, as well as from alpha-

composition of a fine grain fraction, which has been prepared from a bulk material, is not equal to the composition of the latter. The effect of sedimentation and wet-sifting was investigated using XRF on three samples of fired bricks (ref. L4.5, VV12/11 and Bdf1.0) and the results given in table 1 reveal that there are no significant differences in composition between sedimentation and wet-sifting. Both procedures do, however, significantly change the original composition as a consequence of density separation, which is the desired effect in sedimentation, but obviously cannot be totally avoided in wet-sifting. The most obvious change occurs in potassium-oxide, followed by calcium-oxide. These elements are enriched in sedimented/wet-sifted samples; silicon is hardly altered, and aluminium possibly depleted. It may be concluded from these observations that, using both methods of sample preparation, the potassium content is enriched, which would be in logical agreement with the method of coarse-grain feldspar separation from pottery (Mejdahl, 1985). X-ray diffraction was, unfortunately, not sufficiently sensitive to detect the type of mineral. Thus the present measurements cannot confirm the enrichment of quartz during sample preparation, which was the original aim.

ACKNOWLEDGEMENT

I gratefully acknowledge the assistance of S. Henschel in the experimental work.

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[PR] Reviewer's Comments (S R Sutton)

This experiment demonstrates two things concerning the conventional technique for fine grain sample preparation. First, the ultimate grain size distribution can be dependent on the firing history of the material. Second, wet-sifting can be successful in size-separation of these small grains. It is erroneously implied that for accurate dating, such a size separation is required to produce a sample of homogeneous grain size.

The basic assumption of the fine grain dating method is that the measured TL-emitting grains have received the infinite medium dose-rates from alphas and betas corresponding to the bulk sample radioactive element content. Consequently, grain size distributions are irrelevant so long as (1) all measured TL grains are small enough to have experienced negligible alpha attenuation, and (2) the TL grains did not result from the break up of larger grains during vicing. Vitrification may or may not lead to systematic errors. In all cases, one needs to know the TL and radioactivity distributions in order to determine the validity of the resulting glass would tend to be homogeneous in both TL and radioactivity and the infinite medium assumption would apply regardless of the grain size used (of course, laboratory irradiation of such material is another matter). Partial vitrification may prohibit mineral grains from being isolated by vicing but the TL may be dominated by small crystals included within larger glassy fragments.

Clearly, the greatest problem associated with material fired to a high temperature is that it is hard and there will be a greater probability of breaking up large TL grains during vicing. A combination of cathodoluminescence and electron microscopy on the present samples might provide some information on the firing temperature at which such breakup becomes significant.

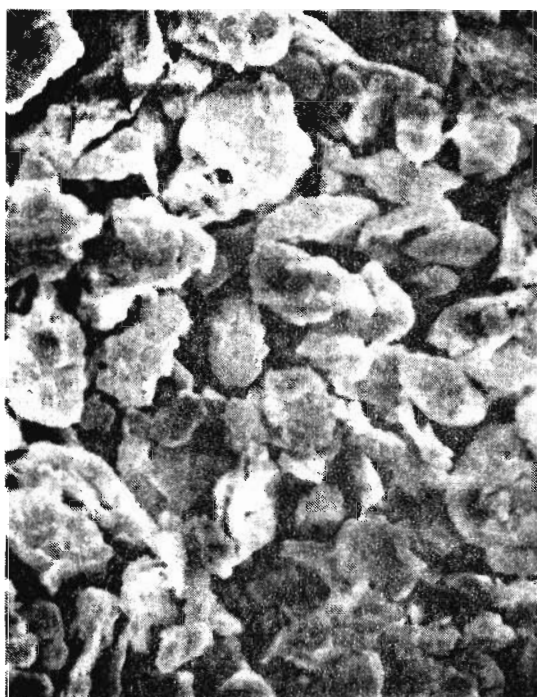
TABLE 1: CHEMICAL COMPOSITION BEFORE AND AFTER FINE GRAIN SAMPLE PREPARATION

SAMPLE		TYPE OF TREATMENT		
		none	wet-sifted	sedimented
			5-10 μ m	2/20min
L 4.5	CaO	3.00	3.25	3.25
	K ₂ O	4.38	5.20	6.09
	SiO ₂	70.80	71.56	71.63
	Al ₂ O ₃	15.44	12.51	12.51
	TiO ₂	0.86	0.84	0.92
	Fe ₂ O ₃	6.09	6.55	6.55
	MnO	0.07	0.09	0.07
	Na ₂ O	0.94	0.92	0.83
	MgO	2.54	3.00	3.34
VV 12/11	CaO	2.35	2.87	2.65
	K ₂ O	5.55	8.37	7.26
	SiO ₂	64.94	67.74	66.48
	Al ₂ O ₃	16.45	11.26	13.62
	TiO ₂	0.90	0.87	0.93
	Fe ₂ O ₃	7.76	8.76	8.87
	MnO	0.12	0.13	0.13
	Na ₂ O	1.54	1.30	1.25
	MgO	3.11	4.18	3.43
Bdf 1.0	CaO	0.98	1.08	1.06
	K ₂ O	2.50	3.43	3.55
	SiO ₂	67.67	67.76	69.62
	Al ₂ O ₃	18.07	18.13	17.26
	TiO ₂	0.82	0.91	0.93
	Fe ₂ O ₃	5.93	8.08	8.12
	MnO	0.11	0.15	0.15
	Na ₂ O	0.83	0.88	0.88
	MgO	2.29	2.33	2.52

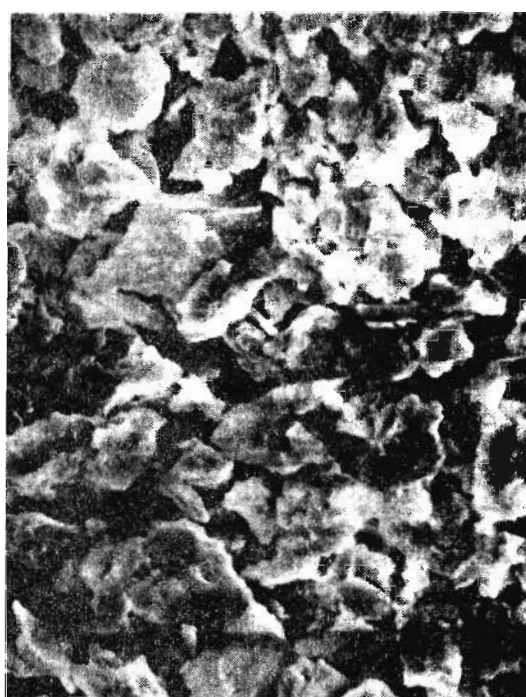
Notes. Values are in wt.% and are means of three samples.

Errors: Na₂O \pm 5%; Mg \pm 10% (determined by AAS), and others \pm 3% (determined by XRF).

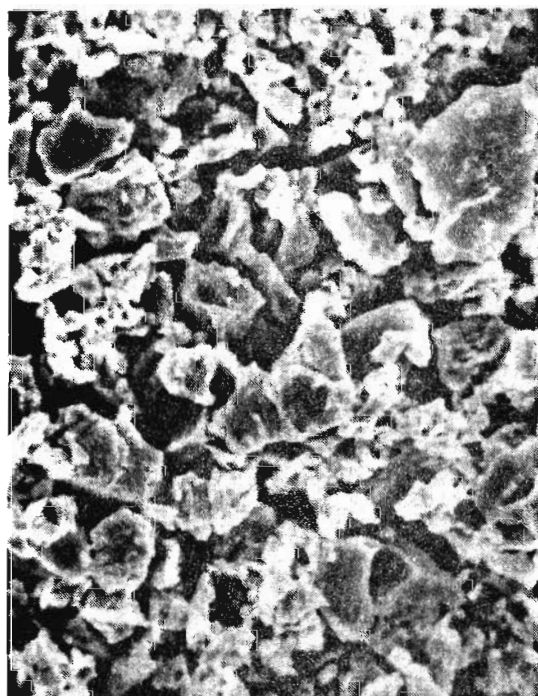
Figure 1.



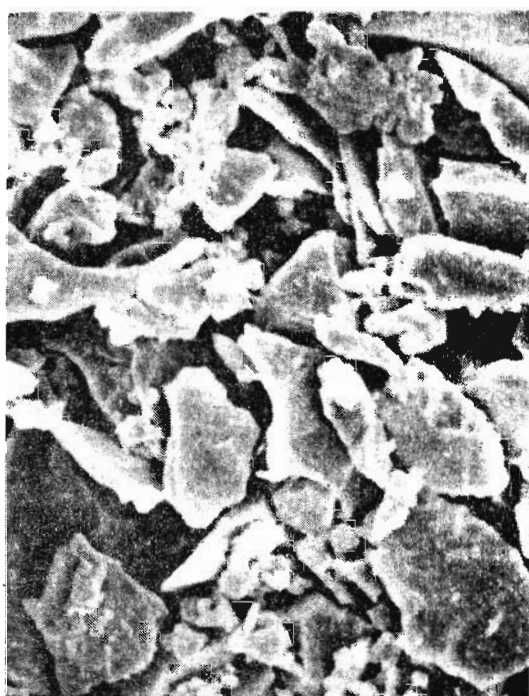
a: 600°C



b: 800°C



c: 1000°C



d: 1200°C

scale |-----| 10 μ m

TL STRATIGRAPHY OF LOESSES: QUARTZ AND FELDSPAR DOSEMETERS WITHIN LOESSIC DEPOSITS FROM NORMANDY, FRANCE

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INTRODUCTION.

In a previous paper (Balescu et al., 1986a), we reported on the TL properties of detrital quartz grains from pure aeolian loesses of NW Europe, using the 40-50 μm grain size fraction, which is representative of the loessic sediment. We studied both the quartz natural TL (NTL) properties, related to the amount of environmental radiation to which the minerals had been exposed since deposition of the loess, and the quartz artificial TL (ATL) signals induced by laboratory irradiation with a Co60 γ source. We demonstrated that the quartz NTL intensity can successfully discriminate between Wiechselian loesses (deposited around 20ka) and Saalian loesses (older than 120 ka). However, this quartz TL technique did not allow any further stratigraphical discrimination since Saalian quartzes were found to be close to saturation.

In this paper, we further investigate loess TL properties of K-feldspar grains from the same grain size fraction (40-50 μm), in an attempt to establish a chronological discrimination between these Saalian loesses.

We present results of a comparative investigation of quartz and feldspar TL characteristics of loesses from Normandy (France). In contrast with most of the existing literature on TL of NW European loesses (e.g. Debenham, Mejdahl, Wintle), we use both quartz and feldspar TL methods as relative dating techniques, without any attempt to estimate absolute ages.

SAMPLES AND PREPARATION

The samples were taken from the loessic sections within Normandy shown in figure 1. Following Lautridou's chronostratigraphical scheme (1985), we sampled:

- Upper Wiechselian loesses deposited around 20 ka;
- Upper Saalian loesses lying below the Eemian soil (Elbeuf 1 or Saint Romain soil) which were deposited between 120ka and 200ka;
- Middle Saalian loesses older than 200 ka which underlie an intrasaalian soil (Elbeuf II).

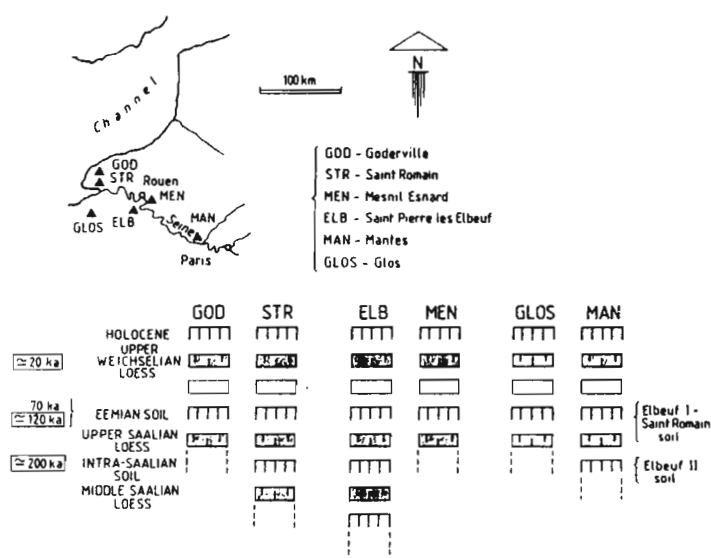


Figure 1: Location of sampling sites in Normandy and schematic representation of the investigated loessic sections.

Note that this chronology relies mostly on regional stratigraphical correlations (Lautridou, 1985) with some references to absolute dates reported by Stremme (1985).

Sample treatments comprised:

- wet-sieving for extraction of the 40-50 μm grains;
- etching with HCl;
- removal of iron oxides by use of the citrate-bicarbonate-dithionite method (Mehra and Jackson, 1960);
- quartz-feldspar separation using heavy liquids ($\rho = 2.60$), in order to obtain two fractions; 1) K-feldspar dominated material and 2) a pure quartz sample after treatment with 40% HF.

RESULTS AND DISCUSSION

Quartz TL properties

In Balescu et al. (1986b), using both the quartz ATL and NTL methods, we proposed a new stratigraphical marker defined as the ratio of the NTL intensity of the highest temperature peak to the intensity of the corresponding ATL peak (termed MQ).

Applying this technique to loesses from Normandy, we obtain the results shown in figure 2. The corresponding MQ values are given on the vertical axis, and the loessic sections on the horizontal axis. All Weichselian loesses taken at the same chronostratigraphical position - but from different sites - show similar ratios ranging between 0.45 and 0.55, within the limits (marked error bars) of experimental reproducibility using this method. Their ratios are systematically lower than those of the Saalian loesses which range between 0.9 and 1.2. As discussed previously, this marker does not allow stratigraphical differentiation between Upper and Middle Saalian loessic deposits since they have reached saturation.

QUARTZ TL

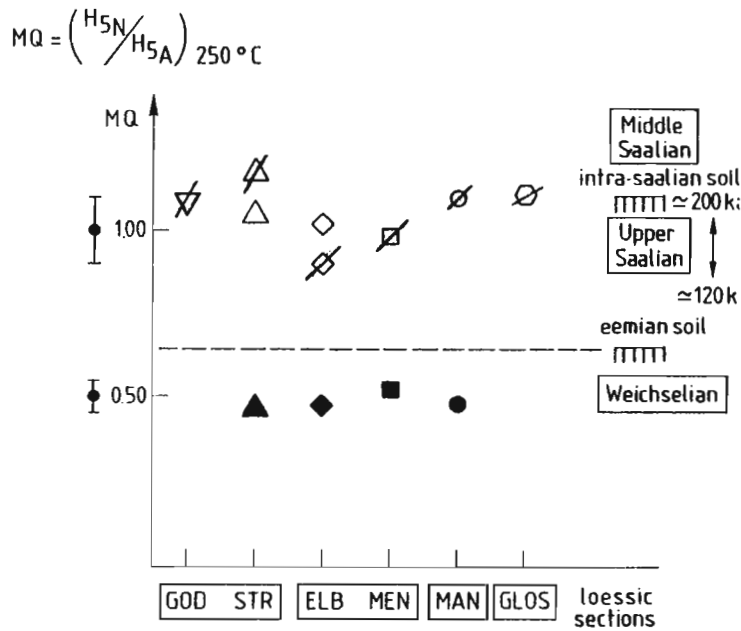


Figure 2: MQ values, on the vertical axis, associated with different loesses from distinct loessic sections, plotted on the horizontal axis. MQ is defined as the ratio of the NTL intensity of the highest temperature peak (H_{5N} ; $250^\circ C$) vs the corresponding ATL glow peak (H_{5A}).

- Weichselian loess
- ◊ Upper Saalian loess
- ◊ Middle Saalian loess
- ◊ error bars (1σ)

Feldspar TL properties

Typical feldspar ATL glow curves obtained after γ irradiation ($Co60 \gamma$), shown in figure 3, contain three overlapping peaks lying between 130 and $320^\circ C$ ($1^\circ C/s$ heating-rate). The double peaked NTL glow curves are also shown in this figure.

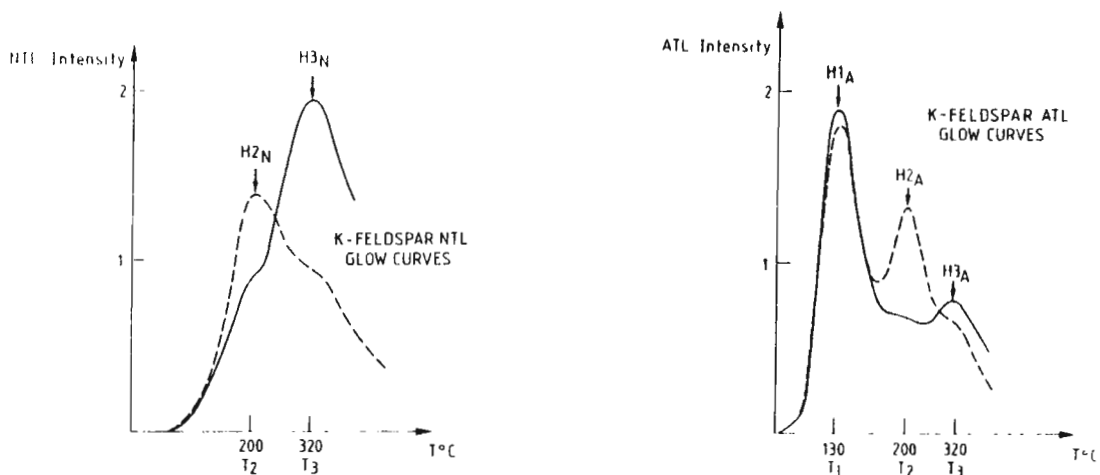


Figure 3. Typical NTL and ATL K-Feldspar glow curves. TL intensity in arbitrary units and normalized by weight as a function of temperature ($^\circ C$). The intensities (H_1, H_2, H_3) are measured from the height of the glow peaks. The intensity values are in the same units on both figures.

a) Equivalent dose (ED) methodology:

For the relative ED determination, an additive γ dose method is used. Giving additional γ doses to a suite of identical specimens of the same natural sample, we build up first-glow growth curves, using the highest temperature peak, as shown in figure 4. The TL response is linear to approximately 6 or 8 hours of γ irradiation after which it curves, and in some cases approaches saturation.

The ED is obtained by linear extrapolation to zero TL of the first part of the growth curve (from 0 to 6 hours of γ irradiation). This yields values of relative ED, defined as EDL, which are given in table 1 (column 2). Very low values of EDL are obtained for Weichselian loesses (~2 hours of γ irradiation) and higher values are obtained in Saalian loesses, ranging between 5 and 18 hours of γ irradiation.

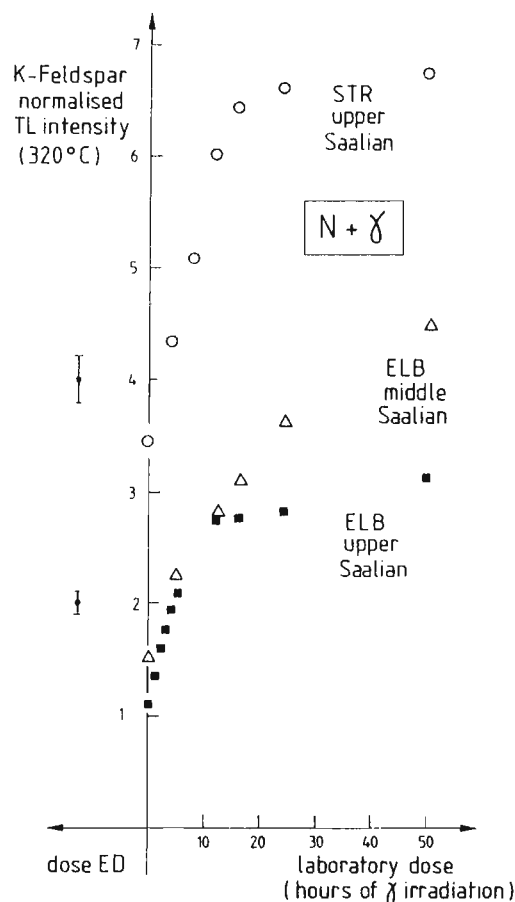


Figure 4.
Feldspar first glow curves, using the additive γ dose method. K-Feldspar intensity of the highest temperature peak (320°C) versus laboratory γ dose (hours).

Φ error bars (2σ)

b) Relative age estimation:

We next measure the β count-rate from the bulk sample, using Geiger-Muller counters (Intertechnique type RA 12, France). The analytical results are given in col.3 of table 1. They range from 5.6 to 8.5 counts/g/min ($\sigma = 0.5$).

The relative ages of these loesses are estimated by the ratio, EDL / β count-rate, defined as the MF ratio. The MF ratio is plotted on the vertical axis of figure 5. It lies between 0.2 for Weichselian loesses and 2.14 for older ones. We see that it clearly discriminates between Weichselian and Saalian loesses, thus confirming the results of the quartz investigation of the previous section. Furthermore, the MF ratio leads to good chronological differentiation between Upper and Middle Saalian loesses and reveals the existence of two distinct loessic generations within the Upper Saalian, which we define as S1 and S2.

TABLE 1.

SECTIONS	MQ	ED	β COUNT-RATE	MF=(ED _L /β)
GOD _{US}	1.01	11.14	8.00	1.39
STR _W	0.46	1.94	8.10	0.24
STR _{US}	1.16	15.43	7.80	1.98
STR _{ms}	1.05	17.75	8.30	2.14
MEN _W	0.52	-	-	-
MEN _{US}	0.99	4.56	7.97	0.57
ELB _W	0.47	-	-	-
ELB _{US}	0.90	5.95	7.97	0.57
ELB _{ms}	1.01	10.38	6.10	1.70
MAN _W	0.48	2.67	6.80	0.39
MAN _{US}	1.10	10.43	5.50	1.90
GLOS _{US}	1.09	9.85	8.20	1.20

Notes: TL results and radioactivity data for loesses from Normandy.
 w: Weichselian; us: Upper Saalian; ms: Middle Saalian.

Units.- ED: hours of γ irradiation;
 - β count-rate: counts/g /minute.

K-FELDSPAR TL

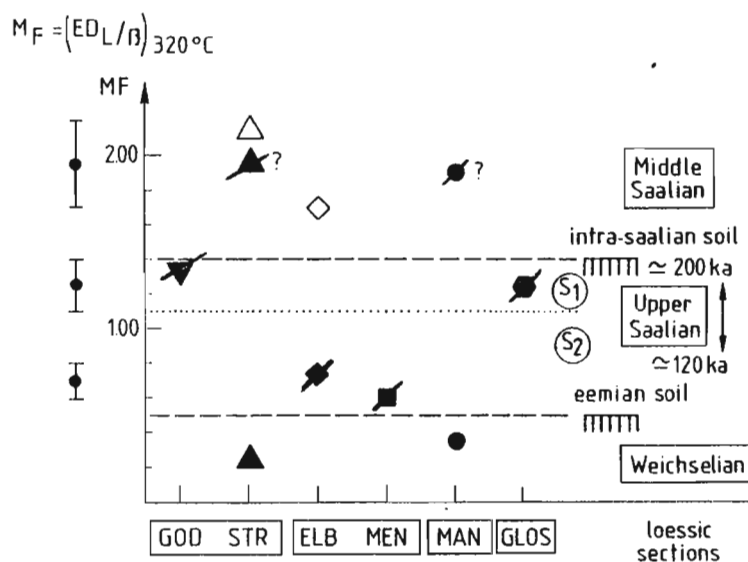


Figure 5.

MF values, on the vertical axis, associated with loess from different loessic sections, on the horizontal axis. MF is defined as the ratio of the ED_L obtained by linear extrapolation to β count-rate from the bulk sample.

- Weichselian loess
- ▲ Upper Saalian loess
- ◊ Middle Saalian loess

S1 and S2:

two upper Saalian loessic generations identified by the TL relative dating technique.

⊕ error bars (2σ)

The feldspar relative dates show stratigraphic consistency both within individual sections and laterally. Indeed, our age estimates are in a correct chronological sequence in each section. Also, adjacent loessic deposits, such as MEN and ELB which are at the same chronostratigraphical position (Upper Saalian), have similar ratios.

There are, however, two "TL anomalies" within the Upper Saalian loesses of Mantes (MAN) and Saint Romain (STR). Their relative ages are higher than would be expected and indistinguishable from those of the Middle Saalian loesses. Note that the relative age estimate of the Saint Romain Upper Saalian loess is nevertheless consistent with the corresponding absolute dates obtained by Wintle (Wintle et al., 1984), which are also abnormally high (as mentioned by Singhvi and Mejdahl, 1984). As the Upper Saalian loesses of Saint Romain and Mantes are generally attributed to the same loessic generation as the loess from Goderville (GOD) using stratigraphical evidence (Lautridou, 1985), further TL and sedimentological investigations are required to identify the origin of these TL anomalies.

The loess chronological discrimination by the MF ratio is in agreement with independent mineralogical results (Balescu et al., 1986a). Also, loesses belonging to different generations also have a distinct heavy mineral content and quartz ATL characteristics.

Finally, we note that these feldspar TL results are consistent with other relative dates we have estimated in loesses from Northern France and Belgium (Balescu et al., in preparation).

CONCLUSION

In this paper we have demonstrated that both quartz and feldspar TL characteristics of loessic deposits from Normandy can provide good chronological differentiation between Weichselian and Saalian loesses. Moreover, we have shown that the feldspar TL properties allow chronological discrimination among Saalian loesses. The agreement of our new feldspar TL data with the stratigraphy suggests that it can be used as a relative dating technique for loesses older than 120 ka. However, some further work is needed to understand the reason for the anomalously "old" values obtained for the Saint Roman and Mantes loesses discussed above.

By contrast with absolute dating methods which provide point date estimates, our technique is more adapted to rapid, comprehensive studies of loess chronology within large areas. It enables definition and comparison of regional relative TL chronologies and therefore can be used for preliminary chronological investigations. This approach, which we have termed "TL stratigraphy", allows a better control of the chronological and regional coherence of the TL results.

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[PR] Reviewers Comments (A.G. Wintle)

The empirical use of TL measurements on separated 40-50 μm potassium feldspar grains described in this paper is interesting since it throws light on the current discussions of TL dates obtained for fine grain loessic sediments from north west Europe as well as providing a relative dating method for these sediments.

In the first study using the regeneration method, geologically acceptable ages were obtained at Saint Romain (Wintle et al, 1984) for samples taken down to the loess immediately beneath the soil thought to result from the last interglacial (Eemian). However, Debenham's study on a variety of loessic sediments from several sites in north west Europe (Debenham, 1985) showed that deviation of the apparent TL age from the geological age occurred for samples as young as 50 ka. Wintle (1985) subsequently found underestimation of ages for deeper samples at Saint Romain. The implication of those studies is that the uppermost interglacial soil, thought to be the Eemian (Lautridou, 1985), is in fact considerably older than this. At other sites the TL age for loess immediately beneath the last interglacial soil is about 85 ± 10 ka (Proszyska-Bordas, 1985). This discrepancy is also shown up in this paper by Balescu et al (1986) and with this further evidence, the geological evidence for interpreting the uppermost soil at Saint Romain as being from the last interglacial should now be re-examined. The use of 40-50 μm K-feldspar grains also seems to give much clearer separation of the Saalian loesses than can be achieved using the regeneration method to obtain TL ages on fine grains (e.g. Debenham, 1985; Wintle, 1985).

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Compiled by Ann Wintle

Announcements

UNIVERSITY OF WASHINGTON, SEATTLE, USA

The Thermoluminescence Dating Laboratory at the University of Washington is pleased to announce that Dr. Mark Readhead of the Australian National University has joined them as principal research scientist.

Thomas G. Stoebe.

UNIVERSITY OF WOLLONGONG, AUSTRALIA

In the present financial climate it is not often that an opportunity arises to announce the reopening of a TL laboratory. The laboratory which was situated in the Physics Department, The Australian National University, Canberra, has been moved and will operate within the Department of Geography, The University of Wollongong, P.O. Box 1144, Wollongong, N.S.W. 2500, Australia.

The main interest of the laboratory will be in the study of sedimentary systems although some work with ceramic objects will be pursued. As a service to the community authenticity testing of appropriate ceramic art objects will also be conducted. Monies raised by the introduction of a service fee for work initiated from outside of the University will be utilised to further the research interests and general operation of the dating facility.

The laboratory is at present in the setting-up stage but should be fully operational by December 1986. All enquiries should be directed to the above address.

David M. Price

FROM THE EDITOR:

🍏 Readers will have noticed the production team's apparently persistent word blindness regarding the title of Balescu et al.'s paper in AnTL 4(i). The Editor has apologized to the authors for the misspelling of "palaeogeographical" and has taken steps to remedy this (a mod. EST course has helped considerably).

🍏 This issue of AnTL has been somewhat delayed because the central word processing facilities used previously are no longer available. However, we are fortunate to have the use of an Apple Macintosh Plus which will now be used for preparing AnTL copy. The Mac+ was donated by Apple UK as part of a research grant made by Apple to the University of Utah (Prasad Kaipa and Ed Haskell) and we are grateful to both Utah and Apple for this donation and its timely availability for AnTL, in addition to the TL research which it is intended to augment.

*Contributors please note; you may now submit articles to Durham on a disc if written using a Mac.

🍏 The system of reviewing is undergoing re-evaluation and the Editorial Board will probably be issuing further guidelines in the next issue.

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