APPENDIX A: RADIOCARBON AGE CHRONOLOGY OF ROSE COTTAGE CAVE.

Below is a summary of 46 ^{14}C analyses done at Rose Cottage Cave. Note a total of 49 samples were submitted of which there was too little sample for 3 of the analyses. Most of the analyses were done on charcoal.

- Pta = the analysis code of the Pretoria Radiocarbon Laboratory (South Africa).
- Grn = the analysis code of the Groningen Radiocarbon Laboratory (Germany).
- Sr = the analysis code of the Radiocarbon Laboratory in Salisbury Rhodesia (Zimbabwe, Lab. does not exist anymore).

* The descriptions are those given by the submitter.
** Analysis numbers 7796 and 7763 were not assigned to any layer

Analysis No.	Description	Position	Submitter	Age Yrs B. P.	Calibrated date (1 sigma range)
Pta-2076	Wilton	60 cm	Butzer, K. W	8640 ± 100	7716 (7595) 7564 BC
Pta-1417	‘Orange Sand”	Layer 6a	Butzer, K. W	23400 ± 200	23714 (23714) 23660 BC
Pta-1416	‘Orange Sand”	Layer 6a	Butzer, K. W	22700 ± 240	23377 (23215) 23054 BC
Pta-350	Potsherd	34 cm (Fh)	Mason, R. J	610 ± 50	AD 1312 – 1358, 1385 (1403) 1417
GrN-5298	Wilton 3 (Pottery)	20-25 cm (Le)	Mason, R. J	1100 ± 30	AD 963 (992) 1015
Grn-5299	Wilton 2	36-46 cm (Ld)	Mason, R. J	6850 ± 45	5728 (5706) 5659 BC
Pta-211	Pre-Wilton	135 cm (Jf)	Mason, R. J	29430 ± 520	33274 (32379) 30870 BC
Grn-5300	ELSA	176 cm (Jf)	Mason, R. J	25640 ± 220	25430 (25259) 25095 BC
Pta-0354	B ‘Orange Sand”	325 cm (Hc)	Mason, R. J	>40950	-
Pta-0213	B ‘Orange Sand’	330 cm (Hd)	Mason, R. J	>50200	-

	Upper Magosian				
Pta-0001	Upper Magosian	366 (Hd)	Mason, R. J	36100 ± 2000	42095 (40731) 38089 BC
Pta-0214	Upper Magosian	378 cm (Ie)	Mason, R. J	>42500	-
Sr-0116	Upper Magosian	378 cm	Mason, R. J	>48000	-
Pta-0231	Upper Magosian	380 cm	Mason, R. J	>48400	-
Pta-6839	Donga	20 cm	Smith, J	3 ± 10	-
Pta-6843	Donga	70 cm	Smith, J	1590 ± 70	AD 423 (534) 597
Pta-3360	Donga	100 cm	Scott, L	2310 ± 50	391 (377) 357, 290 – 229 BC
Pta-7120	Post-Classic Wilton	Level Mn (192 cm)	Wadley, L	85 ± 5	-
Pta-6788	Post-Classic Wilton	Level Mn	Wadley, L	500 ± 50	AD 1421 (1436) 1456
Pta-5622	Post-Classic Wilton	Level A	Wadley, L	680 ± 50	AD 1291 (1304) 1397
Pta-7117	Post-Classic Wilton	Level A2 (219cm)	Wadley, L	2240 ± 60	373 (348, 308, 212) 180 BC
Pta-5934	Classic-Wilton	Level Pt (210 cm)	Wadley, L	5970 ± 70	4848 (4792) 4719 BC
Pta-6783	Classic-Wilton	Level Pt (224 cm)	Wadley, L	7630 ± 80	6237 (6206) 6071 BC
Pta-7122	Oakhurst	Level Ja (247 cm)	Wadley, L	8160 ± 70	7174 (7075) 7055 BC
Pta-5600	Oakhurst	Level jaG (268 cm)	Wadley, L	8380 ± 70	7513 (7462) 7323 BC
Pta-7287	Oakhurst	Level Ph (252 cm)	Wadley, L	8350 ± 70	7489 (7433, 7419, 7351) 7300 BC
Pta-5560	Oakhurst	Level H (281 cm)	Wadley, L	8614 ± 38	7598 (7588) 7577 BC
Pta-5599	Oakhurst	Level O (285 cm)	Wadley, L	9250 ± 70	8539 (8432, 8360, 8337) 8294 BC
Pta-7288	Robberg	Level Lb (278 cm)	Wadley, L	9340 ± 80	8625 (8557) 8442 BC
Pta-7275	Robberg	Level Lb (278 cm)	Wadley, L	9560 ± 70	9124 – 8991, 8910 (8789) 8737 BC

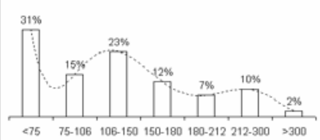
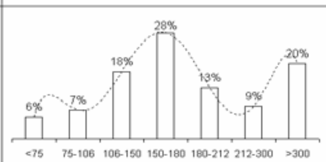
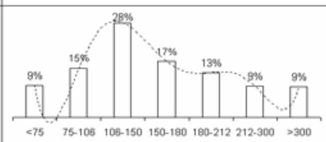
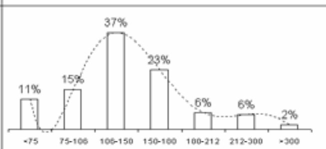
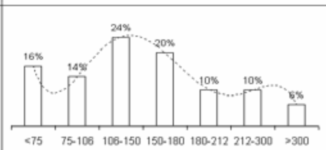
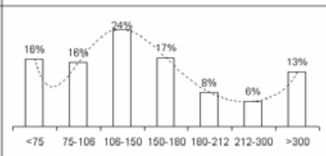
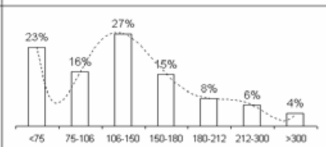
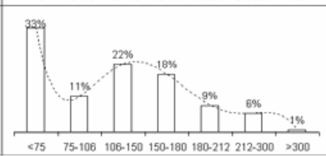
Pta-5593	Robberg	Level Db (322 cm)	Wadley, L	12690 ± 120	13334 (13176) 13018 BC
Pta-5601	Robberg	Level Db (352 cm)	Wadley, L	13360 ± 150	14222 (14049) 13864 BC
Pta-7290	Robberg	Level Be	Wadley, L	14320 ± 120	15291 (15153) 15015 BC
Pta-6195	Robberg	Level Wal (354 cm)	Wadley, L	15700 ± 40	16789 (16740) 16694 BC
Pta-7390	MSA/LSA	Level G (297 cm)	Wadley, L	17800 ± 180	19362 (19155) 18948 BC
Pta-7289	MSA/LSA	Level G/G2	Wadley, L	19600 ± 220	21121 (20963) 20748 BC
Pta-5598	MSA/LSA	Level G/G2	Wadley, L	20600 ± 250	21921 (21735) 21549 BC
Pta-6303	MSA IV	Level J/Ru (344 cm)	Wadley, L	26900 ± 550	26878 (26315) 25827 BC
Pta-6202	MSA IV	Level Ru (343 cm)	Wadley, L	27800 ± 1700	32510 (27309) 25621 BC
Pta-7126	MSA IV	Level Ru (364 cm)	Wadley, L	27700 ± 480	27894 (27177) 26632 BC
Pta-7184	MSA IV	Level Ru (364 cm)	Wadley, L	28800 ± 450	31957 (30298) 28238 BC
Pta-5596	MSA IV	Level Dc (350 cm)	Wadley, L	27200 ± 350	26996 (26610) 26270 BC
Pta-7805	'Orange sand'	Level Dy (340 cm)	Wadley, L	30800 ± 200	34599 (34375) 34143 BC
Pta-7796*	'Orange sand'	Level (354 cm)	Wadley, L	32900 ± 910	37680 (36609) 35650 BC
Pta-5592	'Orange sand'	Level Ge (374 cm)	Wadley, L	31300 ± 900	35868 (34925) 33900 BC
Pta-7763*	'Orange sand'	383-389 cm	Wadley, L	30800 ± 200	34599 (34375) 34143 BC

Source: QUADRU Database, CSIR, Pretoria, South Africa.

The radiocarbon age (Age Yrs B.P.) are reported in conventional radiocarbon years using a half-life of 5568 years given in years BP, i.e. before AD 1950 and are corrected for isotopic fractionation. Calibrated dates were calculated with the Pretoria programme (Talma & Vogel, 1993) which was updated in 2000. The 1 sigma range is given, with the most probable date between brackets.

APPENDIX B: GRAIN SIZE DISTRIBUTIONS OF RCC SAMPLES.

Below is a summary of grain size distribution for 0.5m intervals from the RCC sequence. The sedimentary interpretation is given by Butzer (1984b) for all material at the same depth. Note these distributions are representations of the sedimentary mixture after pre-treatment was performed on the material.

DEPTH	SAMPLE NAME	GRAIN SIZE DISTRIBUTION (µm)	SEDIMENTARY INTERPRETATION (BUTZER, 1984)
2.0	RCC 17		Oraganic silty sand produced from spring influx
2.5	RCC 21		Oraganic silty sand produced from spring influx
3.0	RCC 19		Oraganic silty sand produced from spring influx
3.5	RCC 18		Silty sand produced from spring influx with subangular to angular roof spall
4.5	RCC 16		Subangular to angular roof spall
5.0	RCC 14		Angular roof spall
5.5	RCC 12		
6.0	RCC 11		

APPENDIX C
Radioactivity and dose-rate data.

C.1 TSAC calculations

Alpha particles are emitted isotropically therefore many of the alpha decays will not interact with the scintillant. The equation that expresses the measured alpha activity $\dot{\alpha}$ (Bq/kg) of a sample relative to the total alpha activity is given by

$$\dot{\alpha} = \frac{1}{4} fAR\rho nC \times 10^{-4}$$ (Adamiec & Aitken, 1998)

Equation C1

Where:

f is the electronic threshold fraction

A is the area of the screen (1385 mm^2)

Rρ is the average alpha emission range per density (μg mm^2)

n is the effective number of alpha emissions

C is the activity per unit mass of the parent (Bq/kg)

The value of *Rρ* is determined from the energy of the alpha emission. High energy alphas will obviously have a longer range than low energy alphas in a material of any given density (Aitken, 1985). The value is calculated by averaging the range of each alpha in the decay sequence. This assumes that all alphas in the decay chain contribute equally to the ά dose which will only happen when the decay chain is in equilibrium. Alternate calculations can be made for samples that are not in equilibrium, but this was not done in this study as it requires appropriate knowledge of the disequilibrium. As a result the calculated parent activity is not accurate where disequilibrium occurs. The reported TSAC values are therefore the full chain equivalent parent activity that would give rise to the measured alpha activity.

The value of *R* differs between the Th and U chains. The average alpha range for the Th chain in equilibrium is 67.4 µm and for the U chain in equilibrium is 57.1 µm (Adamiec & Aitken, 1998). Where TSAC is done using the pairs technique, the calculation of the full chain parent activity takes this into account. The threshold fraction (*f*) relates the efficiency of the detector and is determined by the low level discriminator setting of the photomultiplier. This is typically 0.85 for the Th series. Because of the different average energy, the equivalent value is 0.82 for the U series (Aitken, 1985). The *effective alpha range* can then be calculated as the ratio between *Rρ* and *f* (Aitken, 1985). Equation C1 can therefore be rewritten as

$$\dot{\alpha} = (effective\ range \times n\frac{1}{4}AC \times 10^{-4})$$

Equation C2

Combining the contribution of the U and Th decay chains to the total detected alpha count gives the equation

$$\dot{\alpha} = (67.4 \times 6 \times 0.25 \times A \times C_h \times 10^{-4}) + (57.1 \times 8 \times 0.25 \times A \times C_u \times 10^{-4})$$

Equation C3

Where:

C_h is the Th full chain activity and

C_u is the U full chain activity.

This can be simplified to give the equation

$$\alpha = (0.1191c_h \times 10^{-4}) + (0.1302c_u \times 10^{-4})$$

Equation C4

Equation C4 expresses the alpha count rate that is measured on a 42 mm diameter screen in terms of the contribution of Th and U. The contribution of the Th series can be calculated from the slow pair's count. The probability of two random alpha events, which are not "true pairs" derived from ^{216}Po is a function of the count rate of the sample, and of the duration 'coincidence window' circuitry (Aitken, 1985). The random pair's probability can then be calculated according to equation C5

$$P_r = \dot{\alpha}^2 t^{-ks} \quad \text{(Aitken, 1985)}$$

Equation C5

Where:

$\acute{\alpha}^2$ is the raw count rate (cts/ks)^2 and

t^{-ks} is the coincidence time per kilo second (ks)

The true pairs are a measurement of the actual pairs occurring from the Th chain. If $\dot{d}$ is used for the total observed pairs then the true pairs rate is given by

$$\dot{p} = \dot{d} - P_r$$

Equation C6

The probability of recording true pairs is dependant on the duration of the coincidence window, and the lifetime (λ) of fast emitting alpha nuclei. The formula used to express the pairs probability is

$$Pp = 1 - \exp(-\lambda t) \quad \text{(Aitken, 1985)}$$

Equation C6.1

Where:

λ is the lifetime of ^{216}Po (0.209 s) and

t is the coincidence window.

This can be simplified to give a pairs probability of 76% by substituting values into equation C6.1 with

$$Pp = (1 - \exp^{(-0.4 \div 0.209)}) - (1 - \exp^{(-0.02 \div 0.209)}) = 0.7611$$

Equation C6.2

The pair's count rate for the Th series can now be calculated by using equation C7

$$\dot{P}h = \frac{0.7611}{12} A \times 62.39 \left(1 + \frac{0.5(82 - 72.5)}{71.26}\right) \div 1000000 = \mathbf{0.0058}$$

(after Aitken, 1985) Equation C7

Where:

$\dot{P}h$ is the pairs count rate for the Th series

0.7611 is the pair's probability taken from equation 3.5

A is the counting area of the screen ($1385 cm^2$)

62.39 is the effective alpha range for ^{220}Rn

82 and 72.5 are the average alpha ranges for ^{216}Po and ^{220}Rn respectively

71.26 is the effective alpha range for ^{216}Po.

It is now possible to calculate the total Th and U count. The U contribution is calculated by subtracting the total Th counts from the observed count rate. The total Th counts are given by equation C8

$$Ch = \dot{p}\frac{\dot{\alpha}}{\dot{P}h}$$

Equation C8

To convert the parent specific alpha count rates to ppm the counts are divided by the corresponding alpha activity of 1 ppm of the parent. The count rate (ks^{-1}) for 1 ppm of parent for a 42 mm diameter scintillator has been calculated by Adamiec & Aitken (1998) and correspond to 0.483 for the Th series and 1.67 for the U series.

C.2 Radioactive Decay chains

Figures C.1, C.2 and C.2 below are schematic representations of the Th and U decay series. The y-axis, titled “A”, is the atomic number. MeV represents the energy emitted per disintegration; figures are after Ivanovich & Harmon, 1982 and Adamiec & Aitken, 1998.

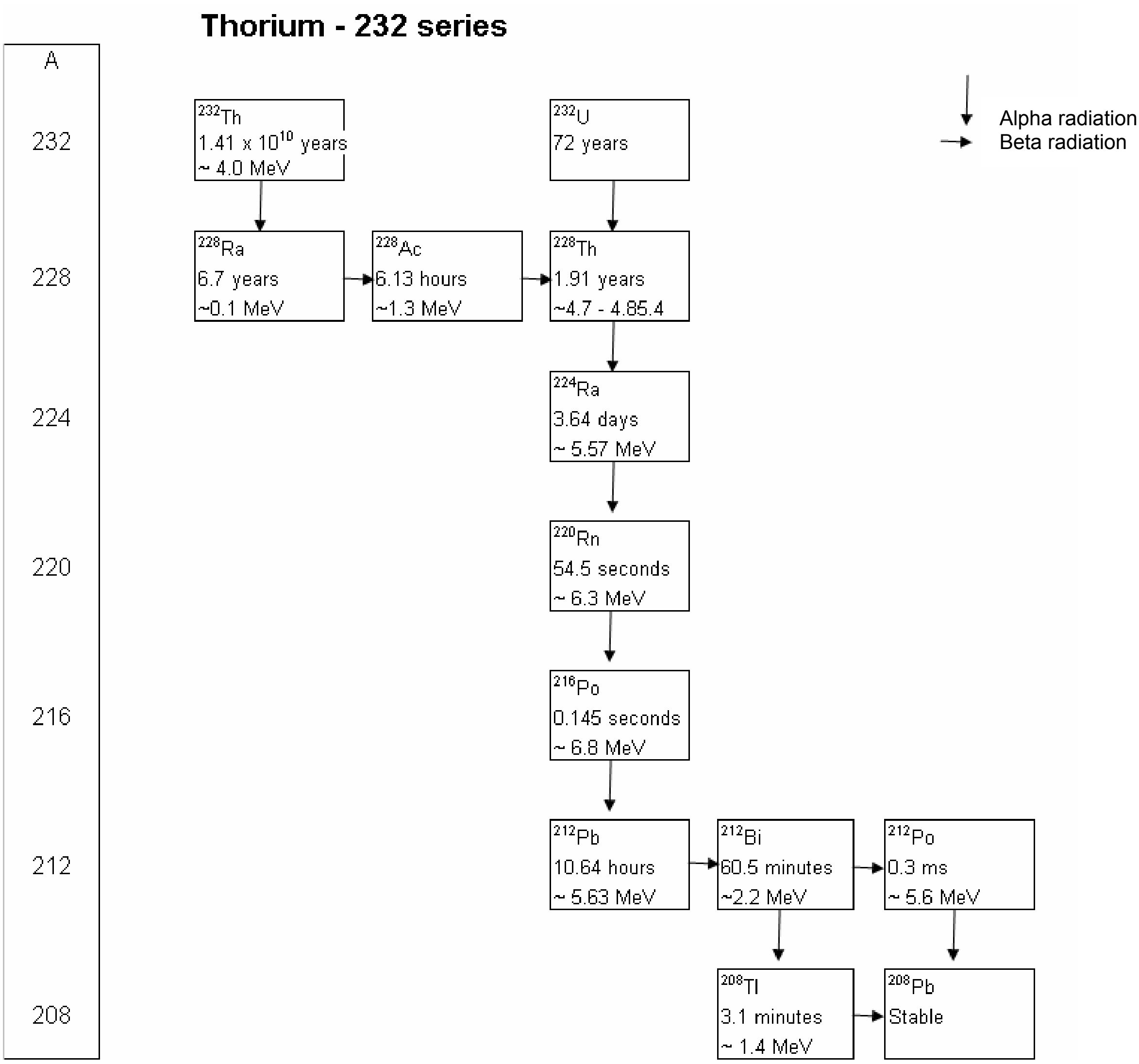


Figure C.1 Energy release and decay series for ^{232}Th.

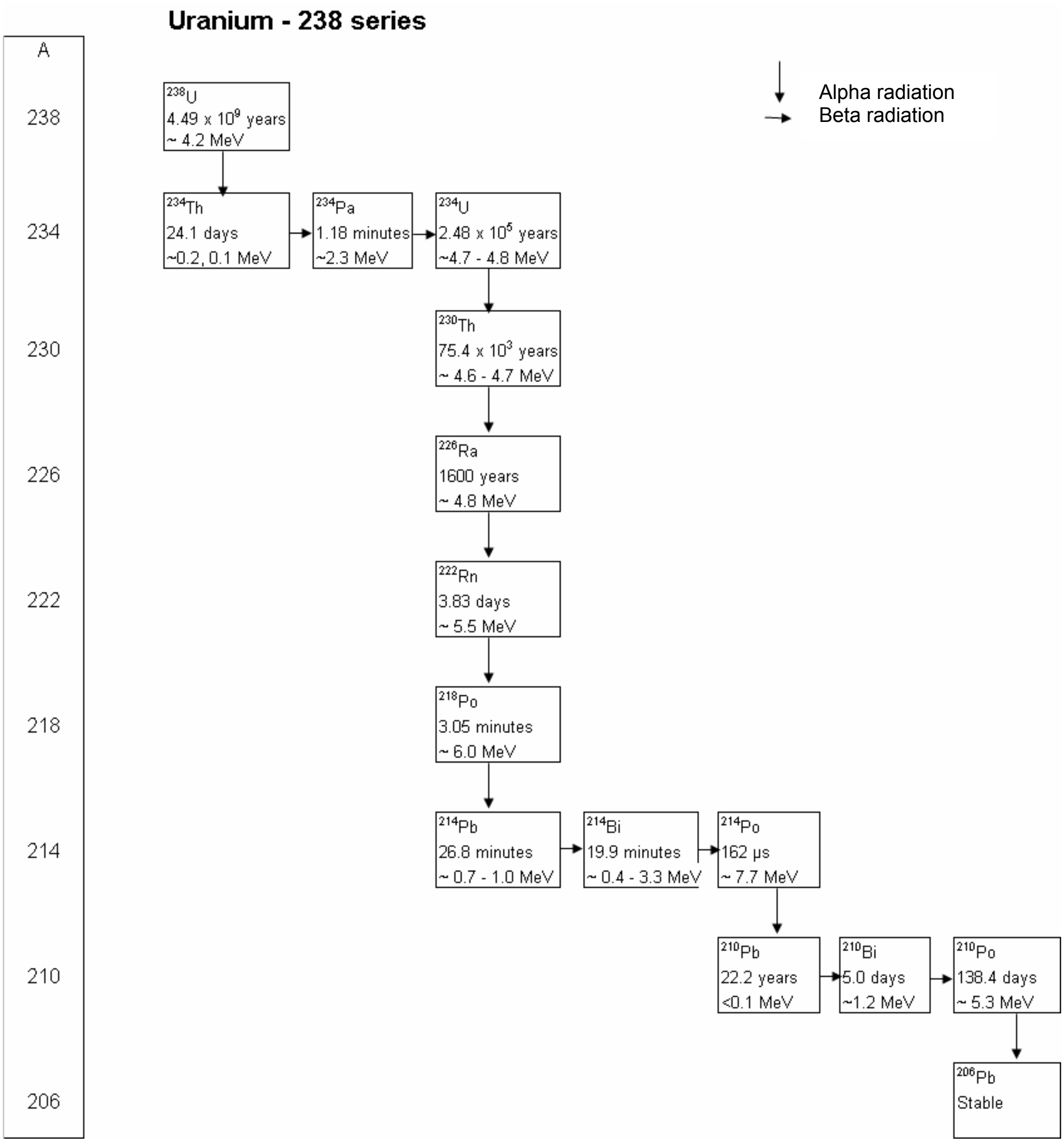


Figure C.2 Energy release and decay series for ^{238}U.

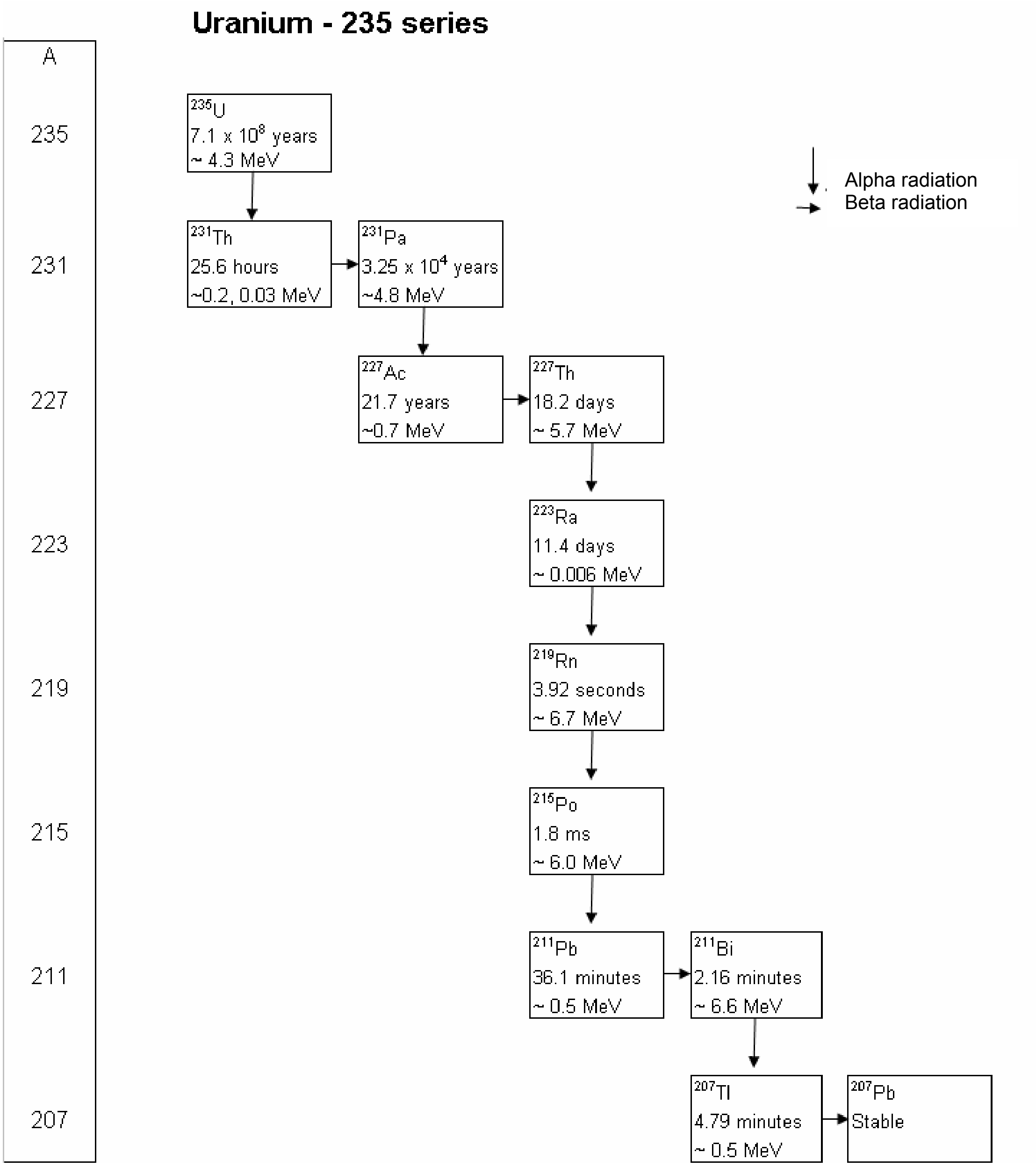


Figure C.3 Energy release and decay series for ^{235}U.

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