

GSA DATA REPOSITORY 2010111

AppendixDR1 - Methods

When ^{238}U decays to ^{234}Th , the daughter nuclide (^{234}Th) is displaced from the original ^{238}U position due to the alpha recoil effect (Kigoshi, 1971). If ^{238}U decay occurs within the “recoil range” of the grain surface, ^{234}Th will be lost from the solid. ^{234}Th decays rapidly into its granddaughter, ^{234}U , such that the surface of a grain can be depleted in ^{234}U relative to ^{238}U . Depletion in ^{234}U relative to ^{238}U is measurable when the grain size is smaller than $\sim 50 \mu\text{m}$ (DePaolo et al., 2006). Consequently, when a rock is physically weathered and fine detrital particles are created, the U isotope chronometer will record this time. The *comminution age*, i.e. the time elapsed since the sediment started to lose ^{234}U - typically the time when physical weathering produced grains smaller than $50 \mu\text{m}$, is calculated as follows (DePaolo et al., 2006) :

$$t_{com} = -\frac{1}{\lambda_{234}} \ln \left[\frac{A_{meas} - (1 - f_{\alpha})}{A_0 - (1 - f_{\alpha})} \right] \quad (1)$$

where λ_{234} is the ^{234}U decay constant ($2.826 \times 10^{-6} \text{ yr}^{-1}$; (Cheng et al., 2000), A_{meas} is the measured ($^{234}\text{U}/^{238}\text{U}$) activity ratio, A_0 the initial ($^{234}\text{U}/^{238}\text{U}$) activity ratio (equal to unity as long as the bedrock is older than 1 Ma) and f_{α} is the recoil fraction. The sediment residence time is then calculated by subtracting the deposition age from the comminution age.

In order to calculate the comminution age of the sediments, we need to determine the recoil fraction, f_{α} , for each sample. Maher et al. (2006) discussed different geometrical models to estimate f_{α} . A weighted geometric model seems to yield satisfying

results, comparable to that obtained with independent approaches (see (Maher et al., 2006) for discussion) and the recoil fraction is calculated using the following equation (Maher et al., 2006):

$$f_{\alpha} = \int_{L/2}^{r_{\max}} X(r) \beta(r) \lambda_s(r) \frac{3}{4} \left(\frac{L}{r} - \frac{L^3}{12r^3} \right) dr \quad (2)$$

where $X(r)$ is the volume fraction of grains with radius r (determined using a particle size analyser), β is the aspect ratio of the grain (spherical grain if $\beta=1$, oblate spheroidal grain if $\beta>1$), λ_s is a surface roughness factor, L is the ^{234}Th recoil range (in nm). In our calculations, we used $L = 30$ nm and similar values for β (1 – 10) and λ_s (1 – 2) to those used by DePaolo et al.(2006). The particle size distribution of the $<50 \mu\text{m}$ fraction was determined using a Micromeritics™ SediGraph III 5120 particle size analyser and the obtained distribution was used with equation (2) to compute f_{α} values for each sample.

f_{α} values range from 0.065 to 0.12 (Table DR1). For TAB2 and THU1, it was not possible to determine the particle size distribution because not enough material was available as these sediments are very coarse. We assumed a f_{α} value of 0.06, at the lower end of the calculated range (since these sediments are the coarsest sampled, they should have the lowest f_{α} value).

Sediments were collected from seven paleochannels with depositional ages determined by thermo-luminescence (TL) dating (Page et al., 1996) and confirmed by optically-stimulated luminescence (OSL) (Banerjee et al., 2002). All paleochannels are located between Hay and Narrandera (Fig. 2). Their distance from headwaters, drainage area and other geomorphic factors are relatively similar. Sediments from a modern point bar at Wagga Wagga (Fig. 2) were also sampled (< 50 yr old). The modern sediment

sampling location is located significantly upstream from the paleochannels. Slope is also greater and drainage area smaller than at the location of paleochannel sampling.

However, this does not affect our conclusions: these geomorphic differences should predict a shorter residence time for the modern sediments but our results show that they are characterized by the greatest residence times. This suggests that in our case, differences in sampling location and associated geomorphic factors do not impact sediment residence time values.

For each paleochannel, samples were collected at several locations in order to assess spatial variability within a given channel. Samples were sieved and the fraction $< 50 \mu\text{m}$ in diameter was retained. Sediments generally contain significant proportions of organic matter and authigenic phases (carbonates, iron oxides) that have a distinctly different U isotopic signature that would contaminate the signal carried by residual silicates. In order to obtain a “pure” residual silicate, the $< 50 \mu\text{m}$ sediment was treated following a procedure that differs from that used by DePaolo et al.(2006): samples were first ashed at 550°C overnight in order to eliminate organic matter. Then, they were leached twice for 6h in 1.5M HCl at room temperature in order to eliminate the uranium previously bound to the organic matter, the exchangeable fraction and any carbonates. The leaching time was determined by monitoring calcium (Ca), iron (Fe), uranium (U) and thorium (Th) concentrations in the leachate with time. After 5h, Ca, U and Th concentrations reach a plateau. The ($^{234}\text{U}/^{238}\text{U}$) activity ratio in the leachate increases with time between 1.207 ± 0.007 and 1.233 ± 0.005 and becomes constant after 6h leaching. Leaching for longer periods of time ($> 10\text{h}$) results in a decrease of U and Th concentrations in the leachate suggesting re-adsorption of these elements on the sediment.

Nevertheless, Fe concentrations reach a plateau only after >24h leaching, indicating that the dissolution of Fe-oxides is incomplete after 6h leaching, justifying an additional leaching step with hydroxylamine hydrochloride (NH₂OH-HCl). After leaching in 1.5M HCl, samples were leached for 5h in 0.04M NH₂OH-HCl at pH = 2, in order to remove any Fe-,Mn-oxides (Schultz et al., 1998). The residue was digested in a mixture of concentrated acids (HClO₄-HF-HNO₃-HCl). Separation of U followed standard anionic resin chromatography (Sims et al., 2008). ²³⁴U/²³⁸U ratios were measured on a Nu Instruments™ Multi-Collector ICP-MS. Accuracy was assessed by analysing the secular equilibrium rock standard TML-3 and was typically ≤ 0.3 % at the 2σ level (Sims et al., 2008). Two or three aliquots of three samples have been processed separately (including leaching) and analysed. They yield a relative external analytical uncertainty of 0.3 % on ²³⁴U/²³⁸U. Results are presented in Table DR1.

Table DR1. Results for the Murrumbidgee paleochannels

Sample	System	Site	Deposition age (kyr)	(²³⁴ U/ ²³⁸ U)	f_{α}	T_{comm} (kyr)	T_{res} (kyr)
BUN1	Coleambally	Bundure	100±9	0.953	0.086	528±86	428±108
BUN2	Coleambally	Bundure	100±9	0.949	0.065	544±89	444±112
KUL1	Coleambally	Kulki	87±8	0.945	0.117	227±37	140±35
KUL3	Coleambally	Kulki	87±8	0.942	0.118	241±39	154±38
GV1	Coleambally	Gala Vale	84±7	0.942	0.084	417±68	333±82
GV2	Coleambally	Gala Vale	84±7	0.953	0.084	292±48	208±51
KER1	Kerarbury	Kerarbury	46±4	0.973	0.093	124±20	78±20
KER4	Kerarbury	Kerarbury	46±4	0.950	0.093	239±39	193±48
TAB2	Gum Creek	Tabratong	25±3	0.978	0.06	158±26	133±38
THU2	Yanco	Thurrowa Rd	15±2	0.993	0.025	42±7	27±8
MB3	Murrumbidgee	Mucklebar	2.2±0.2	0.926	0.124	318±52	316±87
MB4	Murrumbidgee	Mucklebar	2.8±0.3	0.915	0.128	385±63	382±97
MB5	Murrumbidgee	Mucklebar	3.4±0.3	0.930	0.143	341±56	338±58
EUN1	Murrumbidgee	Eunony	n/a	0.941	0.079	480±78	480±78
EUN2	Murrumbidgee	Eunony	n/a	0.949	0.086	316±52	316±52

Deposition ages were obtained by TL dating (Page et al., 1996), except for Mucklebar samples where OSL dating was undertaken (T. Pietsch, pers. comm.). Sediments collected at the Eunony site originate from the modern channel. Their deposition age is believed to be less than 50 yr and have not been dated by TL or OSL. Relative external analytical uncertainty is 0.3% for (²³⁴U/²³⁸U) activity ratios at the 2σ level. External analytical uncertainty has been calculated by successive analysis of different aliquots of samples processed separately (including leaching). f_{α} is the calculated recoil fraction (see text for details). The relative uncertainty on the recoil fraction is 16%. T_{comm} is the comminution age. T_{res} is the residence time of sediments in the catchment (see text for more details). Errors on T_{comm} and T_{res} are external analytical uncertainties at the 2σ level calculated by propagation of the error on (²³⁴U/²³⁸U) and the recoil fraction.

1.

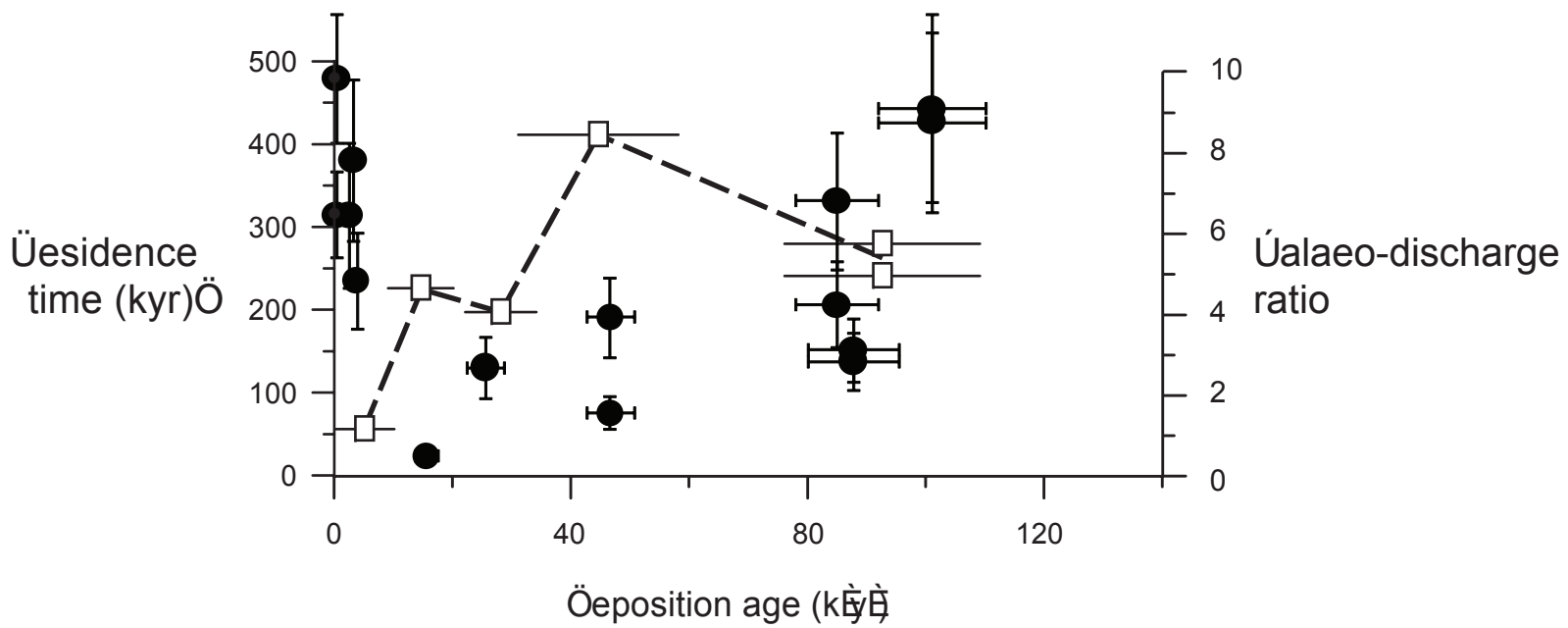


Figure DR1. Variations in sediment residence time (filled dots) compared to the bankfull river discharge ratio of the Murrumbidgee paleochannels to the modern river discharge (open squares and dotted lines) (Page and Nanson, 1996).

References

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