

Reviewer: *These values don't seem all that great to me. I generally try changing my protocol if the dose recovery ratio comes out worse than 1.10 or 0.9. What could be causes of this not-great dose recovery? Is this typical for feldspar from New Zealand?*

Answer: The authors would like to thank the reviewer for the keen observations. So far, several studies reported poor dose recovery results for pIRIR₂₉₀ (e.g. Stevens et al., 2011; Thiel et al., 2011, 2014; Lowick et al., 2012; Roberts et al., 2012; Murray et al., 2014, Veres et al., 2019; Avram et al., 2020). Usually, these poor dose recovery ratios were greater than unity. On the other hand, Sohhati et al., 2016 reported good dose recovery ratios for K-feldspars using pIRIR₂₉₀ extracted from palaeorockfall boulders from South Island, New Zealand.

Qin and Zhou (2012) suggested that the dose recovery ratio is dependent on the test dose size. Yi et al., 2016 concluded that the best dose recovery ratios are found when the test dose ranges between 15 and 80% of the total dose. Here, following this suggestion dose recovery measurements were carried out using a test dose ranging between 20 and 60% of the total dose. On the other hand, a recent study by Avram et al. (2020) reported poor dose recovery ratio using a test dose of 41% of the total dose on polymineral fine grains extracted from Serbian loess.

As the reviewer suggested, two protocols are actually being used, namely pIRIR₂₉₀ and pIRIR₂₂₅. As presented in the manuscript “the ratios between the recovered and given dose for polymineral fine grains are 1.11 ± 0.03 (NZ13A) and 1.01 ± 0.03 (NZ14A) using piIRIR₂₂₅ protocol and 1.14 ± 0.05 (NZ13A) and 1.03 ± 0.06 (NZ14A) using pIRIR₂₉₀ protocol. In the case of coarse K-feldspars, the dose recovery ratios are 0.96 ± 0.01 (NZ13A) and 0.87 ± 0.03 (NZ14A) using pIRIR₂₂₅ protocol, while those obtained by applying pIRIR₂₉₀ protocol are 1.17 ± 0.06 (NZ13A) and 1.16 ± 0.04 (NZ14A).” Please note that in the case of the pIRIR₂₂₅ protocol the results are generally satisfactory – they are within 1σ uncertainty and they are consistent with the 0.9-1.1 interval. We have stated that “We conclude that the overall behaviour of the pIRIR₂₂₅ protocol is satisfactory whereas the pIRIR₂₉₀ protocol overestimates the given dose by $\sim 17\%$.”

Some authors (e.g Stevens et al., 2011; Alexanderson and Murray, 2012) concluded that poor dose recovery ratios can be the result of the incorrect residual dose estimation.

In order to avoid potential complications related to laboratory bleaching of the natural samples, the dose recovery test could be performed by adding a beta dose on top of the natural dose. Then, the dose recovery ratios are obtained by dividing the measured dose to the sum of the natural and the given dose.

Such a dose recovery test was performed in the case of pIRIR₂₉₀ protocol by adding a beta dose of 100 Gy on top of natural dose. The results are presented in the last column of the table below and compared with the previous reported values stated above and presented in the manuscript (column 3).

Sample code	Grain size	Recovered/given ratio (residual dose subtraction)	Recovered/given ratio (100 Gy on top of natural)
NZ13A	4-11 μm polymineral	1.14 \pm 0.05	1.12 \pm 0.05
NZ14A	4-11 μm polymineral	1.03 \pm 0.06	1.15 \pm 0.03
NZ13A	63-90 μm K-feldspar	1.17 \pm 0.06	1.03 \pm 0.03
NZ14A	63-90 μm K-feldspar	1.16 \pm 0.04	1.02 \pm 0.02

For coarse K-feldspars the dose recovery ratio improved from 1.17 \pm 0.06 to 1.03 \pm 0.03 for sample NZ13A and from 1.16 \pm 0.04 to 1.02 \pm 0.02 for sample NZ14A. In the case of polymineral fine grains, the dose recovery ratio for sample NZ13A was still slightly overestimated (1.12 \pm 0.05), while for sample NZ14A, the dose recovery ratio increased from 1.03 \pm 0.06 to 1.15 \pm 0.03. As such there is no clear trend. We can only conclude that while the results are not ideal, they are acceptable, and the used protocols are providing the best attainable results for these samples given state-of-the-art available methods (see also answers below regarding changing the preheat temperature).

Reviewer: *Those g-values might not be insignificant. If you perform the fading correction on the k-feldspar for NZ14A, do the ages agree with the polymineral?*

Answer: The g-values are not significant in our view. We have discussed this in detail in Avram et al. (2020), where we are presenting more extended fading measurements including on calibration quartz. Consequently, as we do not consider these short-term measurements to be reliable and we do not consider the values to be significant, we are not presenting corrected ages. For the sake of the exercise, following the reviewer's suggestion we have calculated the corrected K-feldspars ages (pIRIR₂₂₅) for both samples NZ13A and NZ14A. The results are presented in the next table:

Sample code	g-value (%/decade)	Uncorrected Age (ka)				Corrected Age (ka)
	K-feldspar (pIRIR ₂₂₅)	pfg (pIRIR ₂₂₅)	K-feldspar (pIRIR ₂₂₅)	pfg (pIRIR ₂₉₀)	K-feldspar (pIRIR ₂₉₀)	K-feldspar (pIRIR ₂₂₅)
NZ 13A	0.60 \pm 0.51	16 \pm 0.1	20.1 \pm 1.5	20.9 \pm 2.0	26.2 \pm 2.1	20.8 \pm 1.5
NZ 14A	0.85 \pm 0.09	4.6 \pm 0.4	1.9 \pm 0.1	6.0 \pm 0.7	3.1 \pm 0.3	2.0 \pm 0.1

The corrected pIRIR ages were calculated using the R Luminescence-package (Dietze et al., 2013) according to Huntley and Lamothe (2001) method.

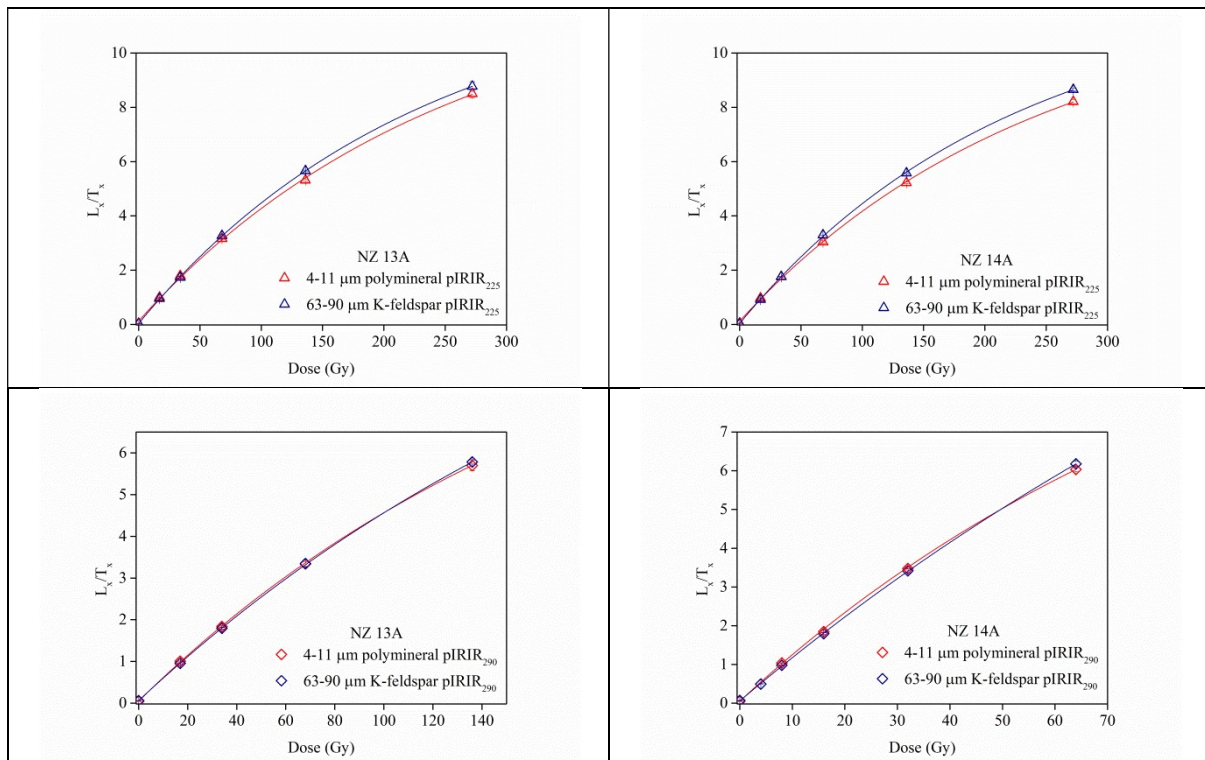
As can be seen, there is no significant difference in the ages obtained.

Reviewer: *Perhaps the discrepancy in age between the polymineral fine grain and the k-feldspar (for NZ14A) is due to the presence of unknown minerals in the polymineral aliquots? It is possible that there are minerals in there with unknown pIRIR properties that might be transferring charge in unexpected ways?*

Answer: This is indeed a reasonable assumption that is worth further study. Indeed, the polymineral fraction consists of a mixture of different kinds of minerals but it is assumed that the measured emission in the violet-blue band is predominantly caused by feldspar minerals

(Tsukamoto et al., 2012; Kreuzer et al., 2014). Li and Wintle (1992) investigated the stability of luminescence signal of polymineral fine grains in comparison with those from K- and Na-rich feldspars, all extracted from loess. They found that the thermal stability of the IRSL signals from polymineral fine grains extracted from different areas around the world is similar, and the IRSL signal from fine grains is less stable than the signal of K-feldspars. Tsukamoto et al., 2012, found that IRSL and pIRIR signals from polymineral fine grains are less stable than K-feldspar sample when a lower preheat temperature (260–300 °C) is used, but the stability among different types of feldspars becomes similar when a higher preheat temperature (>320 °C) is included. From a dating point of view, they suggested that the IRSL in polymineral fine grains behaves similarly to the Na-feldspars signal, rather than to the K-feldspar’s signal. To our knowledge there are few, if any, published luminescence dating studies that documented both polymineral and K-feldspars ages obtained by using pIRIR methods. Rahimzadeh et al., (2019 - conference abstract) reported polymineral fine grains and K-feldspars ages using pIRIR₂₂₅ protocol on Bavarian loess. They have found that the fading corrected ages for the two different grain sizes agree within errors for most of the samples, observing a larger discrepancy for samples with an age above 100 ka. These kinds of studies are worth pursuing, however; in our view it would be better to attempt such studies on sites where independent age control or at least well-behaved quartz chronologies are available.

Here, we have further investigated the growth curves of polymineral fine grains and K-feldspars (see Figures below). As can be seen, the growth curves overlap over the dose range investigated.



Reviewer: *One other thing that might be useful is if the authors could report the distribution of the residual dose. If there is large variance, maybe this could explain the discrepancy of the polymineral and feldspar ages.*

Answer: Residual doses measured for each individual aliquot are reported in the table below. There is no significant scatter in between the measured residual doses for each aliquot, and certainly not a difference that could account for the reported age discrepancy. Therefore, we conclude that this scenario could not explain the observed discrepancy between polymineral and K-feldspars ages.

Sample code	Grain size	protocol	Residual dose	Average residual dose
NZ 13A	4-11 μm polymineral	pIRIR ₂₂₅	4.2 \pm 0.2	3.3 \pm 0.30
			3.1 \pm 0.1	
			3.9 \pm 0.2	
			2.5 \pm 0.1	
			3.0 \pm 0.1	
NZ 14A	4-11 μm polymineral	pIRIR ₂₂₅	2.7 \pm 0.2	3.0 \pm 0.2
			2.8 \pm 0.1	
			3.0 \pm 0.2	
			2.6 \pm 0.2	
			3.7 \pm 0.2	
NZ 13A	63-90 μm K-feldspar	pIRIR ₂₂₅	2.7 \pm 0.1	2.9 \pm 0.1
			2.9 \pm 0.1	
			3.0 \pm 0.1	
NZ 14A	63-90 μm K-feldspar	pIRIR ₂₂₅	1.1 \pm 0.05	1.3 \pm 0.1
			1.5 \pm 0.04	
			1.3 \pm 0.03	
NZ 13A	4-11 μm polymineral	pIRIR ₂₉₀	7.6 \pm 0.3	10.0 \pm 1.0
			11.4 \pm 0.4	
			10.6 \pm 0.4	
			12.5 \pm 0.5	
			7.6 \pm 0.2	
NZ 14A	4-11 μm polymineral	pIRIR ₂₉₀	10.4 \pm 0.4	10.8 \pm 0.9
			12.3 \pm 0.5	
			12.4 \pm 0.5	
			7.4 \pm 0.3	
			11.4 \pm 0.5	
NZ 13A	63-90 μm K-feldspar	pIRIR ₂₉₀	9.7 \pm 0.4	9.0 \pm 0.3
			8.9 \pm 0.3	
			8.6 \pm 0.2	
NZ 14A	63-90 μm K-feldspar	pIRIR ₂₉₀	5.2 \pm 0.2	4.9 \pm 0.2
			4.6 \pm 0.3	
			5.0 \pm 0.2	

Reviewer: *One fairly big issue is that there is limited reporting of what landform the luminescence samples were collected from. The locations are given on the aerial photo, but I cannot determine if they were collected from sediment in the channel or from the walls of the canyon, etc. Because of this, it is hard to interpret the interpretations of partial bleaching fully. As the pIR290 ages overestimate the pIR225 ages, there is likely to be partial bleaching, but how much? Are the ages themselves suspect or not? How do you know? Do you need a lower temperature pIR signal to get a better bleached age?*

Answer:

The samples were collected from the flanks of the two largest canyons, just above the boundary between the gravels below and loess above (see photographs below, which will be included in revised manuscript).



NZ13A



NZ14 A

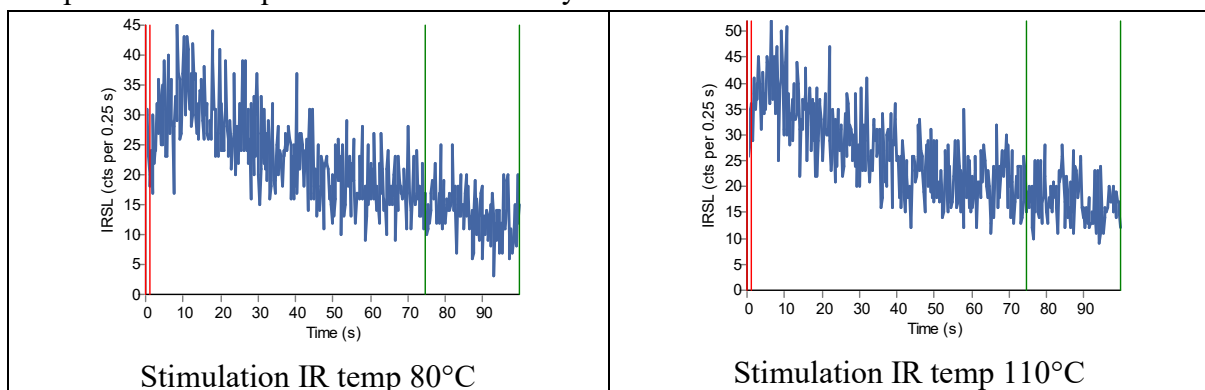
Indeed, the partial bleaching is an important concern especially as pIRIR signals are known to be more difficult to bleach. Existing studies have shown that the pIRIR residual doses can range between a few Gray (<2 Gy) to 10-20 Gy or even more (Thiel et al., 2011; Stevens et al., 2011;

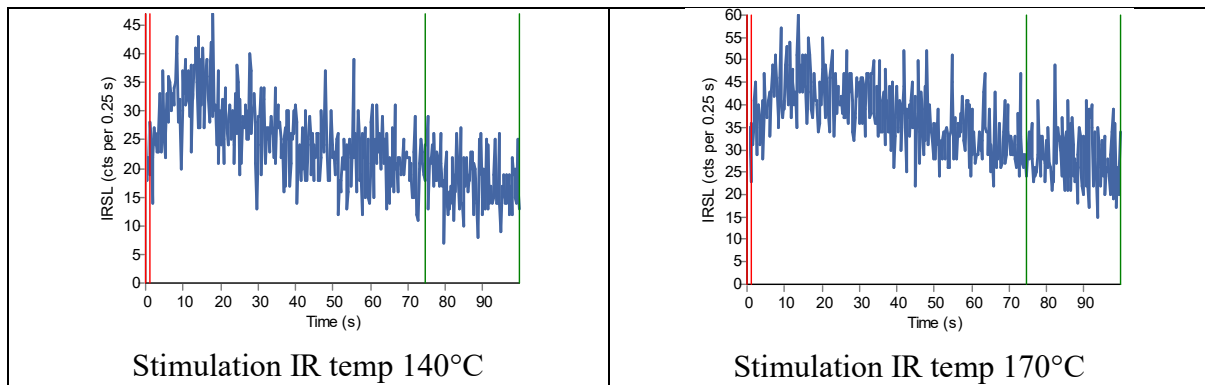
Buylaert et al., 2011, 2012; Murray et al., 2012, 2014; Yi et al., 2016, 2018; Veres et al., 2018; Avram et al., 2020). Several studies reported a slight dependency between the natural and residual dose, the latter increasing with equivalent dose (Sohbati et al., 2012; Buylaert et al., 2012; Murray et al., 2014). Long term laboratory bleaching experiments have been conducted on loess samples from northern (Yi et al., 2016) and south-eastern (Yi et al., 2018) China. They investigated the degree to which the pIRIR₂₉₀ signal was bleachable by exposing several samples in a Honle SOL2 simulator over various periods. For the loess samples from northern China, they have shown that a constant (or highly difficult to bleach) residual pIRIR₂₉₀ signal (corresponding to a dose of 6.2 ± 0.7 Gy) is reached after 300 h, while for the loess samples from south-eastern China a constant residual dose of 4 ± 1 Gy was obtained after 300 h bleaching in solar simulator.

A similar experiment was conducted by our team for a sample collected from a nearby site from South Island, New Zealand (unpublished data). Groups of five polymineral fine grains aliquots were exposed to sunlight (to window – only during daylight) over different periods of time. The residual doses were measured using both pIRIR protocols. In the case of the pIRIR₂₂₅ protocol, a constant residual dose was obtained after 48 h exposure to sunlight while in the case of pIRIR₂₉₀ protocol, the residual dose appeared consistent with the constant dose after a bleaching period of 96 h. Also, we have found that the residual dose decrease to 15% of equivalent dose for pIRIR₂₂₅ after 20 minutes exposure to sunlight. We state that these results are not reported yet. However, this is in our view evidence that pIRIR₂₂₅ signals are bleached.

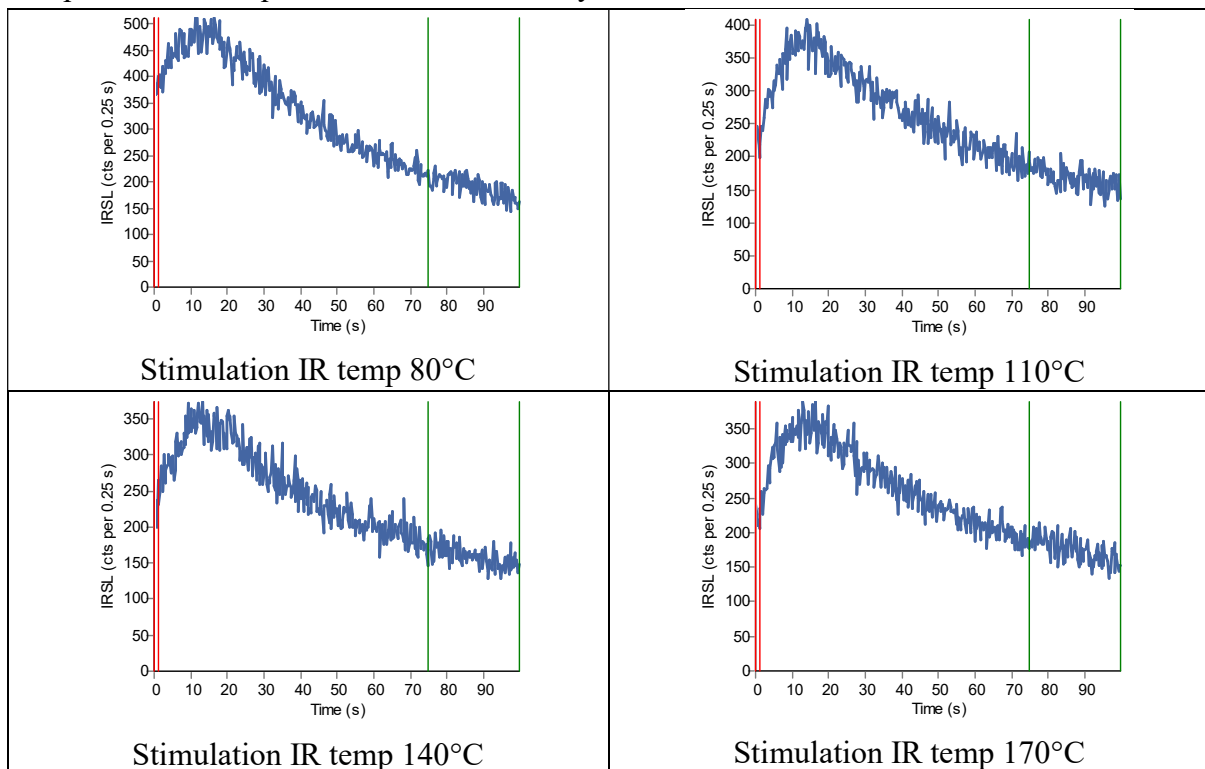
Also, we have tried to measure pIRIR signals using lower temperature on a nearby site from New Zealand, South Island (unpublished data). We have applied the MET protocol (Fu and Li, 2013) on polymineral fine grains extracted from two samples with no success. In the next figures we show the natural pIRIR signals measured using different IR stimulation temperatures (80°C, 110°C, 140°C and 170°C).

Sample 1 with an equivalent dose of ~10 Gy.





Sample 2 with an equivalent dose of ~100 Gy.



Moreover, the corrected IRSL signal does not grow properly with the magnitude of the irradiation dose; therefore, the construction of the dose response curve cannot be achieved.

Given these poor results on samples collected from a nearby site, the authors decided that such measurements will bring no added value for dating the samples investigated in this study.

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