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Luminescence characteristics of quartz and feldspar from tectonically uplifted terraces in Kashmir Basin, Jammu and Kashmir, India

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ABSTRACT

The Kashmir Valley or the Jhelum basin is an intermontane-basin in NW Himalaya bounded by the Pir Panjal Range in the south and southwest and the Great Himalayan Range in the north and northeast. The valley is marked by active major thrust boundaries in its south and southwestern parts. Remote sensing studies and morphometric analysis suggest neo-tectonic activities and the formation of tectonic terraces due to uplift on the major thrust boundaries in NW Himalayas. The quartz from freshly eroded mountain belts is usually found to show very poor luminescence sensitivity and thus not suitable for optical dating. Similar problems occurred with the quartz from the Srinagar Basin. Due to this, feldspar was selected as a natural dose meter for dating tectonically uplifted terraces in an active and dynamic belt of the NW Himalayas. We report here for the first time the luminescence characteristics of quartz and feldspar minerals from the study area. However, feldspar also shows poor luminescence sensitivity, although enough to perform optical dating. Athermal fading was observed in all the feldspar samples, which was corrected using 'g' values; a large scatter was found in the g values, probably due to intermixing of feldspar grains from varying source rock types and also due to poor luminescence sensitivity. An average g value correction to the mean paleodose was found to agree if compared with the thermo-luminescence date of loess deposit dated earlier. The ages show that the terrace formation started taking place at $\sim$100 ka in the southwestern part of the Jhelum basin and continued with pulses at 50 ka and 11 ka towards the northwestern part.

1. Introduction

The optical dating of quartz from deposits in mountainous regions has presented problems due to very low and changing luminescence sensitivity. Recent studies by Preusser et al. (2006) on the luminescence properties of quartz derived from the terraces of the New Zealand Alps show low sensitivity and high recuperation effects and thus were not found suitable for optical dating. The low number of cycles of erosion and burial or young sedimentary history was suggested as the probable reason for such luminescence characteristics. Similarly, Thomas et al. (2007) studied the luminescence characteristics of the quartz from northeast Himalaya, which has shown low sensitivity and posed problems for application of the single aliquot regeneration (SAR) method of luminescence dating. Moska and Murray (2006) studied a weakly sensitized fast component in quartz from the Tatra Mountains in Poland and Jaiswal et al. (2008) have reported finding low sensitivity of quartz eroded freshly from the local host rock in the terrace sediment of Devprayag, NW Himalayas. Therefore, low sensitivity is probably a common problem encountered with sediments that have been freshly eroded from mountain belts. One option to resolve this problem is the optical dating of feldspar where higher sensitivity is expected and also the greater upper bound of the upper age limit compared to quartz. In the present work, we report on the luminescence characteristics of quartz and feldspar from terrace sediment found in the Kashmir basin, Jammu and Kashmir, India, as a part of a project on neo-tectonic activity in the basin.

2. Geology and sampling details of the study area

The Kashmir valley is an intermontane-basin in NW Himalaya bounded by the Pir Panjal Range (PPR) in the south-southwest and the Great Himalayan Range in the east-northeast (please see the supplementary figure for details). The valley is elongated in the NW–SE direction and is currently drained by the River Jhelum, flowing SE–NW following the basin axis in general before entering the famous Wular Lake from where it takes a westerly direction across the PPR through the Uri water gap. The basin was filled by the weakly consolidated Karewas Group of lacustrine sediments

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during 4 Ma to 300 ka or even younger (Burbank and Johnson, 1982). Due to continued uplift of the basin in the western part, fluvial terraces are forming in the western part of the Kashmir basin. Except for its bounding mountain ranges, most of the Kashmir Valley is covered by weakly consolidated Quaternary fluvio-glacial Karewa deposits and younger river alluvium. Such type of lithology, together with its uniform character, is known not to retain surface evidence of faulting for a longer time duration due to fast erosional processes unless tectonic uplift greatly exceeds erosion, and therefore poses a major challenge in the identification of active faults. However, this problem is largely circumvented by analyzing tectonic geomorphological features of fluvial drainage.

Using general topographic maps, the drainage network of the Kashmir Valley was digitized and several morphometric indices were determined. At present, attention was focused on the western sub-basins (from south Veshav, Rambara-Sasara, Romshi, Doodhganga-Shaliganga, Sukhnag, Ferozpur, Ningli, and Pohru in the north) on the PPR side because of its known higher tectonic activity than the Great Himalayan Range. The presence of knick points in the longitudinal profiles of the tributaries indicates the presence of rapid uplift exceeding erosion.

The Plio-Pleistocene Karewa Group is divided into Lower Karewa Formation (Fm) and Upper Karewa Fm, separated by an unconformity (a boulder bed). Because of the rapid uplift of the PPR, the Lower Karewa sediments are tilted and folded. The Upper Karewa is divided into two formations – the basal Nagum Fm and the top Dilpur Fm. Loess soil beds are reported from Upper Karewas. The Bt Loess soil horizon at Karapur represents the last interglacial soil equivalent to stage 5e in the oxygen isotope deep-sea chronology dated to be about $\sim 110 \pm 10$ ka using TL methods on fine grained polymineral sediments (4–11 μm) (Bronger et al., 1987; Singhvi et al., 1987) and ages were in agreement with the paleoclimate records of Loess soil formations. An OSL sample (RM) was collected and is likely from the base of Nagum Fm, just above the unconformity (boulder bed). This sample will help in determining the time span when the terrace formation started. The radiocarbon ages from these areas were significantly underestimated (Kusumgar and Agrawal, 1985).

Another level of terrace is seen $\sim$5–10 m high in the middle reaches of the basin with exposed Karewas sequences as a host rock and the youngest 3–4 m high terraces are exposed near the various tributaries in the western part of the Kashmir basin. Three samples (DN-1, SG-1 and FR-1) for optical dating were collected from these terraces. The terrace sediments were mainly composed of gravels and pebbled with sand matrix. A modern sample (KS) from gravelly river bed was also collected to check the residual level. Detailed field work is due for mapping and tectonic activity in the region of interest. Discussion on the detailed geology and tectonic activity is beyond the scope of this paper. Here we discuss only the luminescence characteristics of quartz and feldspar from the tectonically uplifted terraces. A series of tests were applied to the quartz and feldspar extracted from the tectonically uplifted terrace sediments in the Kashmir Valley.

3. Sample preparation and methodology

All the samples were pretreated with 10% HCl and H_2O_2 to remove carbonates and organic matter and then sieved to separate the 90–150 μm grains. The quartz and feldspar were separated from the sieved fraction using a heavy liquid ($\rho = 2.58$ g/cm^3) solution of sodium polytungstate. The alpha dosed layer vis-à-vis feldspar contamination was removed using 40% HF for 60 min followed by HCl treatment for 45 min. These grains were mounted on stainless steel discs of diameter 10 mm using silicone oil. Quartz samples were checked for any contamination of feldspar using infrared stimulated luminescence (IRSL). Blue light stimulated luminescence (BLSL) using blue LED (wavelength 470 ± 20 nm) and infrared stimulated luminescence (IRSL) was measured using 800 ± 80 nm wavelength LEDs for quartz and feldspar, respectively. All the samples were analyzed in a Risø TL-DA-15 reader having an EMI 9635 QA photomultiplier tube (PMT) attached to the filter pack consisting of U-340 and BG-39 filters transmitting in the UV spectrum for quartz and a filter pack of BG-39+ Corning 7-59 was used for feldspar. β-Irradiation was performed using an ^{90}Sr/^{90}Y source delivering a dose rate of 13.6 Gy min^{-}1. XRF and ICP-MS analyses were performed to determine the U, Th and K concentrations in the sediments and thus dose rates were calculated as suggested by Aitken, 1985.

The SAR protocol was used to determine the paleodoses (Murray and Wintle, 2003), using a 6 point SAR cycle including a zero and a recycling point. A preheat of 240 °C for 10 s was chosen for quartz after a preheat plateau test. For feldspar, after a dose recovery test, a preheat temperature of 220 °C was chosen. The BLSL was measured at 125 °C for 40 s and IRSL was measured at 50 °C for 300 s. Aliquots were chosen having a good recycling ratio (within $\sim$10% of unity) and a low recuperation effect as well. For feldspar, anomalous fading corrections were carried out using the decay rate ‘g’ values (Huntley and Lamothe, 2001; Auclair et al., 2003). The aliquots were stored at room temperature after preheating as suggested by Auclair et al. (2003). The g values were normalized to a t_c of 48 h. The calculations were done using a spreadsheet supplied by Sebastian Huot, Faculté des sciences, Université du Quebec, Montreal, Canada. Since it takes 3–4 days of OSL reader time just to measure the short delay measurement only, it was not possible to measure the g values for all the aliquots and thus a set of 12 aliquots was chosen arbitrarily from the measured aliquots. The average paleodose for all the aliquots from a sample is represented

Table 1
Age table showing radioactive elemental concentration, dose rate, uncorrected paleodoses, ages and average ‘g’ values.

Serial no.	Sample no.	Radioactive element concentration			Dose rate (Gy/ka)	Uncorrected paleodoses (Gy)	Fading corrected age by average g values (ka)	Average g value
		U (ppm)	Th (ppm)	K (%)				
1	RM	2.19 ± 0.01	9.6 ± 0.05	1.68 ± 0.02	3.34 ± 0.2	249.7 ± 6 (D_{ebulk}; $n = 32$) 288.6 ± 17 (D_{e12})	99 ± 7(82 ± 12, Qtz age)	4.4 ± 2.2 (from 9 values) (2.82 ± 0.58, for least 5 values)
2	DN-1	1.66 ± 0.02	7.7 ± 0.05	1.09 ± 0.01	2.59 ± 0.2	83.2 ± 2.9 (D_{ebulk}; $n = 22$) 78.2 ± 3.9 (D_{e12})	47 ± 5	3.8 ± 2 ($n = 11$)
3	SG-1	2.26 ± 0.03	11.5 ± 0.03	1.34 ± 0.01	3.23 ± 0.2	59.4 ± 2.2 (D_{ebulk}; $n = 29$) 58.7 ± 3.9 (D_{e12})	50 ± 3	8.3 ± 1 ($n = 9$)
4	FR-1	2.27 ± 0.03	11.9 ± 0.04	1.97 ± 0.02	3.76 ± 0.4	24 ± 1.2 (D_{ebulk}; $n = 32$) 31.3 ± 3.5 (D_{e12})	11 ± 5	6.2 ± 2.5 ($n = 10$)
5	KS (modern)	–	–	–	–	18.6 ± 1.3 (D_{e12})	–	–

The average paleodose (D_{e12}) was calculated from a subset of 12 aliquots chosen arbitrarily for fading correction from the set of large number of aliquots as indicated by n in the column. The total average paleodose has been indicated by D_{ebulk}.

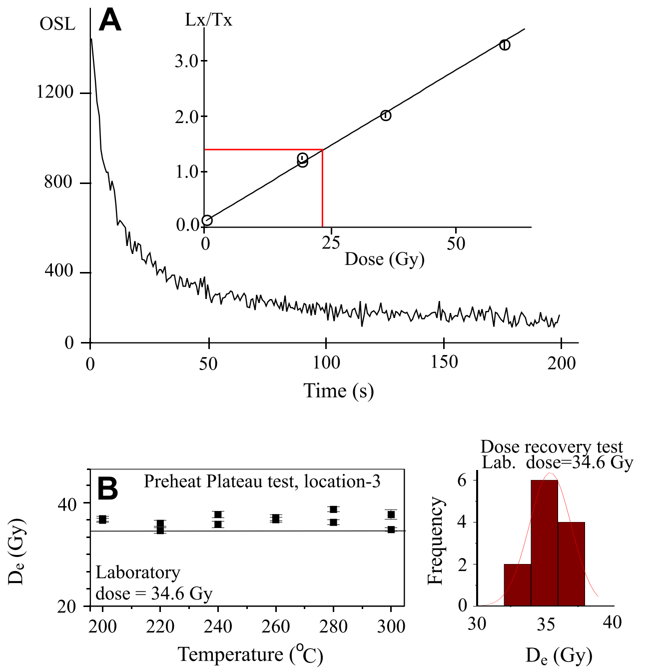

Fig. 1. (A) The shine down and growth curve of IRSL on the sample SG-1. The preheat plateau and dose recovery tests have suggested the successful application of SAR on feldspar.

by D_{ebulk} and the average values of D_e of a subset of 12 aliquots chosen for fading correction is denoted as D_{e12} (Table 1).

4. Results and discussion

The quartz samples showed very low BLSL sensitivity. The photon counts were as low as 500 net photon counts (2 s integral) in response to a dose of 200 Gy. A growth curve, constructed on a laboratory bleached quartz aliquot saturate at $\sim$400 Gy. Sample RM was found to be very old (>100 ka; Table 1) and thus BGSL on quartz was measured. Only 6 out of 17 aliquots passed the recycling ratio test and were chosen for calculating the average paleodose (221.7 $\pm$ 21 Gy), which produced an age of 82 $\pm$ 12 ka. Similar to quartz, feldspar also showed weak emission (Fig. 1A), although it was sufficient to perform all the tests and measure the paleodose. The photon counts varied from 2000 to 4000 (for 4 s integral) (7 mm aliquots dosed for $\sim$35 Gy) for sample FR-1, 8000–12,000 counts for DN-1 and 20,000–30,000 counts for SG-1 in similar conditions. For RM, the photon counts varied from 4000 to 8000 for a 7-mm aliquot dosed for $\sim$24 Gy.

4.1. Preheat-plateau test

For the preheat plateau, all the aliquots prepared from sample SG-1 were laboratory bleached to a residual level. A laboratory dose of 34.6 Gy was given to each aliquot. The given doses were recovered using the SAR procedure at various preheat temperatures starting from 200 °C to 300 °C, but the cut heat for all the aliquots was kept constant at 200 °C. Two aliquots were analyzed for each preheat temperature. A close inspection suggests selecting 220 °C to be the best (Fig. 1B) for preheat. The closing bars on the data points represent the error on each recovered paleodose. At 220 °C, the recovered doses were 34.6 $\pm$ 0.6 and 36.0 $\pm$ 0.5 Gy. In view of this, a preheat of 220 °C was chosen for all the samples.

4.2. Dose recovery test

Twelve bleached aliquots were given a laboratory dose of 34.6 Gy and the SAR procedure was applied using a preheat temperature of 220 °C. All the aliquots passed the criteria of a good recycling ratio and a very low recuperation effect (<5% of natural). The recovered doses show a Gaussian distribution of paleodose values with an average paleodose of 35.1 $\pm$ 0.4 Gy (Fig. 1B). The error calculated is the standard error. Hence, the dose recovery test

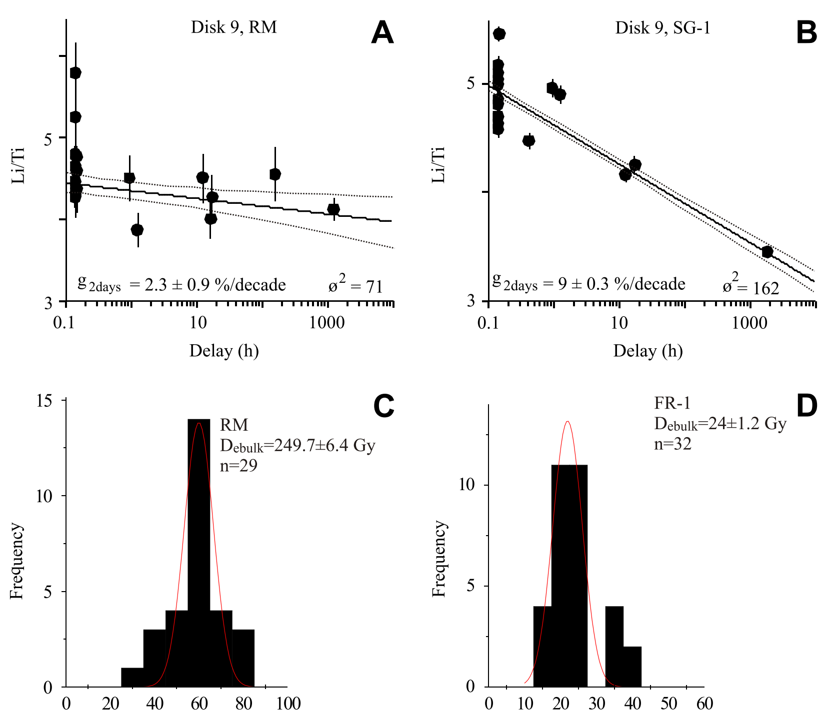

Fig. 2. The g values from RM and SG-1 (A,B). The D_e histogram from bulk measurement including 12 aliquots tested for a-thermal fading (C,D).

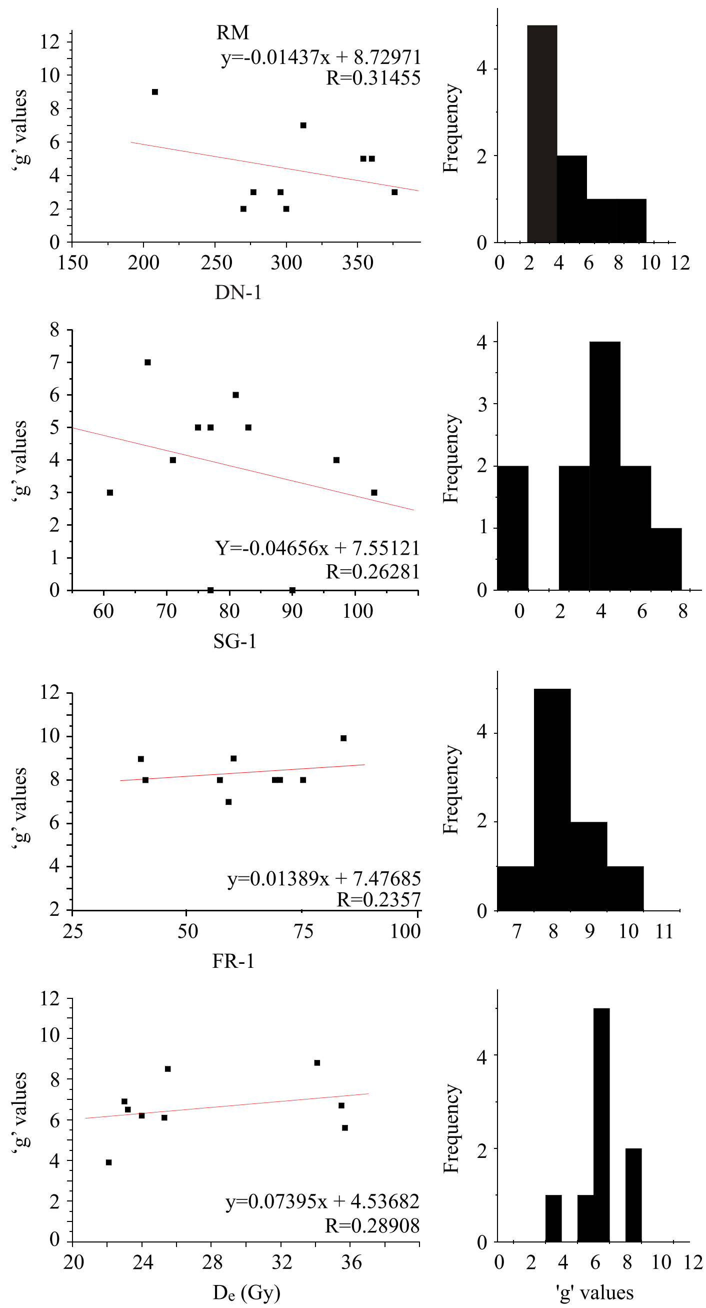

Fig. 3. The plot of g values against their corresponding values of D_e. A poor fitting of the regression line was observed in all the samples probably due to intermixing of feldspar grains of various rock types and also due to the variability in the bleaching of the sediments. The samples from SG-1 show a good cluster of g values probably due to a common source rock but due to large variability in paleodoses, poor fitting is observed. On the left side, histograms of g values are shown for their corresponding samples. The g values >10 are not shown here and also have been discarded from the age computation.

suggests that the currently applied SAR method is applicable to our sediments.

4.3. Athermal fading test and correction

For each sample, 12 aliquots of feldspar grains were prepared. The repetitive IRSL measurements were taken at varying time intervals for the laboratory dose (173.1 Gy) followed by the test dose (23.1 Gy) measurements. IRSL was measured at 50 °C temperature after a preheat of 220 °C for 10 s. Each aliquot was dosed for 173.1 Gy and stored up to ~1000 h after preheat of 220 °C for long delay IRSL measurements. The g values showed a large inter-aliquot scatter within a sample and also inter sample variation. It is not clear why we get such a large variation in the g values but the most probable reason seems to be the intermixing of sediments from two different sources of rock and weak luminescence which is not expected in feldspar samples. Also, there was a significant loss of grains during transportation and storage, which may not be a problem due to the measurement of sensitivity corrected luminescence (Lx/Tx).

4.4. IRSL analysis of sample RM

The sample RM showed a large scatter in the g values ranging from 2.3 to 14.0. The mean value of D_e is 288.7 ± 17 Gy. Since the higher g values (>10) cannot be taken into account for age calculations, the results for 3 aliquots were discarded. The average age from the remaining 9 aliquots after individual fading corrections, is 155 ± 15 ka, which is significantly larger than the quartz age (82 ± 12 ka). An example of the g value data is shown in Fig. 2. Even though the slope is negative, large scatter and a very poor regression line are observed (Fig. 3) between g and the corresponding D_e, suggesting that g is independent of the D_e values. The scatter in D_e values might be due to an effect of micro-dosimetry and poor bleaching as the sediments are from boulder facies. The feldspar grains from a modern analogue (sample KS) provided a mean residual dose of 18.6 ± 1.3 Gy (ranges from 14 to 27 Gy) averaged over 12 aliquots using SAR.

Anomalous fading is an intrinsic property of feldspar crystals. The combined effect of heterogeneous bleaching and micro-dosimetry may be the probable reason for not getting a linear relationship between g and D_e. The average g value calculated from 9 aliquots (excluding higher values >10; Fig. 3) is 4.44 ± 2.22 (1σ) and gave an average age of 138 ka, still significantly larger than the quartz age. We measured paleodoses from 32 aliquots (including 12 aliquots for fading) that gave the average D_{ebulk} of 249 ± 6 Gy (Fig. 2), lower than the 12 aliquots ($D_{e12} = 288 \pm 17$ Gy) measured separately for fading corrections only. This shows that sometimes measuring only a small number of paleodose samples may not represent the subset of the data population. Hence, it is suggested to measure a large number of paleodoses to get close to an accurate D_e. From Fig. 3, it is clear that a large population of g values is clustered at the lower end (least 5 values give an average of 2.8 ± 0.54). When applying this correction to the bulk of the D_e measured from 32 aliquots ($D_{ebulk} = 249 \pm 6$ Gy), it yields an age of 99 ± 7 ka, still overestimated but considering error limits, in agreement with quartz age. If we consider the effect of bleaching (18.6 Gy residual dose from a modern analogue KS sample), the age of the feldspar can be reduced further and makes better agreement. The ages agree with the Loess soil TL ages (Singhvi et al., 1987) within the error limit.

4.5. IRSL analysis of sample DN-1

Sample DN-1 gave an average paleodose (D_{e12}) of 78.2 ± 3.9 Gy from 12 aliquots measured for fading corrections. The g values ranged from 0 to 12 (Fig. 3, highest value of 12 excluded); however, if we exclude the highest value of 12, the remaining values show a good cluster around the average 3.8 ± 2. As in the case of the sample RM, we lack any good relationship between the g values and the values of D_e even though there is a negative slope of the regression line but the fitting is very poor. The average age from 12 aliquots after fading correction on individual aliquots is 47 ± 11 ka. The paleodose ($D_{ebulk} = 83.2 \pm 3$ Gy) was also measured for 22 aliquots including 12 aliquots measured for fading, which seems to be in good agreement with D_{e12}. The average age from D_{ebulk} after applying fading correction from the average g value is 47 ± 5 ka, similar to the average age from 12 individually corrected aliquots. There is no quartz age for this sample due to poor signal to noise ratio and no independent age control is available.

4.6. IRSL analysis of sample SG-1

Twelve aliquots from sample SG-1 gave a paleodose (D_{e12}) of 58.7 ± 3.9 Gy. The g values (Fig. 2) ranged from 7.1 to 18.2, however, if we exclude the high g values (>10), the values show a good cluster (8.33 ± 1; Fig. 3). The relationship between the g values and D_e shows that the scatter in D_e is significant but the g values are better distributed, indicating that that the sample was poorly bleached but most of the grains have a common source. The average age from these aliquots after individual fading corrections is 53 ± 6 ka. The average paleodose from 29 aliquots (including D_{e12}) is 59.4 ± 2.2 (D_{ebulk}), which is in good agreement with D_{e12}. Considering the average g values for D_{ebulk}, the age is 50 ± 5 ka, but there is no independent age control available for this sample.

4.7. Sample FR-1

Similarly for sample FR-1, the average paleodose (D_{e12}) from 11 aliquots (one aliquot was discarded due to high recycling ratio) is 31.3 ± 3.5 Gy. The g values ranged from 3.9 to 12.9; however, the average is 5.9 ± 2.5 if two high values (>10) are excluded. The average age obtained from 9 individual fading corrected aliquots is 15 ± 2 ka. The average D_{ebulk} from 32 aliquots is 24 ± 1.2 Gy (Fig. 2), which underestimates the average D_{e12} by ~ 7.3 Gy and indicates that in poorly bleached samples, a subset of 12 aliquots may not represent truly the populations of the paleodoses. Considering that, the average g value correction was applied on the bulk of paleodoses and the age yielded was 11 ± 5 ka.

5. Conclusion

For the samples from the NW part of Himalayas discussed in this paper, the following conclusions can be drawn. A set of three terraces were observed to have formed around ~ 100 ka, 50 ka and 11 ka resulting from the tectonic activity of the Jhelum basin along its western side. The feldspar minerals in the samples tested suffer from poor bleaching, as shown by modern analogues, with a residual dose level ranging from 14 to 27 Gy. The luminescence was found to be very weak for quartz and thus not suitable for dating a sediment of less than ~ 80 ka. Similar problems have been reported by other workers for deposits of freshly eroded mountainous areas. Similarly, feldspar was also found to be of low sensitivity but nonetheless sufficient to perform optical dating.

The relationship between values of the fading parameter g and their corresponding value of D_e can provide a good visual test for poorly bleached grains and variability of source rock type. A large scatter was observed, probably resulting from the intermixing of feldspar grains from various sources with varying fading rates. Also poor bleaching of the grains adds to the variation in D_e. Further work on well-bleached samples from different rock types and poorly bleached samples from the same rock type is needed. Although tests with sample SG-1 indicated a common source of feldspar grains, there was a poor correlation of g and D_e due to poor bleaching of the samples.

Where a large scatter in g values is obtained it is suggested that the correction is applied using the most probable g value as shown for sample RM, which is in agreement with the quartz age, calculated assuming that quartz is free from anomalous fading.

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Appendix A. Supplemental material

Supplementary information for this manuscript can be downloaded at doi: 10.1016/j.radmeas.2009.04.008

References

Aitken, M.J., 1985. Thermoluminescence Dating. Academic Press, London.
Auclair, M., Lamothe, M., Huot, S., 2003. Measurement of anomalous fading for feldspar IRSL using SAR. Radiation Measurement 37, 487–492.
Bronger, A., Pant, R.K., Singhvi, A.K., 1987. Pleistocene climatic changes and landscape evolution in the Kashmir basin, India: paleopedological and chronostratigraphic studies. Quaternary Research 27, 167–181.

Burbank, D.W., Johnson, G.D., 1982. Intermontane-basin development in the past 4 Myr in the north-west Himalaya. Nature 298, 432–436.
Huntley, D.J., Lamothe, M., 2001. Ubiquity of anomalous fading in K-feldspar and the measurement and correction for it in optical dating. Canadian Journal of Earth Sciences 38, 1093–1106.
Jaiswal, M.K., Srivastava, P., Tripathi, J.K., Islam, R., 2008. Feasibility of the SAR technique on quartz sand of terraces of NW Himalaya: a case study from Devprayag. Geochronometria 31, 45–52.
Kusumgar, S., Agrawal, D.P., 1985. Chronology of the Kashmir Loess, in: Current Trends in Geology. Today and Tomorrow Printers and Publishers, New Delhi. 119–121.
Murray, A.S., Wintle, A.G., 2003. The single aliquot regenerative dose protocol: potential for improvements in reliability. Radiation Measurement 37, 377–381.
Moska, P., Murray, A.S., 2006. Stability of the quartz fast-component in insensitive samples. Radiation Measurements 41, 878–885.
Preusser, F., Ramseyer, K., Schculhter, C., 2006. Characterization of low OSL intensity quartz from the New Zealand Alps. Radiation Measurements 41, 871–877.
Singhvi, A.K., Bronger, A., Pant, R.K., Sauer, W., 1987. Thermoluminescence dating and its implications on the chronostratigraphy of Loess-Palaeosol sequences in Kashmir Valley, India. Chemical Geology (Isotope Geoscience) 65, 45–56.
Thomas, P.J., Reddy, V.D., Kumar, D., Nagabhushnam, P., Sukhija, B.S., Sahoo, R.N., 2007. Optical dating of liquefaction features to constrain prehistoric earthquakes in upper Assam, NE-India – some preliminary results. Quaternary Geochronology 2, 278–283.