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Erik T. Brown, *et al.*

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Comment on "Slip-Rate Measurements on the Karakorum Fault May Imply Secular Variations in Fault Motion"

Chevalier *et al.* (*1*) presented cosmic-ray exposure dates for glacial deposits offset by movement along the Karakorum Fault. They inferred a late Quaternary slip rate on this fault, 10.7 ± 0.7 mm/year, that is higher than rates reported in recent field studies (*2*). The reported rate is also greater than present-day rates based on interferometric synthetic aperture radar (InSAR) analyses (*3*) and Global Positioning System (GPS) measurements (*4*), a finding that led Chevalier *et al.* to conclude that slip on the fault varies over time scales longer than the recurrence interval between earthquakes. Clasts within the two studied moraine systems had cosmic ray exposure ages ranging from 21 to 45 thousand years (ky) (n = 9, mean = 35.6 ky, 1σ = 8.7 ky) and from 103 to 325 ky (n = 18, mean = 177 ky, 1σ = 63 ky). The two moraines were assigned ages of 21 ± 1 ky and 140 ± 5.5 ky, respectively. We question the approach of Chevalier *et al.*, however, for selecting the most accurate date for moraine deposition from a scattered group of ages for individual clasts incorporated in a moraine.

Any postdepositional process that affects the exposure history of individual clasts (for example, burial, erosion, spalling, and shifting position) will reduce cosmogenic nuclide accumulation and apparent exposure ages and increase scatter in the data (*5*, *6*). Moraine boulders thus often show tightly grouped exposure ages in young surfaces (*7*) and wider scatter in stratigraphically older formations. Nevertheless, in certain cases, scatter in exposure ages for a given landform results primarily from variable exposure before deposition in current positions; this has been noted in small alluvial and debris-flow fans (*2*, *8*). In such systems, exposure ages of some clasts will greatly exceed the time of landform deposition. Chevalier *et al.* (*1*) adopted this view in evaluating their data set. In contrast, if material deposited on a landform has been exhumed from depths great enough to minimize previous exposure to cosmic radiation, any scatter will be the result of postdepositional processes. Under these conditions, exposure ages underestimate the age of the feature with which they are associated; the clast with the highest cosmogenic nuclide concentration will most closely reflect the actual landform age.

The data of Chevalier *et al.* provide some basis for evaluation of which of these views more closely represents the processes leading to the observed age distributions. If scatter in apparent ages were due to previous exposure, moraines of similar size and morphology deposited by the same glacier (for which there would be no reason to expect fundamentally different glacial regimes) should show comparable absolute ranges of scatter in their ages. Ages for the younger moraine show far less scatter (1σ = 8.7 ky) than those for the older moraine (1σ = 63 ky), which suggests that variation in prior exposure is an unlikely explanation for the dispersion of dates observed for the older moraine. Furthermore, incision and modification of the older surface [see figure S2 in (*1*)] indicate the influence of surface disturbances that diminish apparent exposure ages.

The ages that Chevalier *et al.* propose for deposition of the two moraines correlate with the coldest episodes of the SPECMAP climate curve (*9*). However, this chronology is inconsistent with other regional studies that indicate that little glacial expansion occurred during the last glacial maximum (LGM) and that the greatest glacial expansion within the last glacial cycle was considerably earlier, at ~40 thousand years ago (ka) (*10*–*12*). This growing body of literature suggests that alpine glacial expansion often depends on regional processes, such as moisture transport, and thus does not necessarily coincide with growth of Northern Hemisphere continental ice sheets.

For the younger moraine, Chevalier *et al.* proposed that the age indicated by the majority of the samples (~40 ka, based on seven of nine samples) represents an earlier advance but that the subsequent glacial event (~21 ka, based on two of nine samples) is correlative with the actual termination of moraine deposition. This scenario is not consistent with the proposed slip rate. If the moraine had been deposited over the 20-ky period between 40 ka and 20 ka while the fault was moving at a rate of 10 mm/year, the material should have been spread across a 200-m lateral span, with the youngest material closest to the valley. This is not the case; there is no systematic spatial pattern of "young" and "old" clasts [see figures 2B and 3B in (*1*)].

Evaluating the data under the assumption of minimal previous exposure yields minimum ages of ~325 and ~45 ky and maximum slip rates of ~4.7 and ~4.9 mm/year for the older and younger surfaces, respectively. Such rates would corroborate the results of previous work that directly dated offset geomorphic markers along the Karakorum fault (*2*). In addition, they would be consistent with recent InSAR (*3*) and GPS (*4*) analyses and thus would not require hypotheses of large fluctuations in fault motion over time.

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References

1. M. L. Chevalier *et al.*, *Science* **307**, 411 (2005).
2. E. T. Brown *et al.*, *J. Geophys. Res.* **107**, doi: 10.1029/2000JB000100 (2002).
3. T. J. Wright, B. Parsons, P. C. England, E. J. Fielding, *Science* **305**, 236 (2004).
4. S. Jade *et al.*, *Geol. Soc. Am. Bull.* **116**, 1385 (2004).
5. J. Putkonen, T. Swanson, *Quat. Res.* **59**, 255 (2003).
6. B. Hallet, J. K. Putkonen, *Science* **265**, 937 (1994).
7. J. C. Gosse, J. Klein, E. B. Evenson, B. Lawn, R. Middleton, *Science* **268**, 1329 (1995).
8. J. Van der Woerd *et al.*, *Geology* **26**, 695 (1998).
9. J. Imbrie *et al.*, in *Milankovitch and Climate, Part I*, A. Berger, J. Imbrie, J. Hays, G. Kukla, B. Saltzman, Eds. (Reidel, Boston, 1984), pp. 269–305.
10. L. A. Owen *et al.*, *Geol. Soc. Am. Bull.* **115**, 1356 (2003).
11. R. C. Finkel, L. A. Owen, P. L. Barnard, M. W. Caffee, *Geology* **31**, 561 (2003).
12. D. I. Benn, L. A. Owen, *J. Geol. Soc.* **155**, 353 (1998).

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