Supplementary Table

(wt%)	MOR basalt	S.Carlos olivine
SiO_2	51.78	40.99
TiO_2	2.52	0.00
Cr_2O_3	0.01	0.00
Al_2O_3	14.88	0.00
FeO^{tot}	5.19	8.96
MnO	0.04	0.23
MgO	11.44	49.81
CaO	11.31	0.00
Na_2O	1.92	0.00
K_2O	0.53	0.00
Total	99.61	100.00
Mg#	0.80	0.91

The Porosity exponent *n*

In principle, our observations can be used to infer the porosity exponent in equation 3 from the linear regression model

$$Y = n\ln\phi - \ln C \qquad \text{A1}$$

relating two observable quantities Y $(\ln k - 2\ln d)$ and ϕ to the parameters n and C. Because we have only 3 observations, over a range of porosities of only 5-12%, the variation in our data cannot be used to reliably infer the porosity exponent. Indeed, even discounting measurement error, a regression of our data to equation A1 yields n = 0.6±14.5, where the uncertainty is a 95% confidence interval. This fit is statistically insignificant, but yields a porosity exponent near unity, a result that is theoretically untenable. For this reason, we assume a cubic porosity dependence in equation 3 as justified by theoretical and empirical studies cited in the main text.

Permeability from the Renner et al. (2003) Experiments

Ref(1) reports an experimental study of compaction driven melt flow through an olivine matrix in an apparatus that permits independent control of melt pressure at the drained end of the experimental samples. In these experiments they observe uniform compaction with low viscosity Li-silicate (μ=2 Pa·s) and basaltic (μ=40-130 Pa·s) melts, but variable compaction with viscous albitic melt ($\mu=10^4$ Pa·s). In this latter experiment, the final porosity increases from the drained end of the 1cm long sample to its initial value at the opposite end. Although the compaction rates for the Li-silicate and basaltic melt experiments are similar, *ref*(1) interprets the former as being rheologically limited, while the latter is presumed to be hydraulically limited. To estimate the matrix permeability for the basaltic melt experiment Renner et al. assume a finite and constant

effective pressure gradient; however this assumption is physically untenable because variable effective pressure cannot result in a uniform compaction regime. For the experimental configuration, the only physically consistent model for uniform compaction is compaction at constant effective stress and therefore zero effective stress gradient. This implies that the compaction was either controlled by the rate of melt drainage beyond the sample boundary, i.e., zero effective stress within the sample, or that compaction was rheologically limited. In either case, the observed strain rates cannot be related to the sample permeability because the hydraulic gradient is unconstrained. Here we suggest that it is more probable that the transition from rheologically to hydraulically limited compaction in these experiments[1] occurs at melt viscosity intermediate between those of the basaltic and albitic melt. Thus, the experiment (C-424) with albitic melt offers the only constraint on the permeability of the olivine matrix. Modifying equation 6 of *ref*(1) to account for the fact that the rate of shortening for small compaction strains is one third the compaction rate, and making use of equation 3, the permeability constant *C* is related to the compaction rate[1] by

$$\frac{1}{1-\phi}\frac{\mathrm{d}\phi}{\mathrm{d}t} \approx 3\frac{d^2\phi_0^{\,3}}{C}\frac{p_0}{\mu l^2} \qquad \text{A2}$$

where l is the sample length (~0.01 m), melt viscosity μ is 10^4 Pa·s, grain size d is $12\cdot10^{-6}$ m, p_0 and ϕ_0 are the effective pressure ($50\cdot10^6$ Pa) and porosity (~0.175, Figure 8[(1)]) at the drained end of the sample, and the compaction rate is $1.3\cdot10^{-6}$ s^{-1}. From the discrepancies in strain as measured by different methods, the compaction rate is uncertain by roughly a factor of two, in which case the values of *C* inferred from equation A1 range from 4.3 to 17.5. In equation A1, the hydraulic gradient p_0/l is a lower bound because the undrained end of sample C-424 is not compacted, thus the analysis places a lower bound on *C*. In contrast, for our configuration, the magnitude of the hydraulic gradient $\Delta\rho$ is an upper bound and our estimates provide an upper bound on *C*.

Supplementary references

1. Renner, J. Viskupic, K., Hirth, G. & Evans, B. Melt extraction from partially molten peridotites. *Geochem. Geophys. Geosyst*. **4**, doi: 10.1029/2002GC000369 (2003).