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Corrigendum

Corrigendum to 'Lower crustal flow and the role of shear in basin subsidence: An example from the Dead Sea Basin'[Earth Planet. Sci. Lett. 199 (2002) 67–79][☆]

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We regret that errors in the numerical evaluation of equations (11) and (12) resulted in an incorrect estimation of the effective viscosity of the lower crust under the Dead Sea Basin.

For the range of the observed heat flow in the region (45–53 mW/m^3), the temperature range is between 280 and 343°C at a depth of 20 km, and between 387 and 483°C at a depth of 30 km. The values depend on the radiogenic heat production and its distribution within the crust. With another commonly used value for the surface value of radiogenic heat production $A_0 = 1.2$ mW/m^3, and the logarithmic decrement of heat production with depth $H = 10$ km (e.g. [1]), the temperature at a depth of 30 km under the Dead Sea Basin can reach as high as 538°C.

The estimated viscosities given in the paper are low by six orders of magnitude. Hence, even with the higher temperatures calculated above, the estimated viscosity is higher than that required for a channel flow regardless of whether the strain rate is calculated from north–south extension of the Dead Sea Basin or from shear strain rate along the Dead Sea transform plate boundary. This is not surprising given the fact that the Maryland diabase in Table 2 has the strongest rheology among lower crustal rheologies quoted in the literature [2].

By choosing a more felsic composition for the lower crust under the Dead Sea Basin, the estimated viscosity range for the lower crust for the shear strain rate case overlaps with the range of channel flow viscosities. Specifically, using Adirondack granulite with activation energy $Q = 243$ kJ/mol and the constants $n = 3.1$ and $A = 8 \times 10^{-3}$ MPa^{-n} s^{-1} [3], a temperature of 538°C and a strain rate of 1.1×10^{-14} s^{-1}, the effective viscosity, 8×10^{20} Pa s, falls within the range of channel flow viscosities (7×10^{19}–1×10^{21} Pa s). The estimated viscosity is, on the other hand, too high for strain rates due to basin extension alone (2.1×10^{-15}–7.2×10^{-16} s^{-1}).

Lower crustal channel flow can be further enhanced in areas of strong shear deformation like the Dead Sea transform, due to weakening resulting from the alignment (clustering) of the weak phase (quartz, mica, or amphibole). Handy et al. [4] have argued that if more than 10% of the rock volume consists of the weak phase, and the weak phase is aligned and connected, viscosity of the mix may be controlled by the viscosity of the weak phase. Such alignment may be produced by the high shear strain in the lower crust along the transform.

Diffusion rates which control creep rates of

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rock are also enhanced by the presence of defects in the quartz structure, whose concentration increases with increasing water fugacity ([5] and references therein). Using a flow law for quartzite of the form:

$$\dot{\varepsilon} = A f_{H_2O}^{m} (\sigma_1 - \sigma_3)^n e^{-Q/RT} \quad (1)$$

Hirth et al. [5] determined the following values: activation energy $Q = 135$ kJ/mol, and constants $A = 10^{-11.2}$ MPa^{-n} s^{-1} $f_{H_2O}^{-m}$ s^{-1}, $m = 1$ and $n = 4$. The fugacity is $f_{H_2O} = P_{H_2O}\gamma$. P_{H_2O}, the partial water pressure, is assumed to be equal to the lithostatic pressure, and the fugacity coefficient, γ, changes with pressure and temperature [6]. For shear strain rate due to transform plate motion, and for temperatures between 300 and 500°C at depths of 20 and 30 km, we estimate the range of lower crustal viscosity to be 3.3×10^{20}–4×10^{21} Pa s. This viscosity range overlaps the range of channel flow viscosities. In contrast, for strain rates due to basin extension and for similar temperature and depth ranges, the estimated viscosity range, 1.1×10^{21}–3×10^{22} Pa s, is too high for channel flow.

In summary, although we cannot unequivocally show that lower crustal viscosity is within the range of viscosities required for lower crustal channel flow, some felsic rheologies, particularly if aligned and connected in a shear zone, may have sufficiently low viscosity in this temperature and depth range to warrant ductile flow in the lower crust. This conclusion holds for the higher strain rate due to lateral shear along the Dead Sea transform plate boundary. The shear strain rate may be even higher if the zone of deformation is narrower than the 15 km assumed in these calculations. On the other hand, the viscosity calculated using the lower strain rates due to north–south extension of the Dead Sea pull-apart basin is too high for a channel flow. We therefore believe that the observations of 5–6 km of subsidence without attendant faulting, of southward expansion of the basin with time, and of symmetric subsidence in cross section, are best explained by lower crustal thinning due to lower crustal flow associated with lateral shear along the Dead Sea plate boundary.

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