

SUPPLEMENTARY FILE

KINEMATIC MODEL OF THE ALPINE FAULT MYLONITE ZONE

The mylonite zone was represented by a rectangle 1000m wide and 150 km long. It was divided into cells each 50m x 5 km in size. Each cell was allocated an initial depth to the peristerite isograd. This value was determined by projecting the sequence of metamorphic zones currently exposed along the main divide onto the fault, and then using thicknesses of the various zones measured in sections along the Southern Alps to estimate the initial depth of the peristerite isograd. This method assumes that the isograds were regionally relatively flat-lying prior to mylonitisation, and that exhumation since commencement of rapid uplift at c. 6 Ma has largely been concentrated west of the main divide. The initial surface distribution of isograds produced (Fig 4A) is consistent with the metamorphic pattern further east where the schists are overlain by Tertiary sediments, and with the pattern of metamorphic zones exposed in the Marlborough Schists, now offset by c. 450 km northwest of the Alpine Fault and which have not therefore been uplifted in the hangingwall of the fault.

Norris and Cooper (2003) used deformed pegmatite veins to estimate total strain in the mylonite zone. They calculated average shear strains for the protomylonites, mylonites and ultramylonites and fitted an exponential curve to the data by assuming an exponential distribution of shear strain. Using their strain estimates, the shear strain at a distance x_1 m from the fault may be represented as:

$$\gamma = 2\exp\{(1000-x_1)/200\} \quad 1$$

By integrating across the mylonite zone to x_i , the displacement of point x parallel to the y -axis

is given by: $\Delta y = 0.4[\exp\{(1000-x_1)/200\}-1] \text{ km} \quad 2$

Because the major component of displacement is horizontal, assuming that all the shear strain may be expressed as horizontal shear only introduces a very small error, which may be ignored considering the large uncertainties of the actual strain estimates themselves.

Calculation of the vertical displacement of a point is more difficult, however. As the mylonites are exhumed, displacement changes from distributed ductile shear across the zone to localized brittle shear on the present fault trace. The horizontal component of this brittle shear will not affect the distribution of rock units within the mylonite zone but the vertical component will result in uplift of the whole zone and thus will affect depth of exhumation. The rates of hangingwall uplift have been estimated for the late Quaternary (Norris and Cooper 2001) for points along the fault. They vary from zero at the southern end of the fault around the Jackson River to 8 mm/yr or more in the vicinity of the Franz Josef. Here, we assume a linear gradient in uplift rate over the 150 km length of our model of

$$a = 0.053 \text{ mm km}^{-1}\text{y}^{-1} \quad 3$$

If we assume that this rate of displacement has been constant over the c. 5 my of convergence, then the total vertical displacement of a point at distance y along the fault will be

$$\Delta z = yat \text{ km, where } t \text{ is time in my} \quad 4$$

If we consider a point with initial position $x_1y_1z_1$, the effects of shear will be to change the y and z values to y_2 and z_2 respectively. The vertical displacement of the point given by eqn 4 will depend therefore on both y_1 and y_2 , so that

$$\Delta z = [(y_1 + y_2)/2]at = [(2y_2 - \Delta y)/2]at \text{ km} \quad 5$$

We assume that two-thirds of the total uplift is accommodated by ductile shearing across the mylonite zone, and that the distribution of this is proportional to the distribution of total shear strain given by eqn 1. The remaining one third (representing the top 10 km or so of the crust) is localized as brittle shear on the present fault trace and so affects the whole zone equally. Combining all equations, the resulting height z_2 of a point $x_1y_1z_1$ will be

$$z_2 = z_1 + 0.67[(2y_2 - \Delta y)/2]at(1.5 - \Delta y/\Delta y_{\max}) \text{ km} \quad 6$$

Where $\Delta y_{\max} = 0.4[\exp\{5\} - 1] = \sim 60 \text{ km}$.

For $\Delta y_{\max} = 60 \text{ km}$, $at = 0.27$,

$$z_2 = z_1 + 0.18[(2y_2 - \Delta y)/2] (1.5 - \Delta y/60) \text{ km} \quad 7$$

z_1 was taken as the initial height of the peristerite isograd for a cell. The value of Δy and y_1 and from that the value of z_1 was calculated for each cell in the final array, and then the value of z_2 , the final height of the peristerite isograd calculated. The z_2 values of zero were used to indicate the present outcrop at the surface of the peristerite isograd.

References

- Norris, R.J. and Cooper, A.F., 2001, Late Quaternary slip rates and slip partitioning on the Alpine Fault, New Zealand: *Journal of Structural Geology*, v. 23, p. 507-520.
- Norris, R.J. and Cooper, A.F., 2003, Very high strains recorded in mylonites along the Alpine Fault, New Zealand: implications for the deep structure of plate boundary faults: *Journal of Structural Geology*, v. 25, p. 2141-2157.