Extensional offset along the Brenner Fault and orogen-parallel extension in the Eastern Alps: a reassessment

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The relative amounts of thickening vs orogen-parallel extension are a matter of debate in most Tertiary orogens of the Alpino-Himalayan system. The quantification of these two processes is a key to understand material transfer during continental collision, hence the related processes of exhumation. In the Eastern Alps, the major structure accommodating orogen-parallel extension is the Brenner Fault, which forms the western boundary of the Tauern Window. The inferred amount of extension along this Fault varies between a minimum of 10-20 km (Selverstone, 1988) to a maximum of 70 km (Fügenschuh et al., 1997). All investigations that attempted to constrain this amount of extension, calculated the fault-plane parallel displacement, required to restore the difference of structural level between foot-wall and hanging wall, as constrained by geo-barometry. These calculations neglected the component of exhumation of the footwall resulting from folding and erosion. Therefore, the total amount of extensional displacement was systematically overestimated.
In the present study we calculate the vertical offset along the Brenner fault, by projecting along a N-S cross section a tectonic surface, inferred to occupy the same structural level in the hanging wall and in the foot wall of the Brenner Fault. This tectonic surface is the base of the Patscherkofel unit in the footwall and the base of the Ötztal basement in the hanging wall. The difference in height between these two levels projected in one and the same cross section is a quantative measure of the vertical component of offset between footwall and hangingwall. The advantage of this approach is that it allows one to quantify the vertical offset all along the Brenner Fault, hence estimating the along-strike change of offset. This construction leads to the following results:
1. The vertical offset of the chosen marker horizon on both sides of the Brenner Fault varies strongly and continuously along the strike of the Brenner Fault.
2. The maximum vertical offset attains a maximum of 15 km, and coincides with the hinge of the folded footwall (Tauern dome). The amount of offset increases from the area immediately south of Innsbruck southward until it reaches the hinge of the Tauern Dome and decreases south of the latter structure.
4. The Brenner Fault is barely folded, it has an average dip of 40°, and it crosscut the upright folds of the western Tauern Window.
The along-strike change of vertical offset is explained by the large-scale antiformal folding of the footwall, that did not affect the hanging-wall of the Brenner Fault. Therefore, the difference of vertical offset between the area of the Brenner Pass and the area immediately south of Innsbruck, which corresponds to ca. 10 km, defines the shortening (upright folding) component of exhumation of the footwall. The remaining part of the vertical offset must be attributed to extensional deformation, which consequently amounts to 5 km. Depending on the dip of the Brenner Fault plane, this amount can be translated in an extensional displacement of ca. 8 km.
This amount of extension, which is by far smaller than previously estimated, is easier to reconcile with geophysical data, indicating that the present day base of the crust is located at a depth > 50 km. These results suggest that orogen parallel extension in the central portion of the Eastern Alps was smaller than 10%.