Relevance of viscous flow in accretionary wedges *Vortrag*

Hagen Deckert[1] Uwe Ring[2]

The orogenic wedge model (Davis et al. 1983; Platt 1986) marks a conceptual breakthrough in understanding the growth and long-term evolution of accretionary wedges. The characteristic rheology of subduction-related accretionary wedges is thought to change from Coulomb to viscous when the wedge becomes thicker than ca. 15 km, a transition that may influence the stability and dynamics of these wedges. Platt (1986) proposed that viscous flow may trigger extensional faulting in the upper rear part of the wedge and Wallis et al. (1993) argued that viscous flow may cause vertical ductile thinning of the rear part of the wedge.

Material fluxes control the geometric shape of an accretionary wedge (Brandon et al. 1998; Platt 1986). Frontal accretion and erosion both tend to drive the wedge into a subcritical condition as the taper angle of the wedge is progressively reduced. This leads to horizontal shortening across the wedge. If underplating is dominantly controlling the flow field in the wedge and frontal accretion or erosion at the rear of the wedge are small, the wedge is supercritically tapered and leading horizontal extension. Horizontal extension leads to a subhorizontal foliation and may eventually lead to normal faulting in the rear-part of the wedge. Despite the importance of these issues, there remains a paucity of detailed information about ductile deformation and how viscous flow influences the stability of subduction-related accretionary wedges.

Strain measurements are an instrument to address whether viscous flow strongly influences the deformation in accretionary wedges. They provide direct information about the kinematics of ancient orogenic belts. Additionally, they allow understanding important tectonic processes in subduction wedges such as the pattern of flow within the wedge.

We focus on deformation analysis on a suite of samples from the Otago wedge exposed in the South Island of New Zealand. The Otago accretionary wedge offers a unique opportunity to study the tectonic evolution of a typical subduction-related accretionary complex. Its across-strike length of ca. 600 km makes it one of the largest exposed ancient accretionary wedges on Earth. Pressure and temperature estimates indicate that our samples are representative of deformation conditions to depths as great as ca. 35 km. This is similar to maximum depths observed for subducting slabs beneath modern forearc highs.

The deformation measurements show that the strain magnitude is generally small in the Otago wedge. The γ_{oct} values, a measure of the distortion a sample experienced (independent from the strain geometry), range from 0.34–3.87 for the R_f/ϕ strains, 1.01–4.28 for XTG strains across the whole suite of the Otago rock pile, and 0.08–0.70 for the absolute strains obtained from low metamorphic grade rocks. The Otago samples are characterized by considerable volume strain that increases from the lower textural zones towards the high-grade interior of the wedge.

Our strain results are inconsistent with

[1] Institut für Geowissenschaften, Johannes Gutenberg-Universität, Becherweg 21, 55099 Mainz, Germany [2] Department of Geological Sciences, University of Canterbury, Christchurch, New Zealand

the models which advocate supercritically tapering of accretionary wedges and that supercritical tapering eventually triggers normal faulting. Taking averages of our strain measurements, a residence time in the wedge of 35 Myr, burial depths of 30 km, coaxial deformation and a depth-dependent rate for ductile deformation, we calculate vertically-averaged strain rates. Because the principal strain axes of the tensor average are all inclined, the vertical averaging changes the principal stretches. The horizontal principal stretch parallel to the 160°-striking Otago wedge becomes 0.79, that for across strike 0.88 and for vertical strain 0.44. Averaged strain rates are $-1.44^{-16}\,s^{-1}$ for parallel-strike horizontal strain, $-6.2^{-17}\,s^{-1}$ for across-strike horizontal strain, and $-8.02^{-16}\,s^{-1}$ for vertical strain. The strain rates are related to volume loss and to the efficiency with which dissolved chemicals are advected away. The rates are similar to the ones calculated by Bolhar & Ring (2001) and Ring & Richter (2004) for the Franciscan wedge. These strain rates are orders of magnitude smaller than the $1^{-14}\,s^{-1}$ strain rates assumed by Platt (1986). Thus, our data imply that the Otago wedge could not shorten horizontally fast, and hence could not have steepened up its surface slope. The fact that shortening was accompanied by volume loss has another important and interesting consequence. Even if a case was envisioned in which horizontal shortening was fast enough to steepen up the surface slope of the wedge, the volume loss would not necessarily change the wedge geometry into a supercritical configuration triggering normal faulting. As a consequence of the slow strain rates and the high volume loss, viscous flow probably was not fast enough to significantly influence the stability of the wedge and to form a supercritically tapered wedge.

References

Bolhar R & Ring U (2001) Deformation history of the Yolla Bolly terrane at Leech Lake Mountain, Eastern belt, Franciscan subduction complex, California Coast Ranges. Geological Society of America Bulletin 113: 181–195

Brandon MT, Roden-Tice MK & Garver JI (1998) Late Cenozoic exhumation of the Cascadia accretionary wedge in the Olympic Mountains, NW Washington State. Geological Society of America Bulletin 110: 985–1009

Davis D, Suppe J and Dahlen FA (1983) Mechanics of fold-and-thrust belts and accretionary wedges. Journal of Geophysical Research 88: 1153–1172

Platt JP (1986) Dynamics of orogenic wedges and the uplift of high-pressure metamorphic rocks. Geological Society of America Bulletin 97: 1037–1053

Ring U & Richter PP (2004) Normal faulting at convergent plate boundaries: Mylonitic extensional fabrics in the Franciscan subduction complex in Del Puerto Canyon, California, revisited. Tectonics 23: art. no. TC2006

Wallis SR, Platt JP & Knott SD (1993) Recognition of syn-convergence extension in accretionary wedges with examples from the Calabrian arc and the Eastern Alps. American Journal of Science 293: 463–495