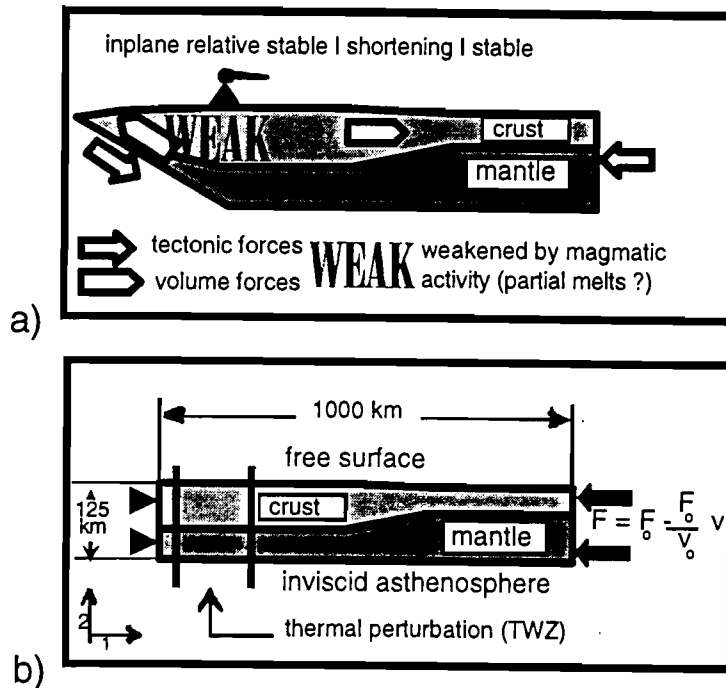




part of a larger system the physical idea behind this type of b.c. is that the finite viscosity of the "outside world" limits the indenting velocity even when the model itself is very weak.



**Figure 1** a) Schematic cross section showing the upper plate of the Central Andean subduction zone (vertical exaggerated). b) Geometry and boundary conditions of the numerical model. The (inplane) relative stable forearc region is not part of the model.

In order to keep it simple the inplane relative stable forearc region is not part of the studied numerical model (Fig. 1). Since the weakened lithosphere in the area of the magmatic arc is not capable to transmit tectonic stress this simplification should have no effect on the deformation in or east of the magmatic arc, where the largest part of crustal shortening is accommodated (e.g. Schmitz, 1994). This model also assumes that mantle drag forces at the base of the lithosphere (within the modelled area) are negligible. The finite element (FE) code used in this study is an adopted version of the code written by Shimon Wdowinski, used and described by Wdowinski and Bock (1994a and b).

## RESULTS

Fig. 2 shows the velocity field and the effective strain rate (the second invariant of the strain rate tensor) of the model with  $F_0 = 6 \times 10^{12} \text{ Nm}^{-1}$  at two different stages of plateau evolution (two and four km elevation). Similar to the models of Wdowinski and Bock (1994a and b) deformation is concentrated in a thermally weakened zone (TWZ) up to about two km plateau elevation and migrates to the non-elevated parts of models with higher plateau elevation (see also Fig. 3a). But in contrast to their models the indenting velocity strongly depends on temperature deflection in the TWZ (not shown here) and decreases with increasing plateau elevation (Fig. 3b) because of the force b.c used here. The tectonic force  $F_0$  necessary to drive a plateau evolution of 4 km is at least  $4.5 \text{ Nm}^{-1}$ . This value which coincides with results of static models (Froidvaux

an Isacks, 1984; Richardson and Coblenz, 1994) exceeds the value of the ridge push force (e.g. Bott, 1993). This supports the assumption of additional mantle drag forces acting to drive the South America Plate in western direction (Meijer and Wortel, 1992) and therefore contributing to Andean plateau evolution. The force  $F$  applied at the models increases with plateau topography and decreasing indenting velocity (Fig. 3c). In contrast to the indenting velocity the force  $F$  is remarkably independent of  $F_0$  except for elevations between 2.5 and 3.5 km, where the transition from symmetrical pure shear compression in the TWZ (Fig. 2a) to asymmetric plateau forces controlled deformation (Fig. 2b) occurs.

## CONCLUSION

The indenting velocity, the velocity of the right model boundary, decreases significantly with increasing plateau elevation. Because of the non-linear stress-strain relation of dislocation creep controlled rheology this affects not only the velocity but also the style of deformation within the model. This emphasises the importance of a force boundary condition for numerical models of plateau evolution. A comparison between the recent shortening rate and the average value over the last 26 Ma (about 1 cm/a) can be used to constrain the dynamic parameter controlling Andean deformation. The velocity of the model surface can be compared with GPS data of the SAGA 95 profile running from the coast to the undeformed Brazilian shield (at about 23°S), provided that the data between the magmatic arc and the Brazilian shield reflect the long term deformation.

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