FOREARC DYNAMICS AND NEOTECTONIC ARC DEFORMATION CENTRAL ANDES, NORTHERN CHILE

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INTRODUCTION

The upper brittle crust of the wedge shaped forearc lithosphere between the Chile trench and the Western Cordillera of the Andean System can be subdivided into distinct crustal sub-wedges characterising an outer forearc domain with submarine toe erosion and active extensional deformations onshore, and an inner forearc domain with recent compressional deformation which also affects the western margin of the active magmatic arc. Dynamic wedge models, developed by Dahlen et al. (1984), are applied to explain the neotectonic processes of the north Chilean trench-arc system between 22° S and 24° S.

RECENT NORTH CHILEAN TRENCH - ARC SYSTEM

The forearc prism is bounded by (a) the recent slope between the trench and the active magmatic arc, (b) the subduction zone, and (c) a intracrustal detachment in the overriding continental plate. The forearc region is segmented by large N-S trending strike-slip fault zones (fig. 1a) and the Atacama fault separates the onshore outer extensional forearc from the inner compressional forearc region (Buddin et al. 1993). The forearc prism consists of several sub-wedges and we distinguish between tectonic wedges within the brittle upper crust and deeper crustal/mantle wedge structures (fig. 1b)

The outer forearc region extends 120 km from the trench axis to the Atacama fault zone and is devided into two wedges: The toe-wedge with a trench slope dipping 6° and the outer forearc wedge with a trench slope of 3,5° continuing onshore into the western slope of the coastal range (bathymetry data from Schweller et. al 1981). The bottom of the toe- and outer wedge dips 10° and parallels the subducting Nazca plate. The toe and the upper part of the outer forearc wedge consist predominantly of magmatic, volcanic and sedimentary rocks of an old Jurassic-Early Cretaceous arc system, Palaeozoic basement rocks and an incomplete succession of Cretaceous to Recent deposits. The lower part of the outer forearc wedge has been interpreted as partly serpentinized Jurassic-Cretaceous mantle rocks (Wigger et al. 1994).

The inner forearc wedge extends over a distance of 210 km and is situated between the Atacama Fault and the western margin of the active magmatic arc. The topographic slope of the wedge is approximated with 1°. We define the base of this internal forearc wedge with an intracrustal discontinuity dipping 7° to the east, represented by a low velocity zone in interpreted seismic sections between Tocopilla and Chuquicamata/Calama (Schmitz 1993; Wigger et al. 1994). The inner forearc wedge hosts Mid Cretaceous to Upper Cretaceous arc rocks and uplifted Precambrian to Lower Palaeozoic metamorphic rocks, Carboniferous-Permotriassic magmatic and sedimentary rocks, and a Cretaceous to recent marine / continental sediment succession with intercalated evaporitic layers. The western rim of the active magmatic arc is dominated by Upper Miocene to Pleistocene ignimbrites and Neogene to recent andesites and dacites.

Neotectonic surface structures between the Chile trench and the Western Cordillera are caused by active extension in the outer forearc domain, affecting Pliocene and Pleistocene deposits between the Mejillones Peninsula and the Atacama fault. The inner forearc domain and the western margin of the active magmatic arc are characterised by recent compression. Here Quaternary lacustrine sediments and Upper Miocene to Pleistocene ignimbrites are faulted by trenchward verging thrusts north of San Pedro de Atacama in the Rio Salado and Vilama areas and arcward verging thrusts, with the eastern most, the Talabre thrust, beneath the Tumisa and active Lascar volcanoes bounded in the east by a more than 100 km N-S trending lineament, the Miscanti fault, where post-Pliocene transpressive deformation can be observed (fig. 1).
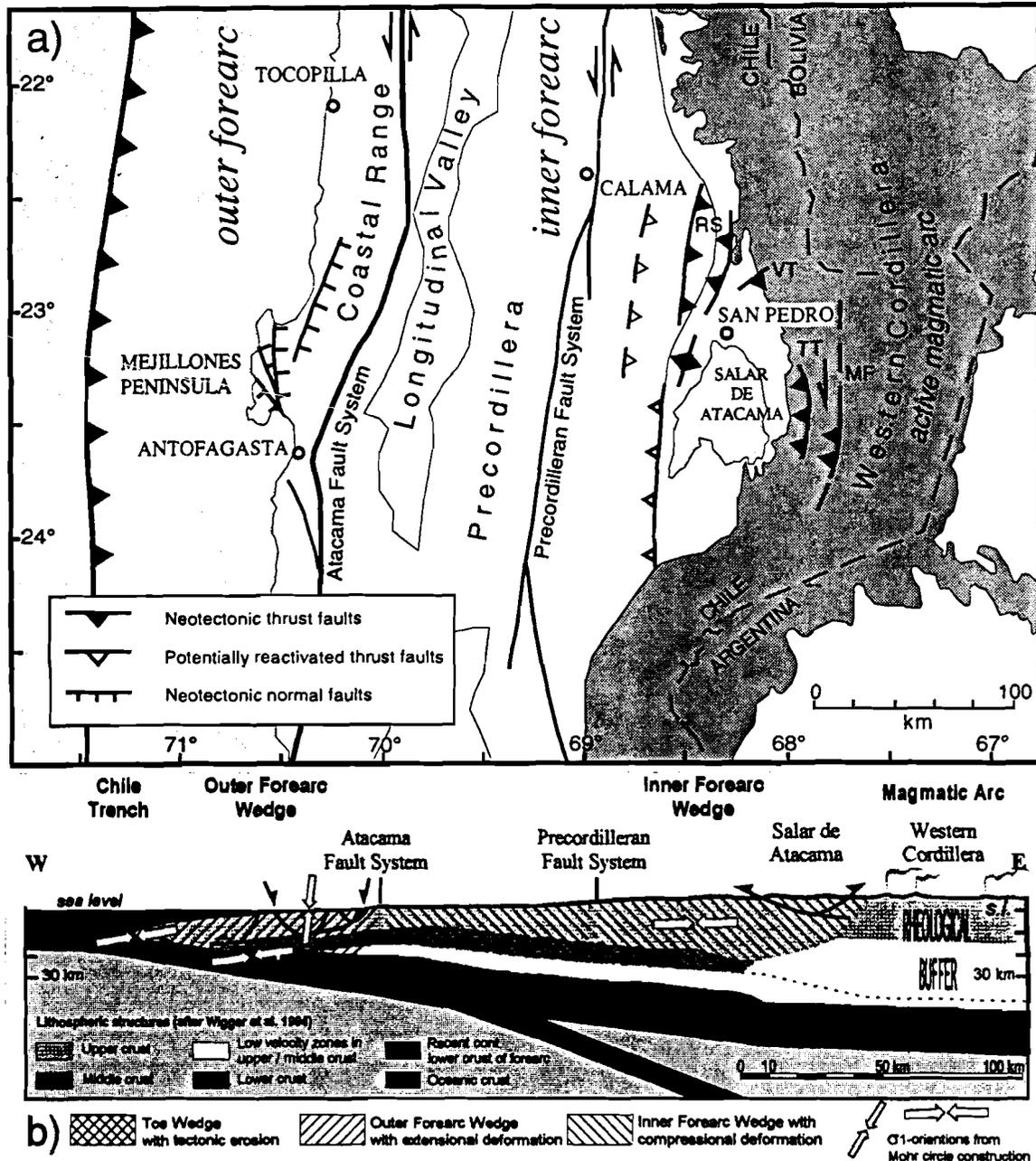
Fig. 1:   a. Main structural features and neotectonics of the North-Chilean trench-arc system.
          (RS Rio Salado Area, VT Vilama thrusts, TT Talabre Thrust, MF Miscanti Fault;
          Atacama- and Precordilleran fault kinematics after Armijo & Thiele 1990; Yáñez et al. 1994).
          b. Schematic dynamic cross section of the trench-arc system of Northern Chile.

WEDGE MECHANICS AND DYNAMICS

Active lithospheric stresses are transmitted from the subducting Nazca Plate onto the overriding South-America Plate due to high frictional resistance between the plates. For Northern Chile, between 18° S and 24° S, Tichelaar & Ruff (1991) estimated a plate coupling extending to depths of 45 - 48 km. The North-Chilean convergent plate margin is a non-accreting margin characterised by subduction erosion with removal and transport of rock material from the upper plate to greater depths (Huene & Scholl, 1991). In our dynamic model the rigid wedges of the forearc lithosphere are backstopped by the rheological buffer of the thermally weakened active magmatic arc (fig. 1 b).

Wedge mechanics illustrated by Mohr stress circles (fig. 2) demonstrate the limit stress conditions and required geometric relationships between the topographic slopes, subduction fault, crustal detachments, internal toe detachments, normal- and thrust faults, and stress field orientation of the rigid forearc wedges.
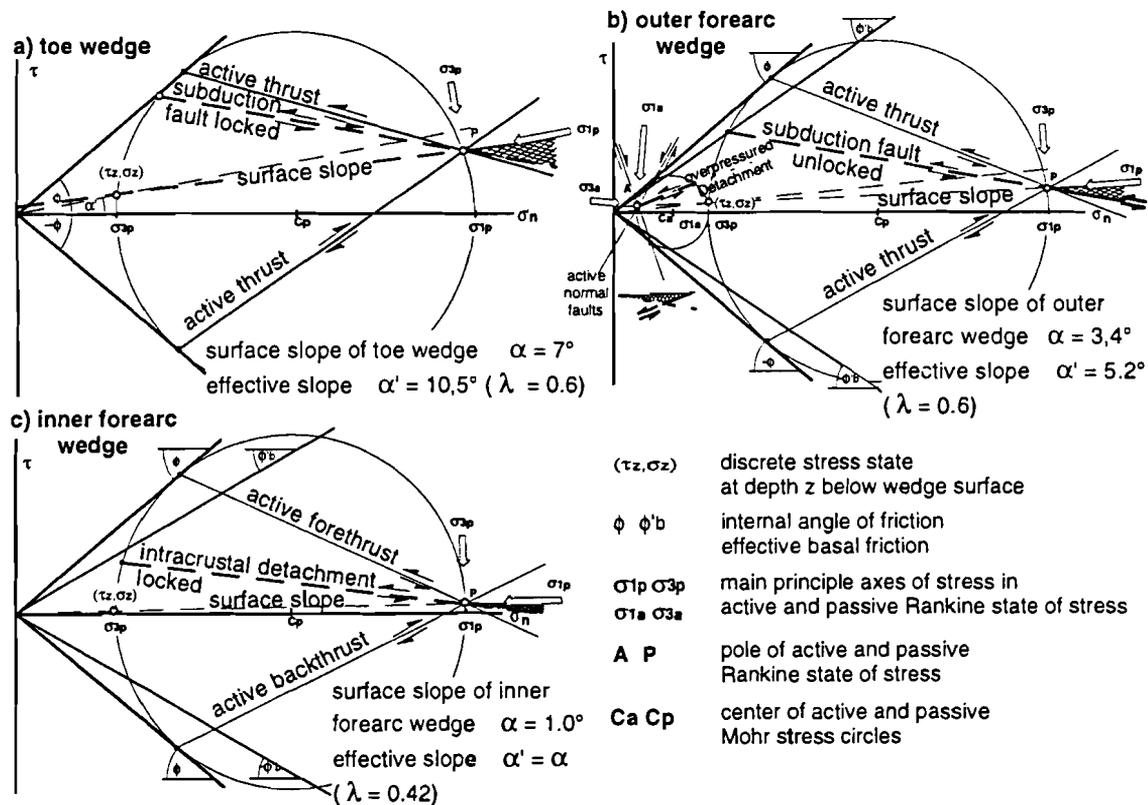
Fig. 2: Limiting stress conditions and fault mechanics in the North Chilean forearc system
(a) toe wedge (b) outer forearc wedge (c) inner forearc wedge.

The compressional stress regime and similar rheological properties in the toe-wedge and along its base prohibit a discrete wedge base and a stable wedge geometry. Internal deformation favours west verging detachments with off-scraping of the basal part of the toe-wedge carried away with the subducting Nasca plate, stress conditions are shown in fig. 2a. Increasing pore fluid pressure and/or decreasing basal friction along the descending subduction fault lead to underplating of these crustal slices and thickens the outer forearc wedge. The basal accretion rises basement rocks into upper crustal levels (Platt 1986). This mechanism influences the uplift of the basement rocks of the Coastal Range in the north Chilean onshore outer forearc. Thrust faulting indicated by focal mechanisms of shallow earthquakes (depth $\leq$ 30 km, Comte et al. 1992) support this dynamic model. In contrast to this compressive basal accretion mecha-

nism, neotectonic and active surface structures in the outer forearc show trench parallel extension. These normal faults are dynamically interpreted as a result of the extensional collapse of a supercritical wedge build up by continuous thickening during basal accretion. The simultaneous critical extensional and compressional stress conditions and the geometric relation of fault mechanics in the outer forearc wedge are modelled in the Mohr stress circles in figure 2 b.

The inner forearc wedge is characterised by neotectonic west-verging forethrusts and east-verging backthrusts, represented by out-of-the-sequence thrusts, favoured by numerous evaporitic layers within the rock succession and by older upper crustal discontinuities of former tectonic stages. This wedge is under active compression and in a subcritical stage (fig. 2 c).

CONCLUSIONS

Based on observations of surface structures in the Chilean trench-arc system frictional plastic wedge models have been developed which help to understand the dynamics of the rigid crust in the forearc region. Mohr circle constructions illustrate the varying rheological conditions in defined subwedges of the forearc system and explain the relationships between neotectonic deformation processes and the active state of stress. The uplifted basement rocks of the Coastal Range and neotectonic to active N-S trending normal faults in the onshore region of the outer forearc are governed by toe erosion and underplating processes and by contemporaneous internal extensional adjustment of wedge geometry. Synchronous post Pliocene/Pleistocene west verging forethrusts, East-verging backthrusts and folds in the inner forearc and along the western rim of the recent Andean magmatic arc reflect compressional internal deformation within a subcritical crustal wedge backstopped by the rheological buffer of the active magmatic arc.

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