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Investigating the deformation of upper crustal faults at the N-Chilean convergent plate boundary at different scales using high-resolution topography datasets and creepmeter measurements

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The Chilean convergent plate boundary is one of the tectonically most active regions on earth and prone to large megathrust earthquakes as e. g. the 2010 Mw 8.8 Maule earthquake which ruptured a mature seismic gap in south-central Chile. In northern Chile historical data suggests the existence of a seismic gap between Arica and Mejillones Peninsula (MP), which has not ruptured since 1877. Further south, the 1995 Mw 8.0 Antofagasta earthquake ruptured the subduction interface between MP and Taltal.
In this study we investigate the deformation at four active upper plate faults (dip-slip and strike-slip) located above the coupling zone of the subduction interface. The target faults (Mejillones Fault – MF, Salar del Carmen Fault – SCF, Cerro Fortuna Fault – CFF, Chomache Fault – CF) are situated in forearc segments, which are in different stages of the megathrust seismic cycle. The main question of this study is how strain is accumulated in the overriding plate, what is the response of the target faults to the megathrust seismic cycle and what are the mechanisms / processes involved. The hyper arid conditions of the Atacama desert and the extremely low erosion rates enable us to investigate geomorphic markers, e .g. fault scarps and knickpoints, which serve as a record for upper crustal deformation and fault activity about ten thousands years into the past. Fault scarp data has been acquired with Differential-GPS by measuring high-resolution topographic profiles perpendicular to the fault scarps and along incised gullies. The topographic data show clear variations between the target faults which possibly result from their position within the forearc. The surveyed faults, e. g. the SCF, exhibit clear along strike variations in the morphology of surface ruptures attributed to seismic events and can be subdivided into individual segments. The data allows us to distinguish single, composite and multiple fault scarps and thus to detect differences in fault growth initiated either by seismic rupture or fault creep. Additional information on the number of seismic events responsible for the cumulative displacement can be derived from the mapping of knickpoints.
By reconstructing the stress field responsible for the formation of identified seismic surface ruptures we can determine stress conditions for failure of upper crustal faults. Comparing these paleo stress conditions with the recent forearc stresses (interseismic / coseismic) we can derive information about a possible activation of upper crustal faults during the megathrust seismic cycle.
In addition to the morphotectonic surveys we explore the recent deformation of the target faults by analyzing time series of displacements recorded with micron precision by an array of creepmeters at the target faults for over three years. Total displacement is composed of steady state creep, creep events and sudden displacement events (SDEs) related to seismic rupture. The percentage of SDEs accounts for >50 % (SCF) to 90 % (CFF) of the cumulative displacement. This result very well reflects the field observation that a considerable amount of the total displacement has been accumulated during multiple seismic events.