Cyclic frictional-viscous slip oscillations along the base of an advancing nappe complex: Insights into brittle-ductile nappe emplacement mechanisms from the Naukluft Nappe Complex, central Namibia

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[1] The Naukluft Nappe Complex (NNC) forms a far-traveled fold and thrust belt klippe of the Panafrican Damara Belt in central Namibia. Estimates of the SE directed displacement range between 50 and 80 km. The entire nappe stack was thrust along an out-of-sequence, nearly planar, horizontal structure, the "Naukluft Thrust." The thrust zone consists of several distinct lithological components whose typical distribution, when all present, from bottom to top is (1) a massive, ochre-yellow weathering dolomite; (2) a polymict "gritty dolomite" (called in the past "Sole Dolomite"), (3) strongly foliated and isoclinally folded calcmylonites, and (4) an upper massive dolomite. A very discrete (<50 mm thick, often <10 mm thick) planar brittle fault (component 5) can occur at any level within this sequence. Our investigations show that the gritty dolomite forms by progressive cataclasis of the massive dolomite (component 1). Moreover, clasts of gritty dolomite are observed randomly oriented within a similar gritty dolomite matrix, suggesting multiple pulses of brecciation and self-brecciation. The gritty dolomite locally forms injection veins into the calcmylonites, and these veins are themselves boudinaged, indicating broadly coeval cataclastic and ductile deformation. The evolution of structures within the thrust zone is linked to the presence and flow of overpressured pore fluids. Field observations suggest that several pulses of fluid-induced brittle deformation overprinted, in a cyclic fashion, ductile structures formed during the emplacement of the nappe edifice. A "fault valve" behavior is suggested for the basal detachment of the NNC, with bulk shortening being accommodated by incremental slip during a history of combined viscous and frictional flow. **Citation:** Viola, G., N. S. Mancktelow, and J. A. Miller (2006), Cyclic frictional-viscous slip oscillations along the base of an advancing nappe complex: Insights into brittle-ductile nappe emplacement mechanisms from the Naukluft Nappe Complex, central Namibia, *Tectonics*, *25*, TC3016, doi:10.1029/2005TC001939.

1. Introduction and Aims of the Study

[2] Overthrusts, especially when well exposed, are spectacular structures that have been documented systematically since the end of the 19th century. Recognition in the Alps of the Glarus overthrust by *Escher van der Linth* [1841] and its subsequent explanation by *Bertrand* [1884] were classic milestones in the earth sciences, introducing the concept of "nappe tectonics." This theory, soon to become a revolutionary model and a key element in the understanding of collisional belts, was applied with great success worldwide and many examples of fold and thrust belts have since been identified and described (see *McClay and Price* [1981] for a comprehensive overview).

[3] However, the application of this theory to large-scale natural examples has had difficulty in explaining the lateral displacement of large but relatively thin rock masses along low-angle thrust faults over distances often exceeding 50 km [*Chapple*, 1978]. Since the recognition of this mechanical problem, research has therefore dealt not only with a clarification of the specific geometries, kinematics and metamorphic conditions associated with these important fault structures, but also with understanding the physical-mechanical conditions that allow such large displacements along near horizontal overthrusts. Proposals to solve this mechanical paradox have included (1) large strength contrasts between exceedingly weak rocks in the decollement horizon and much stronger ones within the hanging wall thrust sheet, (2) propagation of incremental slip domains, and (3) close to lithostatic fluid pressures within the thrust fault plane itself [e.g., *Hubbert and Rubey*, 1959; *Schmid*, 1975; *Price*, 1988; *Henry and Le Pichon*, 1991; *Twiss and Moores*, 1992; *Badertscher and Burkhard*, 2000]. In particular, the pioneering work of *Hubbert and Rubey* [1959], who first recognized high pore pressure as an efficient mechanism to reduce effective stresses along fault zones, led to innovative interpretations of fault mechanics and tectonic processes in general. Subsequently, fluids have been repeatedly shown to play an important role in the

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