Supporting Information for

**Multiphase structural evolution of a continental margin during obduction orogeny:
Insights from the Jebel Akhdar Dome, Oman Mountains**

A. Grobe^{1,2}, S. Virgo¹, C. von Hagke¹, J.L. Urai¹, R. Littke²

¹ Institute for Structural Geology, Tectonics and Geomechanics, EMR Group, RWTH Aachen University

² Institute of Geology and Geochemistry of Petroleum and Coal, EMR Group, RWTH Aachen University

Tectonics

Introduction

These supporting information present additional, locally observed, structures and additional images fostering our interpretation presented in the aforementioned article.

Figure S1 (separate PDF). Table summarizing the attributes of our identified structural generations.

Outcrops		Northing	Easting
Al Raheba Pavement	UTM 40Q	2565843.85	514441.86
BPV Sampling Location	UTM 40Q	2566485.28	518050.60
Donkey Pavement	UTM 40Q	2576160.89	510838.29
Resort South 1	UTM 40Q	2564297.28	519877.40
Resort South 2	UTM 40Q	2564400.41	520003.14
Resort East	UTM 40Q	2566240.96	520496.95
Resort West 1	UTM 40Q	2566717.42	520179.49
Resort West 2	UTM 40Q	2566547.29	518949.56
Resort West 3	UTM 40Q	2566423.79	518062.38
Resort West 4	UTM 40Q	2565950.83	519517.96
Spider Pavement	UTM 40Q	2576035.46	511849.72
Sundown Pavement	UTM 40Q	2570691.12	515646.66
The Edge	UTM 40Q	2566539.25	520855.70
Upper Donkey Pavement	UTM 40Q	2576174.49	510824.37
Wadi Dam	UTM 40Q	2569020.02	507094.88
Swimming Pool Pavement	UTM 40Q	2569401.32	507628.93
Lower Gorge Pavement	UTM 40Q	2573448.52	513643.67
Upper Gorge Pavement	UTM 40Q	2573798.97	513726.50
Gorge Loc20	UTM 40Q	2573772.38	513815.09
Gorge G10	UTM 40Q	2573763.44	513844.15
Gorge Fault 2	UTM 40Q	2573825.57	513749.79
Cuesta del Mandaa	UTM 40Q	2573991.90	513814.38
Cuesta Ghul	UTM 40Q	2562307.37	523649.44
Entrance Wadi Nakhr	UTM 40Q	2560322.17	521243.68
Wadi Nakhr Sa	UTM 40Q	2563786.91	521138.75
Jebel Sara Bathroom	UTM 40Q	2579138.69	512855.16
Jebel Sara Antenna	UTM 40Q	2578846.75	513806.83
Kharb Plateau View	UTM 40Q	2577467.54	518928.29
Kharb Plateau Muti	UTM 40Q	2575384.80	520457.19
Isaba Fi Ar'ras	UTM 40Q	2574891.94	2574891.94
Jur.-Tr. Fault	UTM 40Q	2582246.28	515809.53
The Tree	UTM 40Q	2582081.88	516209.28
Cathedral	UTM 40Q	2584112.42	516046.80
Heavens Staircase	UTM 40Q	2584059.52	516182.33
Nusar Wall	UTM 40Q	2584907.43	516771.85
Entrance Wadi Taisa	UTM 40Q	2585291.55	517629.11
Entrance Wadi Yiqah	UTM 40Q	2584381.00	518267.90
Wadi al Hawqayn	UTM 40Q	2583897.66	526072.35

Figure S2. GPS data of presented outcrops and Figures in UTM coordinates.

Figure S3 (separate PDF). Stereoplots of the structural data. Columns represent different structural phases, rows the locations sorted from N (top) to S (bottom, numbered locations were mapped by S. Virgo, lettered locations by A. Grobe). Multiple stereonets in one box refer to structures of same relative age relation. Black circles outline vein orientation, red circles faults and associated fault lineations are dashed. If a shear sense was observable at en-échelon sets or shear veins, sinistral displacement is depicted in orange, dextral counterparts in green. Stylolites are brown. Towards the northern locations top-to-NNE shear is overprinting the earlier vein generations. (*data assembled from Virgo and Arndt, 2010)

Figure S4. Rigid boudinage (IIIc) appears at different concretions extended in NNE-SSW orientation: a) Boudinaged, solid bitumen containing irregular surface of a lb vein at the Natih-Muti boundary, Kharb plateau (top-view). NW-SE veins (III) cut the vein surface, but not the host rock. b) Rigid boudinage of clasts within the Muti conglomerate. c) Chert concretions with veins parallel to IIIa veins post-dated by later veins (IX).

Figure S5. Invariably NNE-SSW (020°) trending lineation (IV) appears on different structures, e.g. on bedding parallel shear veins (a) and sheared veins (b, c).

Figure S6. Recumbent, synshear folding (IVc) of a former bedding parallel shear vein (a) and of a layer opposite the Heavens Staircase (b).

Figure S7 (following page) Representative micrographs (crossed polarizers) of calcite veins cut normal to bedding and parallel to lineation (NNE-SSW): a) NW-SE striking vein (generation III) strongly deformed in generation IV, top-to-NNE shear. Strongly deformed, undulose and mechanically twinned grains show evidence for dynamic recrystallization by twin and grain boundary migration (top of figure), while in the bottom part of the figure the rock is almost completely recrystallized, with relict old grains in a microstructure of elongated new grains (grain size about 10 μm , bottom), forming a calcite mylonite. b) Top-to-NNE sheared, highly deformed, mylonitic rock with recrystallized calcite grain size of c. 10 μm and a preferred grain shape orientation and inclusion-rich dolomite porphyroclasts. The rock is crosscut by later, undeformed calcite veins. c) Laminated, blocky, bedding parallel shear vein with large calcite grains and mechanical twins showing evidence for small deformation after formation of the veins. Laminations consist of host rock inclusion bands; these frequently show evidence of dissolution in the form of stylolites, and occasionally oblique, periodic inclusion bands which can be used as sense of shear indicators [Koehn and Passchier, 2000]. d) Vein sampled from the fault zone of a low angle normal fault (detachment) on the N-flank (location A) showing blocky calcite with evidence for mechanical twinning, undulose extinction and incipient recrystallization. e) Undeformed, blocky, NW-SE striking vein in limestone host rock of the southern flank for comparison (Ghul Ramps, southern flank, Arndt, 2015).

a) bedding parallel shear vein, Nakhr

b) low angle normal fault, Wadi Yiqah

c) top-to-NNE sheared, sub-bedding parallel, NW-SE oriented vein, Wadi Taisa

d) mylonitic shear zone, Wadi Yiqah

e) undeformed, NW-SE vein, Ghul Ramps (Arndt, 2015)

Figure S8 (previous page) Normal faults (V) occur on orogen scale with offsets up to 750 m and form a large-scale horst structure in the center of the northwestern Jebel Akhdar. a) A NW-SE striking, NE-dipping normal fault forms the northern hinge of the horst, offsetting Triassic against Jurassic units in the Wadi Yiqah (Loc. A, B, orange = Mafrq Fm. as marker bed). b) Within the large-scale horst, smaller-scale horst-graben-structures occur. c) The southern hinge of the horst is formed by a NE-SW striking, SE-dipping normal fault opposing the base Jurassic against the top-Cretaceous (view to Loc. 29).

Figure S9, S10 (following page). Wadi Yiqah (northern flank, looking to the SE) illustrates the localization of the top-to-NNE shear zone: Below the marly layer (Kh2, middle) shear and increased fault density is observable, the area above is characterized by continuous layering.

Figure S11. Sketch illustrating the interpreted orientation of the blind thrust (gray) under the Jebel Akhdar Dome (green). In the Jebel Akhdar window no blind thrust is outcropping down to pre-Permian strata, hence, a blind thrust needs to be located deeper in the subsurface. At the Murri anticline, the character of folding without any hints of flexural-slip needs a blind thrust located closer to the surface and in relatively higher strata. Therefore, the blind thrust underneath the Jebel Akhdar is tilted towards the NNE and towards the E. The narrowing character of the dome shape towards Murri could represent a surface continuation of this features.

Figure S12. a) Small scale thrust connecting bedding parallel slip planes at the entrance of Wadi Nakhr. IIIa veins occur in the competent calcite layers. Thrust planes are reactivated by fault related en-echelon sets (V) and hence, formed earlier (view to the East). b) Detail of thrust plane, here unaffected by later faults, striations indicate top-to-S sense of shear (view to East).

Figure S13. Top-to-S thrust on the southern flank of the Jebel Akhdar offsetting a marly layer and its cleavage.

Figure S14(previous page). On the southern flank, we only found one argillaceous layer (L. 26) with a top-to-NNE sheared, pinch-and-swell vein that is surrounded by cleavage and S/C fabrics [cpr. Holland et al, 2009a, Fig. 15 c, d]. C. v. Hagke for scale.

Figure S15. Late stage bedding parallel, top-to-S shearing in an argillaceous bed in the Upper Gorge Area. Veins and conjugated slip planes of a miniature graben are dragged southwards indicating formation after normal faulting (view to W).

Figure S16. Stratigraphy of the Mesozoic carbonate platform, view from a crest between Wadis Yiqah and Taisa towards the SSE (Kharb Plateau).

Figure S17. Comparison results and previously published data in relation to convergence rates.