Supplement of Solid Earth Discuss., 7, 1517–1554, 2015
http://www.solid-earth-discuss.net/7/1517/2015/
doi:10.5194/sed-7-1517-2015-supplement

Solid Earth Discussions
Open Access

Supplement of

Pinch and swell structures: evidence for brittle-viscous behaviour in the middle crust

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Swell centre samples e.g. AS1331I (see Fig. 1d): Amphibole, biotite (to 1.2 mm) and chlorite (to 0.3 mm) define the foliation. Euhedral to anhedral, up to 2.5 mm amphibole grains exhibit minor fracturing and some twinning. Fractures are narrow and filled with quartz and calcite. Quartz grains are anhedral to 1 mm and commonly fill areas between amphibole grains giving tight (20^{o}) angled junctions. Quartz grains display minor undulose extinction and irregular boundaries. Mineral modes of the swells comprise amphibole (69 vol.%), biotite (16 vol.%), quartz and plagioclase (7 vol.%) and accessory chlorite, calcite and opaques (together 8 vol.%).

Swell edge samples e.g. AS1331G (see Fig. 1e): Up to 2 mm, anhedral amphibole grains define the foliation, with larger, up to 4 mm fractured grains (Fig. 1e asterisks). Fractured areas (Fig. 1e red arrows) are filled with elongate biotite (to 0.45 mm) and chlorite (to 0.4 mm) defining an S-C fabric. Quartz grains are anhedral to 1 mm and commonly fill areas between amphibole grains giving tight (20^{o}) angled junctions. Quartz grains display undulose extinction, subgrains and commonly have irregular boundaries. Garnet grains are up to 3.2 mm wide poikiloblastic porphyroblasts seen at the edge of the pinch and swell structure. The zones rich in biotite appear to be joining to form zones at 30 to 40^{o} from the primary foliation (Fig. 1e white dashed line). Mineral modes of the swell edge samples comprise amphibole and garnet (55 vol.%), biotite (26 vol.%), quartz and plagioclase (16 vol.%) and accessory chlorite, calcite epidote and opaques (together < 3 vol.%).

Supplementary Figure Labels:

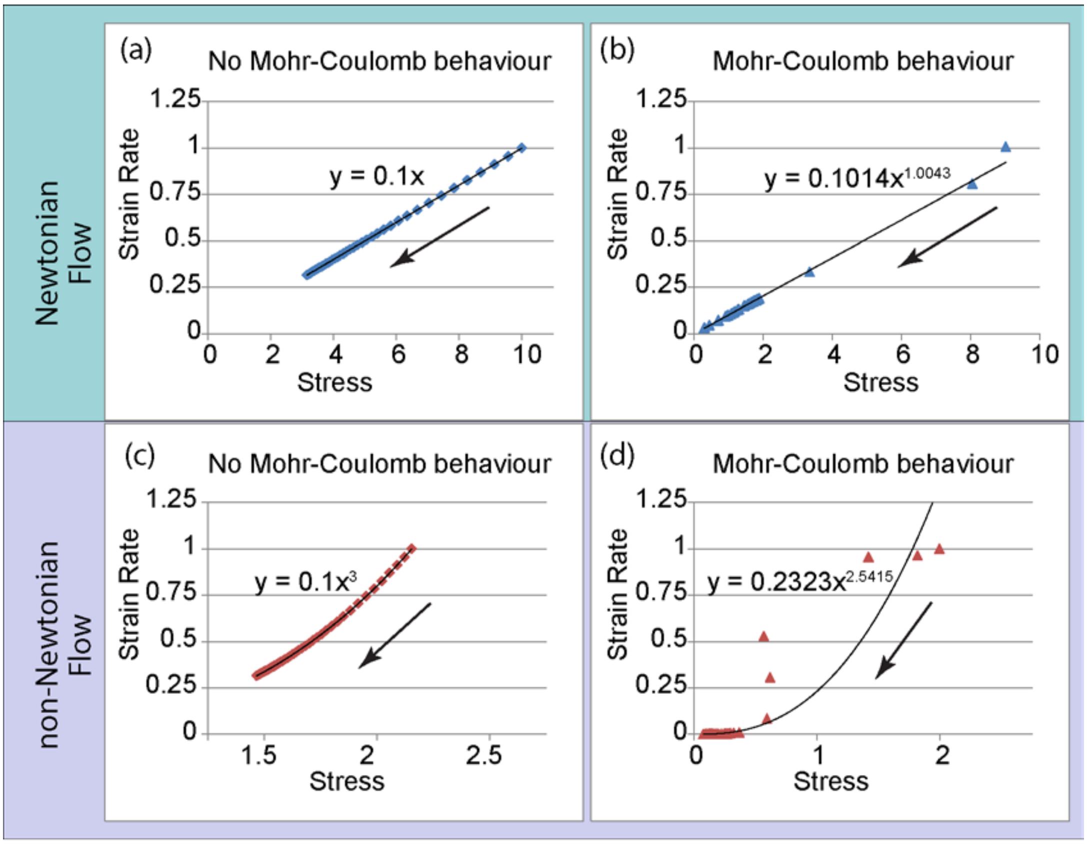

Figure S1: Graphs of Newtonian (a, b) and non-Newtonian (c, d) flow with Mohr-Coulomb b rittle deformation behaviour (b and d) and with no Mohr-Coulomb behaviour (a, c). Relations hip equations on (a) and (c) indicate Underworld is working as expected for Newtonian and n on-Newtonian flow regimes. Black arrows indicate direction of simulation steps.

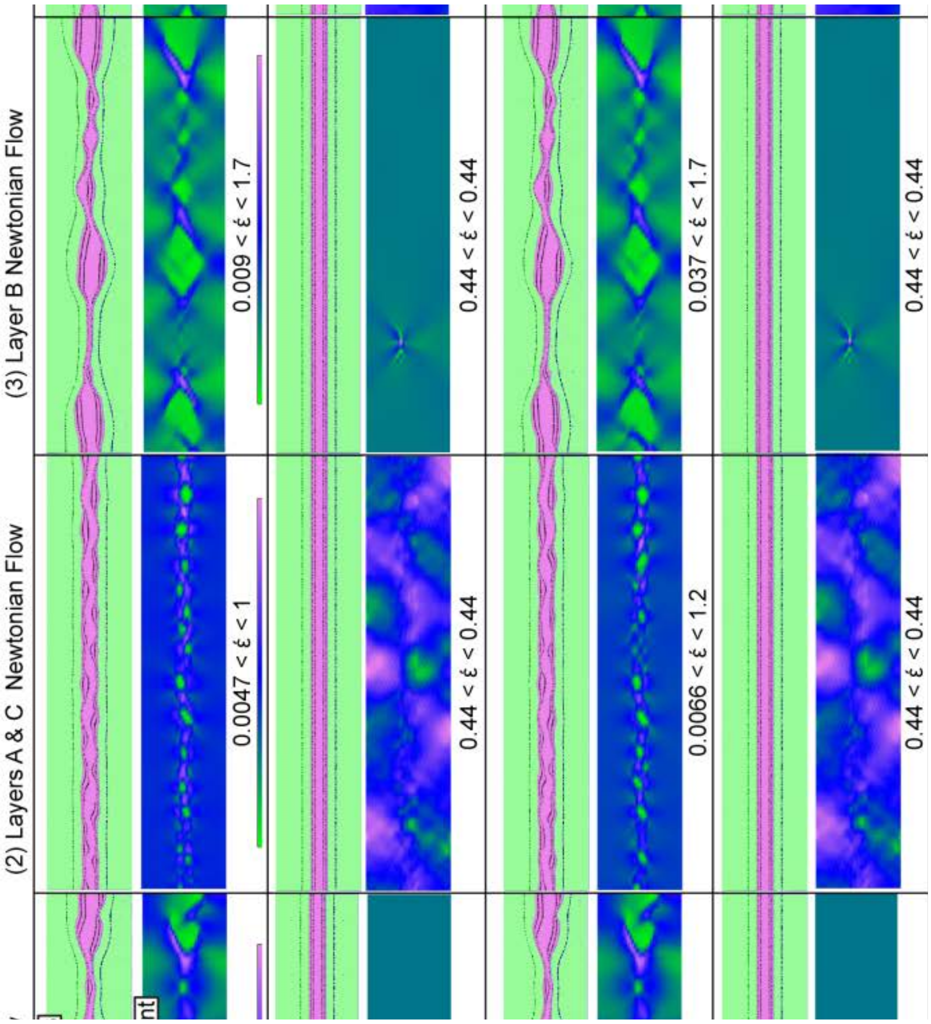

Figure S2: Sensitivity analysis II results: Numerical results at stretch 2.3 where Newtonian/no n-Newtonian flow and Mohr-Coulomb behaviour (M-CB) characteristics of layer B have bee n varied systematically with respect to layers A & C (for summary see Table 2). All models h ave $R_V = 10$. Strain rate invariant (ranges of values are as specified while range of colour is t he same for all results: colour bars are included at (i) all layers M-CB.

Supplementary Table:

Material	Stress Exponent (n)
Quartz aggregate[1]	3.9 ± 0.8 to 4.1 ± 0.7
Feldspar aggregate[2]	3.0 ± 0.1
Olivine[3]	3.0 ± 0.1
Pyroxene aggregate[4]	4.7 ± 0.2
Natural marble[5]	1.7 ± 0.5 to 3.5 ± 0.6

Supplementary Table 1

Table S1. Experimentally determined stress exponents (n) for various materials undergoing non-Newtonian flow. References are: 1. Gleason and Tullis (1995; 2. Rybacki and Dresen (2004; 3. Mei and Kohlstedt (2000; 4. Bystricky and Mackwell (2001; 5. Rybacki et al. (2003.

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