Supplement A: Scaling of sandbox model to the NMSZ

Scaling of the geometry and material properties needs to be within about an order of magnitude for an analog sandbox experiment to properly simulate behavior in nature (van Mechelen, 2004; Koyi and Sans, 2006). Dry sand is widely viewed as a nearly perfect Coulomb material for modeling brittle upper crustal rocks because it is exceedingly weak, complementing low confining pressures in the model. If we assume that the sand in the model is equivalent to the brittle upper crust, the geometry of the 10-cm, right-angle stepover model described in this paper scales appropriately for comparison with the NMSZ. The seismicity in the New Madrid area, which presumably delineates the brittle upper crust, extends to 15 to 20 km depth (Fig. 1, inset), which is 33% to 44% of the ~45-km NMSZ stepover distance. In the model, the sand representing the brittle upper crust is 5 cm thick, or 50% of the model's stepover distance. There is thus an approximate geometric similarity between the thickness of the brittle upper crust in the NMSZ area and the thickness of sand layers in the model, relative to the stepover distance. Dry sands have coefficients of internal friction (or angles of internal friction) comparable to those of upper crustal rocks (Krantz, 1991; van Mechelen, 2004; Koyi and Sans, 2006).

The shear strength of the materials also must scale properly. The sandbox experiments were designed assuming a scaling to geologic structures of 1 cm ≈ 1 km, whereas comparison with the NMSZ requires a scaling of 1 cm ≈ 4.5 km. The initial scale factor assumed structures in sedimentary basins above "basement" rocks; the larger scale factor necessary for comparison with the NMSZ is balanced by the involvement of deeper rocks that have greater cohesive shear strength than the sedimentary strata assumed in the model. The sand used in the experiments was dry quartz with a grain size of about 190µm, which was sifted onto the model. Measurements of comparably-sized, sifted quartz sand (van Mechelen, 2004) showed a density of 1634 kg/m^3 and a cohesive shear strength of 69 Pa. For the model to be realistic, the non-dimensional shear strength values must be approximately the same in the model and the NMSZ (Koyi and Sans, 2006). To stay within an order of magnitude of proper scaling, the model rheology requires upper crustal strengths between 52 MPa and 500 MPa (Table 1); brittle rocks in the upper 20 km of the Earth's crust are estimated to have strengths of 50 to 400 MPa (Byerlee, 1978; Kirby, 1980; Zoback et al., 1993; Kohlstedt et al., 1995). Thus, the model appears to scale, within an order of magnitude, to the NMSZ area.

Table 1: Calculation of non-dimensional shear strengths (Koyi and Sans, 2006)

	Sandbox model	NMSZ upper crust
Cohesive shear strength (C_0)	69 Pa	50-400 MPa
Density (ρ)	1634 kg/m^3	2700 kg/m^3
Gravity (g)	981 m/s^2	981 m/s^2
Length scale (l)	0.01 m	45000 m
shear strength ($\sim C_0/\rho gl$)	0.435	0.042-0.25

Supplement B: Boundary Element Modeling

Modeling of three upper crustal faults above one lower crustal fault was carried out using a 3-D boundary element code (Gomberg and Ellis, 1993). The three upper crustal faults in the model represented the faults on opposite sides of the Joiner Ridge and Reelfoot stepovers. These three faults were modeled as 300 km long by 15 km deep, vertical, and trending N47°E. The centers of the faults were set to overlie the lower crustal fault to minimize the effects of fault terminations. In the NMSZ the graben boundary and other faults with similar trends extend well beyond the stepover zones, suggesting that fault terminations do not control the stepover locations. The upper crustal faults were specified as stress-free boundaries that could slip freely, with no assigned displacement. The stress-free condition is consistent with the assumption that slip relieves the long-term crustal strains and that faults are weak enough to not retain substantial stress. Each fault was divided into 20 horizontal by 3 vertical elements.

In the first model, the lower crustal shear zone had a length of 800 km, extended vertically from 20 to 45 km depth, and was divided horizontally into 40 elements. The central 440 km of the deep fault was assigned a displacement of 10 m with slight tapering for 60 km on each end, and the remaining fault length (120 km on each end) was allowed to move freely to accommodate decreasing slip towards the ends of the fault. The deep crustal fault was directly beneath the centers of the upper-crustal faults, and slip died away along the northern part of the fault until reaching zero at an arbitrary location beneath southern Illinois.

In the second model, the lower crustal fault again had a length of 800 km and was divided into 40 elements. The elements were allowed to slip freely in the regional compression, but no displacement was assigned. However, the fault extended vertically into the mantle from 20 to 140 km depth, giving it a much larger area than in the previous model. This deep fault simulates, in part, the relaxation of ductile material in the lower crust and upper mantle (see discussion in Gomberg and Ellis, 1994). This larger area resulted in more slip (~5.4 m) than was induced on the smaller upper crustal faults (~3.6 m), thus giving a result that was similar to the first model in which slip was assigned to the deep fault.

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