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Supporting Information for

Mechanisms of shear band formation in heterogeneous materials under compression: The role of pre-existing mechanical flaws

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S1. Homogeneous model experiments at lower strain rate

We performed an additional set of experiments to test the sensitivity of homogenous PS blocks to strain rate in forming shear band structures (Fig S1). The experiments were run at a lower strain rate, 3×10^{-5} sec^{-1} to 2×10^{-5} sec^{-1}, as compared to those presented in the main text (Fig 2a). This range of strain rates produced sharp and narrow bands that are finely spaced and uniformly distributed in the entire model. They typically formed in conjugate sets, symmetrically oriented with respect to the compression direction. The bands multiplied in number with increasing finite strain, as observed in similar experiments at relatively higher rates, and they had no tendency to widen, but grow in length. The PS produced distributed narrow bands in its homogeneous state under the entire range of strain rate conditions used in our laboratory experiments. We thus conclude that uniformly thick bands of homogeneous shear (HBs) in low-strain rate experiments reflect the influence of weak flaws in the model.

Figure S1: Uniform development of closely spaced, conjugate narrow bands (NBs) in homogenous PS models deformed at low strain rate ($\dot{\varepsilon} = 2 \text{ x } 10^{-5}\ sec^{-1}$). Note that strain rate doesn't have any effect on shear band formation in homogeneous model.

S2. Across-band strain profiles in numerical models

This section discusses the strain profiles calculated from the numerical simulation MS2 run at relatively high rates (results presented in the main text). The profiles are constructed along the lines AB, CD, EF, as shown in Figure 6 in the main text. They represent plots of the 2nd invariant of the strain rate tensor (sum of the elastic, viscous and plastic strain components) as a function of distance in the model. The strain profiles contain multiple peaks that reveal the composite nature of shear bands, as observed in the PS experiments at a high strain rate (3 x 10^{-5} sec^{-1}).

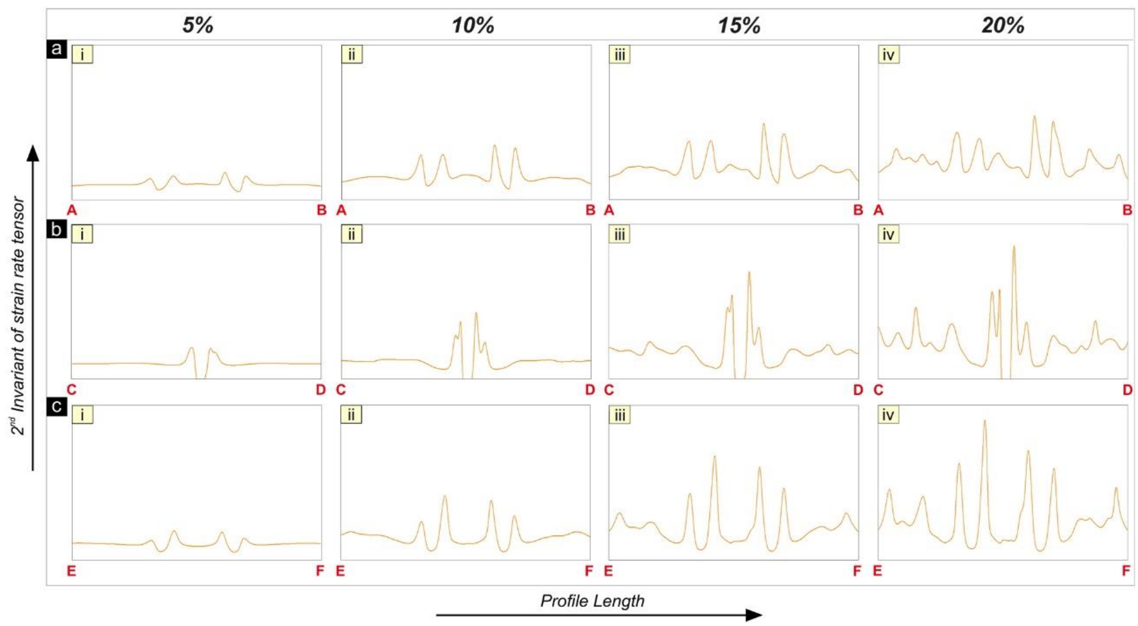

Figure S2: Across-band strain profiles in MS2 (locations of the profile lines: AB, CD, and EF, shown in Fig 6). Note that the strain profiles show multiple peaks signifying the formation of multiple shear bands in the core zone.

S3. Field study of natural shear zones

We studied a few centimetres to tens of metres long ductile shear zones in the Chotonagpur Granite Gneissic Complex (CGGC), focusing upon regions north of the South Purulia Shear Zone (SPSZ). The shear zones are associated with alkali granite, brecciated quartzite, apatite-magnetite bearing chert, U-Th mineral-bearing pegmatite and maficultramafic rocks. The host rock types include banded, porphyritic and augen granite gneisses, garnet-bearing quartzo-feldspathic gneisses, khondalite, amphibolites and mafic granulites, which generally contain penetrative tectonic foliations of single or multiple generations. The host foliations act as markers, showing sharp deflections across shear bands that allow us to identify the mode of shear localization. In places we could recognize mechanical heterogeneities as nucleating agents of shear zones. For example, high-temperature metamorphic rocks in the Jasidh area show band localization in the vicinity of quartzo-feldspathic aggregates, which possibly represent melt lenses (weak zones) produced by partial melting during the granulite facies metamorphism. This kind of field examples support our experimental interpretation that mechanically weak heterogeneities can be a crucial factor for the formation of isolated shear zones in continua.

We chose three prominent locations: 1) Bero Hillocks (23°32'09.5" N, 86°40'01.3" E) near Raghunathpur town, 2) Purulia-Asansol Road transect near Baraseni (23°25'20.9"N 86°28'48.8"E), and 3) Jasidih (24° 31′ 19.2″ N, 86° 38′ 51.72″ E) (Fig S1). Location 1 is predominantly composed of biotitic granite gneiss, which shows excellent shear band structures with thick strongly shear core, sometimes flanked by excellent drag zones on both sides, while some shows relatively weakly deformed matrix. Lithologically, Location 2 is a fine-granied granulite-facies rock, primarily composed of alkali-feldspar, with minor amounts of quartz, mica, garnet and tourmaline. Classically this rock type is also termed as Leptynite and they often show a planar gneissic structure. Location 2 exhibits extensive micro shear band structures with a cross cutting relationship throughout the exposure (Fig 8 a). Location 3 is situated near the Jasidih area, which lies in the northernmost part of CGGC. Lithologically, this area is predominantly of migmatitic felsic orthogneiss origin, with random enclaves of meta -sedimentary and meta-mafic rocks. We found excellent shear bands occurring in the vicinity of elliptical to semi-elliptical heterogenous clasts (Fig 8b), that can be well correlated with our heterogenous models (Fig 2 b).

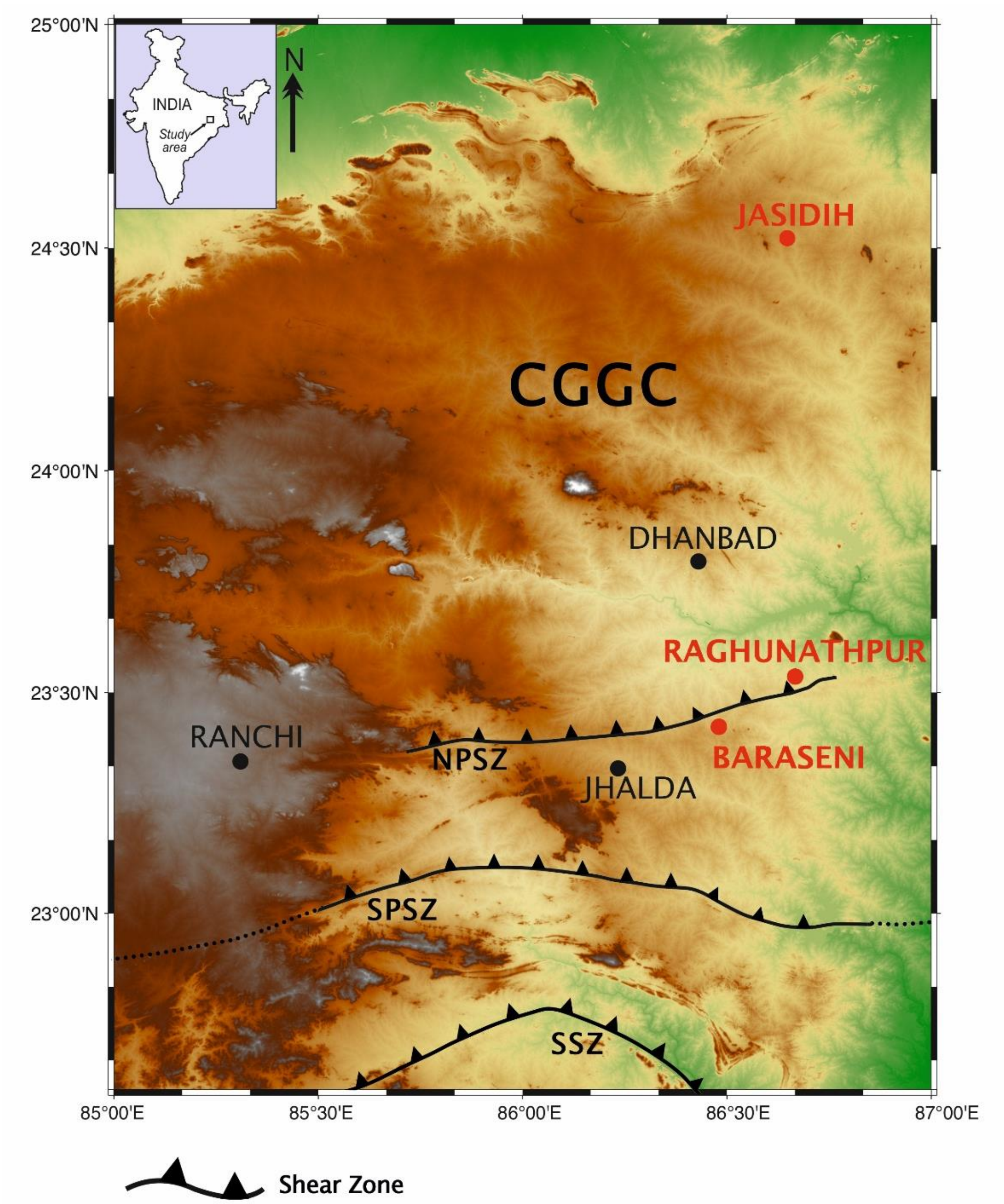

Figure S3: A simplified geological map of the East Indian Precambrian craton, showing the locations of the Singhbhum Shear Zone (SSZ), the South Purulia Shear Zone (SPSZ), the North Purulia Shear Zone (NPSZ) and the Chotanagpur Granite Gniess Complex (CGGC). Field areas are marked by red dots in the map.

S4. Strain profiles from field studies

This section presents the strain profiles obtained from strain analyses performed in field outcrops. Strain profiles were obtained by calculating the finite strain (ε) across various types of shear zones. Type I shear zones containing narrow shear bands observed in an area near Purulia town, showed a characteristic curve with a high peak showing large ε values implying intense shear localisation across the narrow shear bands (Fig 9b-i). Type II shear zones showed gradational shear strain variation from weakly deformed wall to highly sheared core forming a typical bell-shaped curve (Fig 9b-ii). On the contrary, Type III shear zones are characterized by a plateau like strain profile with very narrow gradational zone (Fig 9b-iii). This characteristic shape results due to formation of a very narrow drag zone on both sides of the homogenous core zone.

Table S1: Numerical Parameters and Their Values

Parameters	***Symbol***	***Natural Values***	***Numerical Input Values***
Model length	L	60 km	6
Model width	W	40 km	4
Model reference strain rate	$\dot{\gamma}_o$	1.00e^{-15}	1
Model reference density	ρ	2700 kg m^{-3}	1
Model reference viscosity	η_0	1e^{20} Pas	1
Initial Cohesion	C_i	20 Mpa	0.08
Cohesion after Softening	C_s	5 Mpa	0.02
Angle of friction	ϕ	25° - 30°	25° - 30°
Maximum Yield stress	σ_{max}	1000 Mpa	3.7
Minimum Yield stress	σ_{min}	10 Mpa	0.04
Elastic shear module	G	5 x 10^9 Pa	18.5