# Nanoparticles in the 2008 Yangjiagou rock avalanche

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Yangjia Gou is the name of a very famous location in China; the site of the original headquarters of the Red Army. But *gou* means valley, *jia* means family, and *Yang* is a common Chinese family name. So there are many Yangjiagou locations in China. Some are in western Sichuan province, and some of these have large landslides dating from 2008. Two different 2008 Yangjiagou landslides are described in the literature. Our Yangjiagou rock avalanche fell into a valley called Yangjiagou, from the summit of Weijia Mtn (31° 58' 01.68" N, 104° 34' 47.3" E) (Fig. 1), one of many landslides triggered in the 2008 Wenchuan Earthquake (Wasowski et al. 2021). It buried the deposit of an earlier large rock avalanche probably triggered by a previous large earthquake. But our site possibly is more notable for being the site of ongoing mitigation from repeated destructive debris flows since 2008 (Li et al. 2021).

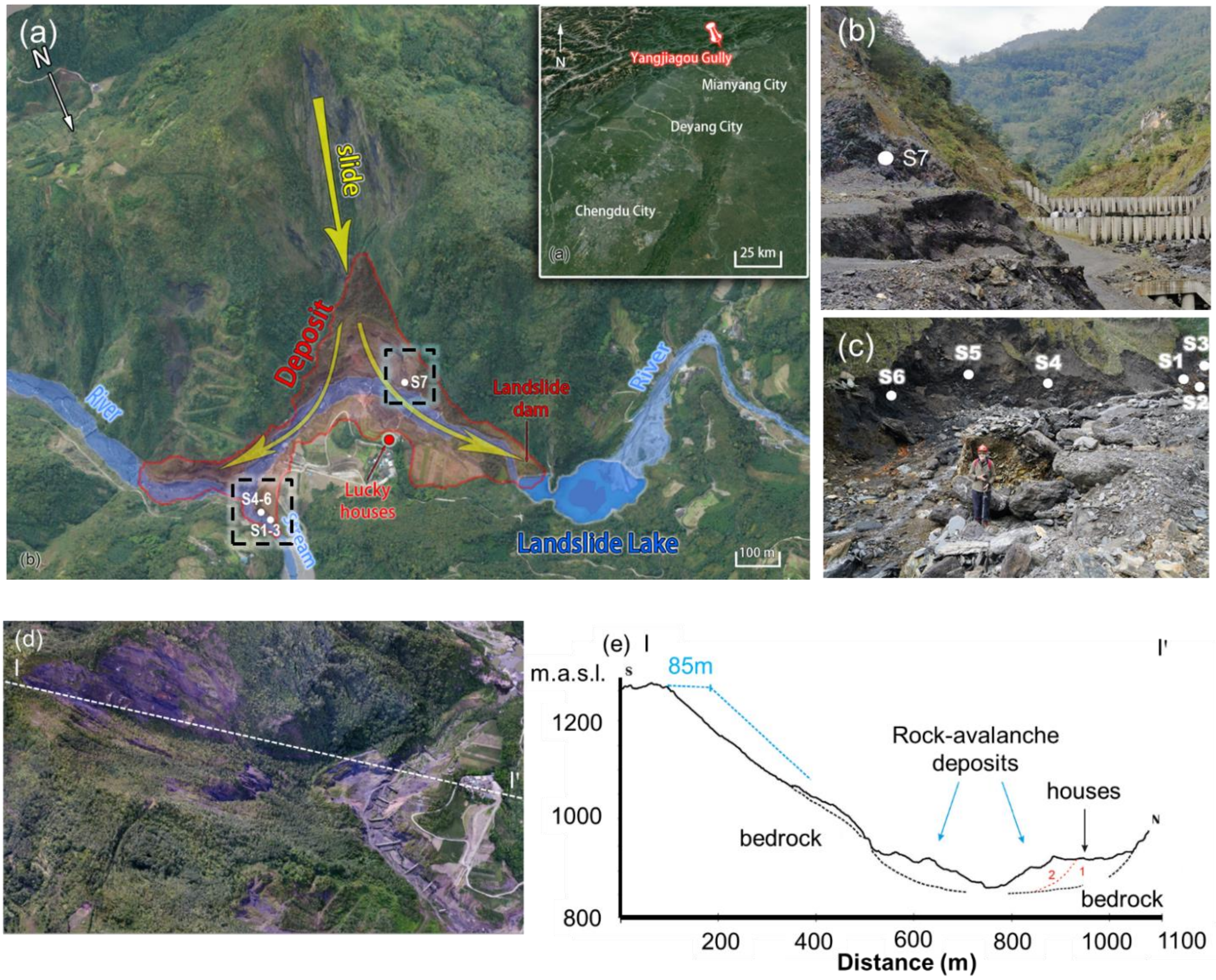


*Fig. 1. (a) Annotated image of the Yangjiagou rock avalanche from Weijia Mtn (after Li et al., 2021, from Google Earth) showing sites where the deposit was sampled for grain-size analysis (inset: location relative to Chengdu in Sichuan). (b) Debris-flow mitigation check dams and sample site S7. (c) Sample sites S1 to S6 (author MM stands in front of weathered pre-landslide alluvium). (d) Drone image of landslide source area and line I-I` of illustrated profile. (e) Profile of landslide from Weijia Mtn (1 and 2 refer to older and younger rock-avalanche deposits (see Wasowski et al. 2021).*

The 2008 Wenchuan Earthquake destroyed the pre-2008 road access to "our" Yangjiagou. As a consequence, the rock avalanche received little scientific study in the initial flurry of publications on Wenchuan Earthquake giant landslides. Post-earthquake topographic mapping of Weijia Mtn was not completed until 2018 (Wasowski et al. 2021). In the years since May 2008, the deposit of this Yangjiagou rock avalanche has been deeply eroded, largely in summer monsoon debris flows from breakout floods from a lake dammed by the landslide deposit (Fig. 1(a)).

The volume of the 2008 rock avalanche is ~3.5 million but its contact with the underlying older rock avalanche of undetermined age and volume is poorly defined. Both giant landslides came from Weijia Mtn and travelled a similar path. Their source rock is a melange of largely black calcareous shale. It contains substantial pyrite which weathers rapidly on exposure to oxygen in the finely comminuted landslide deposits. A part of the deposit has been quarried for manganese ore, formerly mined from Weijia Mtn.

The two deposits are distinguishable only at one small outcrop where they are separated by a truncated soil and bits of wood. We took seven bulk samples of rock-avalanche deposit from the sites indicated in Figs 1(b) and 1(c). Some samples were of sheared vein quartz (such as S1 in Fig. 2); others were of sheared shale (such as S2 and S3 in Fig. 2).

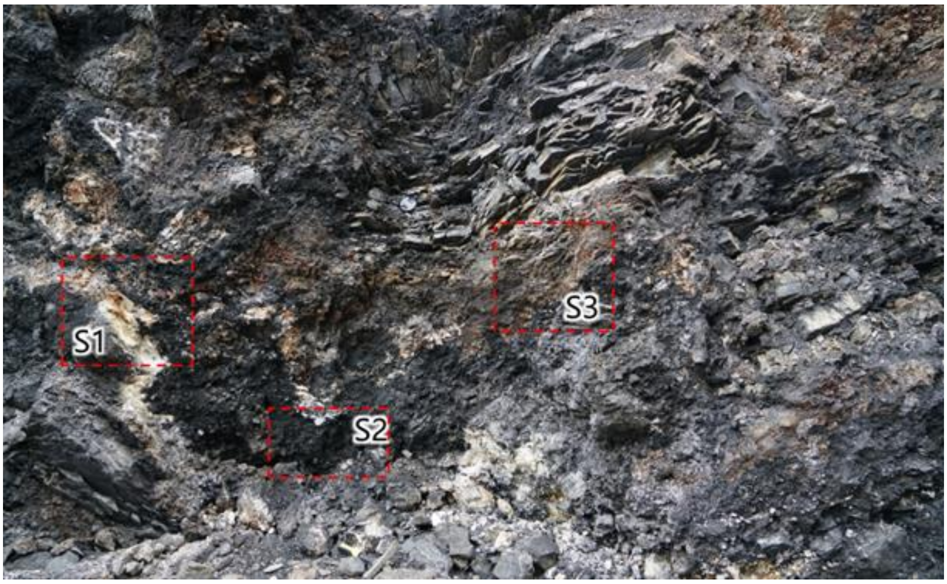


*Figure 2. Stream-side outcrop of 2008 rock avalanche, near but not at the deposit base. Location is shown in Fig. 1. Many of the whitish bands are remnants of highly sheared quartz veins – as at S1.*

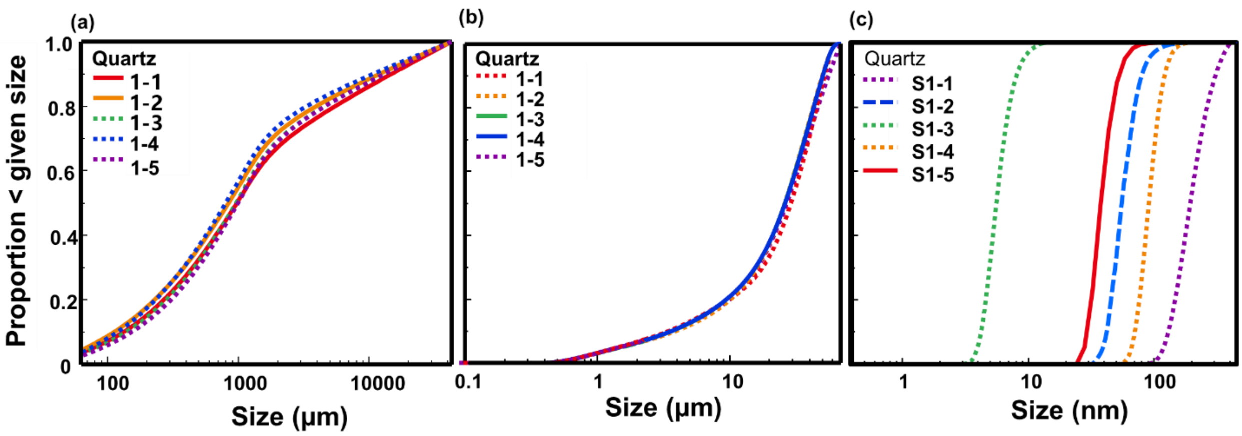


*Figure 3. Grain-size distributions across 3 size ranges of sample S1, an intensely sheared quartz vein. (a) is by sieving, (b) is by laser sizer of fraction passing finest sieve, (c) is by high-resolution nanoparticle sizer. Particles as small as ~4 nm are present after agglomerate disaggregation.*

*Figure 4. Outcrop of sheared shale near where sample S7 was collected from within a quarry (see Fig. 1a). This area is much closer to the rock-avalanche source, and much higher in the deposit than the sites of samples S1 to S6. As a consequence, this shale debris has experienced less shear strain than have the other samples from near the deposit base close to a distal margin (see Fig. 1a).*

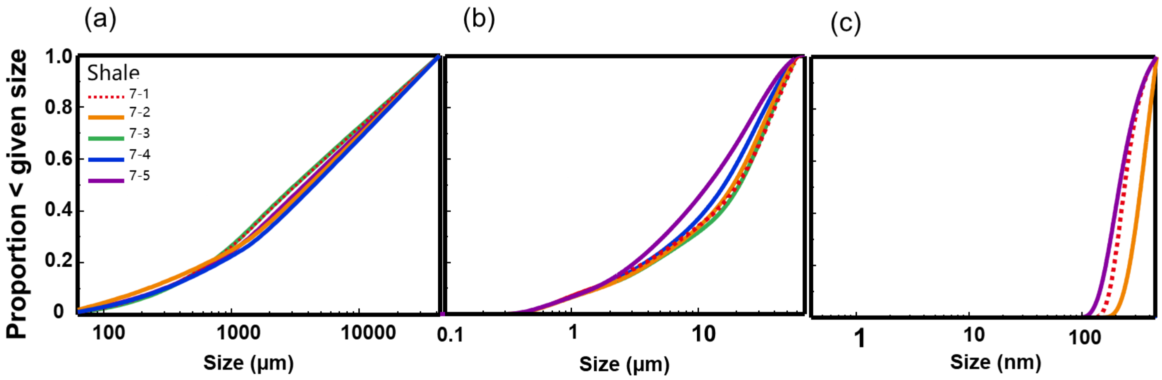


*Figure 5. Grain-size distributions across 3 size ranges of sample S7, sheared shale. (a) is by sieving, (b) is by laser sizer of fraction passing finest sieve, (c) is by high-resolution nanoparticle sizer. Particles as small as ~100 nm are present after disaggregation of agglomerates.*

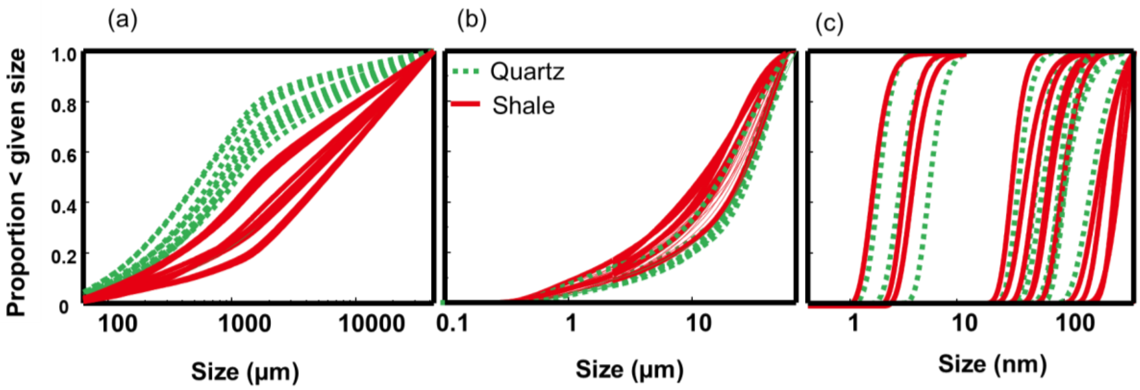


*Figure 6. Grain-size distributions across 3 size ranges of samples S1-S7, differentiated by whether they are of sheared shale or sheared quartz vein. (a) is by sieving, (b) is by laser sizer of fraction passing finest sieve, (c) is by high-resolution nanoparticle sizer. Particles as small as a few nanometers are present after agglomerate disaggregation.*

To further explore the effect of shear strain on grain-size distribution, we experimentally sheared quartz sand, and determined grain-size distributions after a range of different shear strain (Fig. 7). Methods are discussed in Hu et al., (2021).

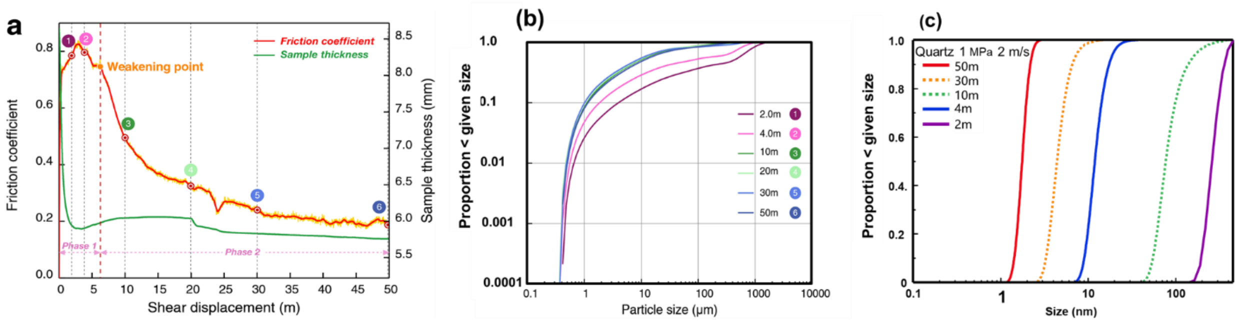


*Figure 7. Experimentally sheared quartz sand showing evolution of size grading with increasing shear displacement. After 50 m of shear displacement, particles as small as a few nanometers were present after agglomerate disaggregation.*

We then followed Turcotte (1986) to examine the fractal dimensions represented in our particle-size distributions (Fig. 8).

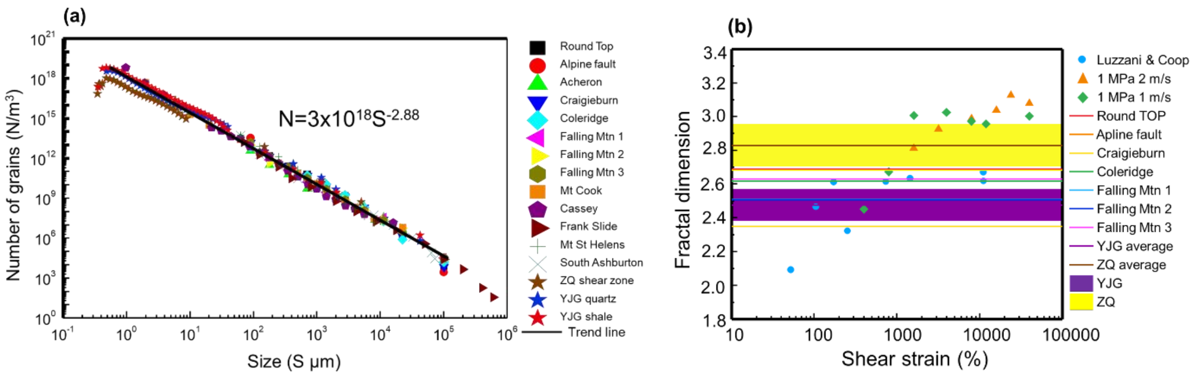


*Figure 8 (a) Distribution of numbers of grains per m³ by grain size for a number of rock avalanche size distributions. The trend line has a gradient of -2.88, suggesting a fractal dimension of 2.88. (b) Distribution of fractal dimensions by shear strain from a number of experiments, compared with the fractal dimensions from some rock avalanches and a fault gouge. The intersection of the trend in fractal dimensions of shear experiments with fractal dimensions of rock avalanche deposits confirms the suggestion of Zhang & McSaveney (2017) that such deposits store quantitative evidence on internal shear during runout.*

The fractal dimensions exhibited by our deposit samples at Yangjiagou (YJG, Fig 8b) suggested that the sampled deposits had undergone shear strain in the range 100–500% during emplacement: an example of rapidly progresssive brittle rock failure in about 100 seconds.

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