Multiple modes of deformation in a fault zone juxtaposing dissimilar rock types, southern Chupadera Mountains, Socorro County, New Mexico

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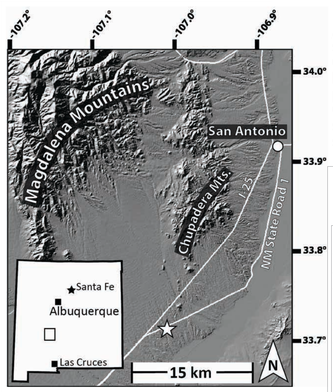
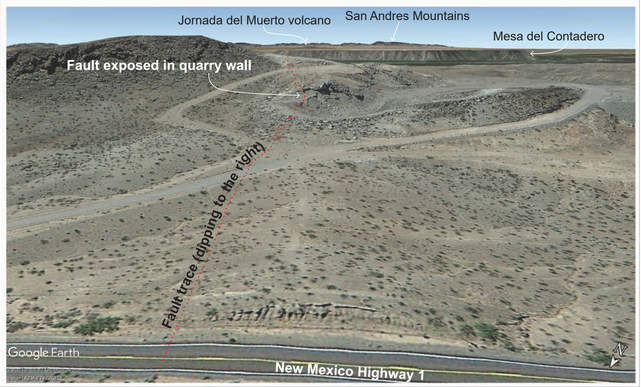
Abstract

In the southernmost outcrop of pre-Quaternary rock in the Chupadera Mountains, Socorro County, New Mexico, a down-to-the-south normal fault is exposed in a bedrock quarry just east of New Mexico State Road 1. Physical characteristics of this fault zone grant insight into timing and methods of faulting in the San Marcial basin, a Rio Grande rift sub-basin that contains few fault outcrops. This quarry exposes silty sandstones of the Spears Group and the Andesite of Willow Springs, which are of similar upper Eocene age. The east wall of the quarry exposes the fault, where both the hanging and foot walls comprise andesite in a ~20 m-wide fault zone around a 1.5 m-wide fault core. Outcrop geometry suggests that the Spears Group sedimentary rocks are no more than ~10 m below the fault outcrop. Nearly all fractures in the fault zone are filled with cataclasized sediments showing physical and mineralogical similarities to the sedimentary rocks of the Spears Group. Cataclasites at the study site contain clasts with a smaller average diameter than the nearby Spear Group sediments, and microtextural observations suggest grain-to-grain comminution during faulting likely caused quartz spalling. While the majority of cataclasite in the fault zone appears to have been transported into fractures via particulate flow processes, interpreted here to represent faulting prior to lithification or during poorly-lithified conditions, the presence of angular clasts of sandstones within the fault zone also suggests that portions of the Spears Group also exhibited cohesive behavior during faulting, interpreted to represent relatively well-lithified sands. Other features in the fault zone include zones of oxide clast concentration within cataclasites and post-faulting calcite vein mineralization. Because the San Marcial basin lack a topographically-expressed uplifted footwall block or basin-bounding horsts, little is known about timing and styles of faulting during the basin's tectonic and sedimentary evolution. This fault is the most basin-central known fault in the San Marcial basin and therefore offers insight into increasing understanding of its tectonic history.

Location



Left: Hillshade digital elevation model of study area in the San Marcial Basin. Quarry site marked by white star in bottom center at southermost outcrop of pre-Quaternary rocks associated with the Chupadera Mountains uplift. Inset map shows study area (empty rectangle) in southwest New Mexico.



Below: Oblique aerial image looking southeast at the study outcrop location. The fault strikes 155° and dips 45° SW. The quarry pit just right of the fault trace is approximately 12 m deep. The fault trace is mostly obscured except in the quarry walls. Scale varies in this perspective, but the two-track dirt roads give some sense of scale.

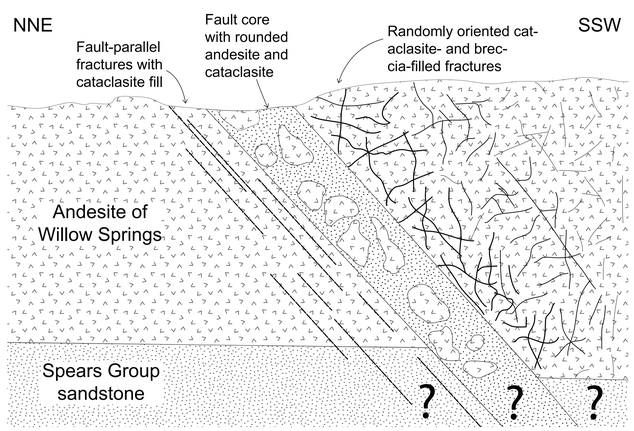
Key Points

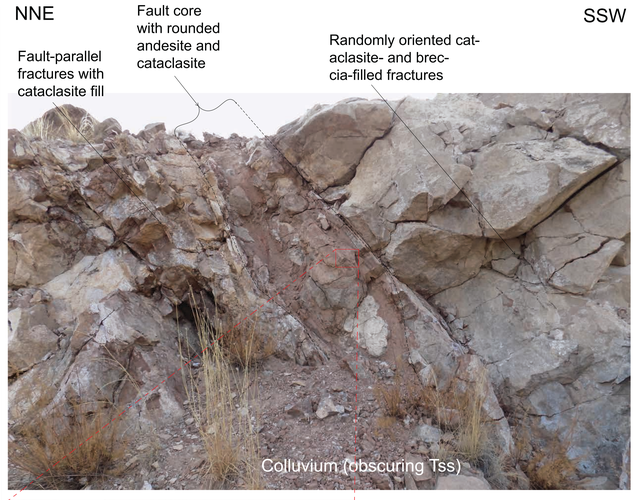
- The San Marcial basin (SMB) is a Rio Grande rift subbasin located between the Socorro and Engle basins in southern Socorro County.
- The SMB lacks a topographically well-expressed uplifted footwall block or basin-bounding horsts.
- Interpretations of SMB structural development have relied upon gravity data (e.g., Gallant et al., in press) and projection of faults from surrounding highlands (e.g., Cikoski et al., 2013).
- **Deformation features at this fault suggest that some motion occurred while the Eocene Spears Formation was unlithified or poorly lithified.**
- **Other deformation features within the fault zone suggest fault motion post-lithification of the Spears Group.**

Geologic Setting

- The San Marcial Basin (SMB) contains at least hundreds of meters' thickness of Neogene and Quaternary basin-filling sediments.
- The Chupadera Mountains comprise myriad rocks of Mesoproterozoic to Cenozoic age.
- Pertinent Chupadera Mountains rock units to this study are the Eocene Andesite of Willow Springs (Twa) and the Eocene sandstones of the Spears Group (Tss).
- Tss was deposited in alluvial environments during the eruptive episode of the Mogollon-Datil volcanic field which produced Twa; the two units are interbedded.
- The timing of fault motion at the study site is constrained only by the maximum age (Eocene) provided by the faulted rocks and the assumed minimum age (Pleistocene) provided by the apparent unfaulted nature of the surrounding surficial basin fill.

Fault zone geometry





Left: Aligned fractured cobbles and pebbles of Tss arenites from within fault core. Darker red fractures are filled with cataclasite of similar composition to Tss but which shows evidence of fluidized and disaggregated flow during faulting.

Right: Brecciated Twa with fractures filled with disaggregated Tss in the hanging wall. Tss filled fractures with apertures as narrow as 100 µm.

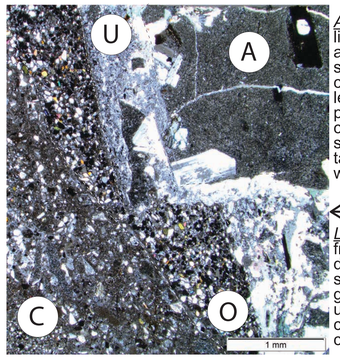
Microscopy

- To test the hypothesis that the fine-grained cataclasite in the fault zone was derived from the Spears Group, I measured clast long-axis diameters in Tss and in cataclasites.
- Results (Table 1) show that cataclasites are finer and better-sorted than Tss.

	Cataclasite	Spears Group Sandstone
Average grain size	65 µm	96 µm
Median grain size	63 µm	80 µm
Standard deviation	24.08	82.43
n	383	419

Table 1. Clast size summary from arenites of the Spears Group and of fine-grained cataclasites from within fault zone fractures at the San Marcial quarry.

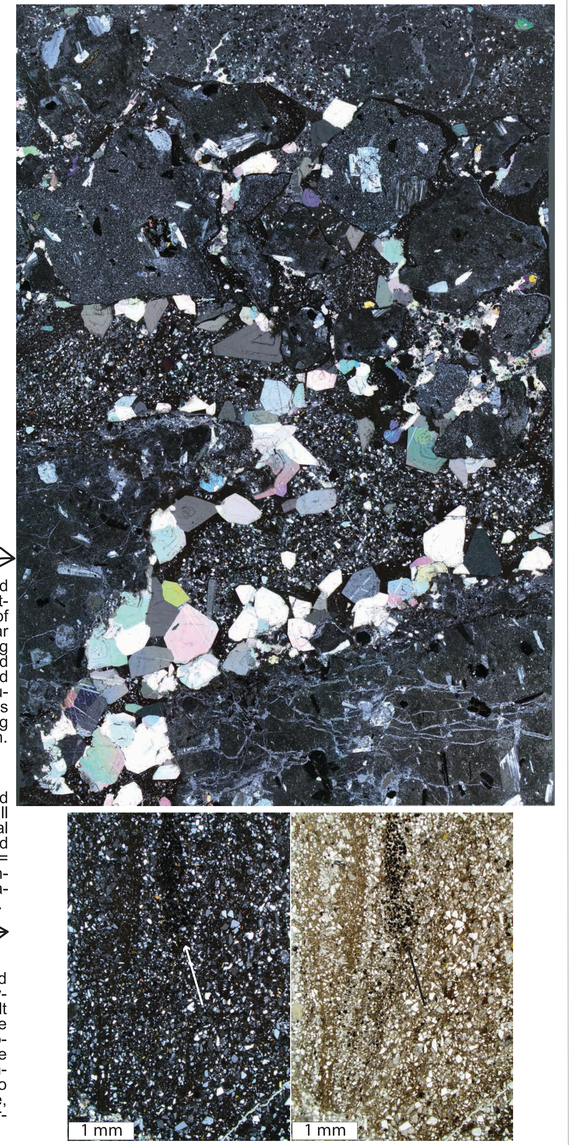
- Tss sandstones contain moderately sorted angular to subrounded (predominately subangular) medium silt through granules (predominately very fine sand) with a sand composition of 50±10% quartz, 30±5% feldspar, and 20±10% lithic fragments (lithic arkose).
- Fine-grained cataclasites contain moderately to well-sorted angular to rounded (predominately subangular) medium silt through fine sand (predominately very fine sand) with a sand composition of 55 ± 10% quartz, 10 ± 4% feldspar, and 35 ± 8% lithic fragments (lithic arkose and feldspathic litharenite).
- Cataclasites display sorting based on both clast size and composition; concentration of oxide grains is seen in cataclasites throughout the fault core and hanging wall damage zone but not in Tss.



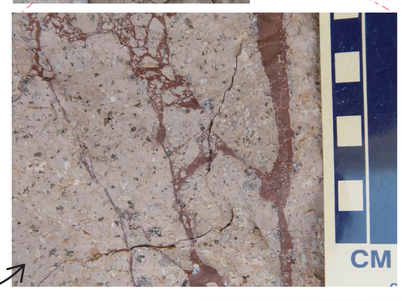
Above right: Full thin section cross-polarized light (XPL) photomicrograph showing ultracataclasite-filled fractures in Twa (bottom right of slide), fine sand-sized cataclasite of similar composition to Tss in a large fracture running left-to-right across middle of slide, and post-faulting carbonates (higher-order colored crystals, some exhibiting zoning and fluid inclusions, throughout slide). This sample was taken 3.5 m from the fault core in the hanging wall damage zone. Dimensions = 27 x 46 mm.

Left: XPL photomicrograph of cataclasite-filled fracture 30 cm from fault core in hanging wall damage zone. Cataclasite exhibits internal sorting based on mineral composition and grain size. A = Andesite of Willow Springs; U = ultracataclasite; O = zone of oxide grain concentration within cataclasite; C = typical cataclasite bearing compositional similarity to Tss.

Right: XPL (left) and plane-polarized light (right) photomicrographs of layering in cataclasite within the fault core. Arrows indicate zone of oxide clast concentration, a feature observed in sandy cataclasites at the study site but not in Tss, which contains 1-3% oxide grains. Note also bands of size sorting. In this sample, the layers were originally roughly parallel to the fault.

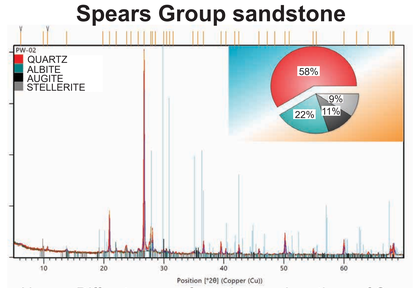


Left: Hanging wall damage zone with fractured and brecciated Twa. Fractures are filled with fine-grained cataclasite bearing compositional similarity to Tss, which is approximately 10 m stratigraphically below this outcrop.

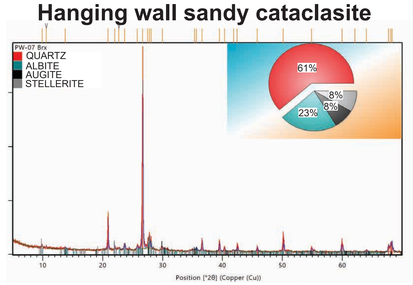


X-ray Diffraction

Spears Group sandstone



Hanging wall sandy cataclasite



Above: Diffractograms from the sand portions of Spears Group sandstones (left) and cataclasite from within the hanging wall damage zone (left) at the study site. The mineral compositions of the two samples are indistinguishable, suggesting that the unlithified or poorly lithified sediments of the Spears Group were incorporated into the fault zone prior to lithification.