# Development of Micro-fractures within Shear Zone Revealed by X-ray Micro-CT Scan: Examples from Rock Halite in Ring-shear Experiments

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## Introduction

Fractures, generally referring to Riedel shear structures, within shear zones of different scales manifest itself as a system of fractures/shears on a relatively smaller scale [Tchalenko, 1970], ranging from continental-scale strike-slip faults, shear zones along the sliding surfaces of landslides, to microscopic deformation bands. They are believed to develop during early episode of fault motions or landsliding, and can offer critical knowledge such as rock properties, fracturing temperature, and changes in regional stress field [Anders et al., 2014].

In order to understand the formation mechanism and sequence of fractures with different orientations, various experiments and field work were performed during several decades around the world, most of which contribute to two-dimensional field mapping and/or thin-section observations under optical microscope or scanning electron microscope (SEM) besides mechanical behavior studies.

Until now three-dimensional microstructural observations on fractures are rare compared to intense two-dimensional researches mentioned above. Thus, present study tries to render three-dimensional information about fractures within shear zones and provide a more comprehensive insight into the mechanism behind.

## Methodology

Twelve ring-shear experiments using rock halite materials (grain size > 2 mm) were conducted on two ring-shear apparatuses (producing two different kinds of annular samples in size) in terms of (1) shear displacements (1, 2, 3, 4, 6, and 8 m), (2) normal stresses (200, 500, and 1000 kPa) as well as (3) shear velocities (0.05, 0.5, and 5 cm/s), respectively.

In each test, the shear box was opened and the shear zone was observed after all operations finished. Annular shear zones formed in all the tests. The annular shear-zone products were cut into 3 or more segments, which were then scanned using X-ray micro-CT (XCT) scanner to obtain high-resolution images in three-dimensional space.

## Results and conclusions

Six types of Riedel shear structures (conjugate R and R’, passive P, displacement-direction-parallel Y shears, X, tension T, as shown in Fig. 1; subsidiary fractures in micro-scale, micro-fractures) and preferential orientations of rock halite grains can be recognized in three-dimensional images obtained by non-destructive XCT (see Fig. 2).

As shown in Fig. 2, small shear displacement (1 m) generates 5 types of shears except Y shears. And the number of Y shears increases as shear displacement becomes larger.

Some conclusions could be drawn as follows:

1) Long shear displacement or high shear velocity (not shown as attached figures here and will be in the formal presentation) leads to multi-layered (Y shears) shear zone individually. These Y shears are the potential sliding surfaces of landslides, and can be also related to bedding structures as well as repeated seismic slips within strike-slip faults.

2) High normal stress (not shown as attached figures here and will be in the formal presentation) will otherwise prevent the development of Y shears.

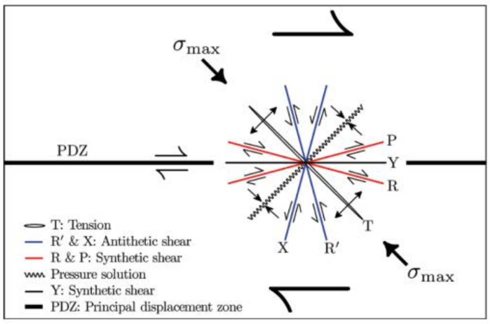


**Fig. 1**: An idealized Riedel shear system containing six types of shear structures [Xu and Ben-Zion, 2013].

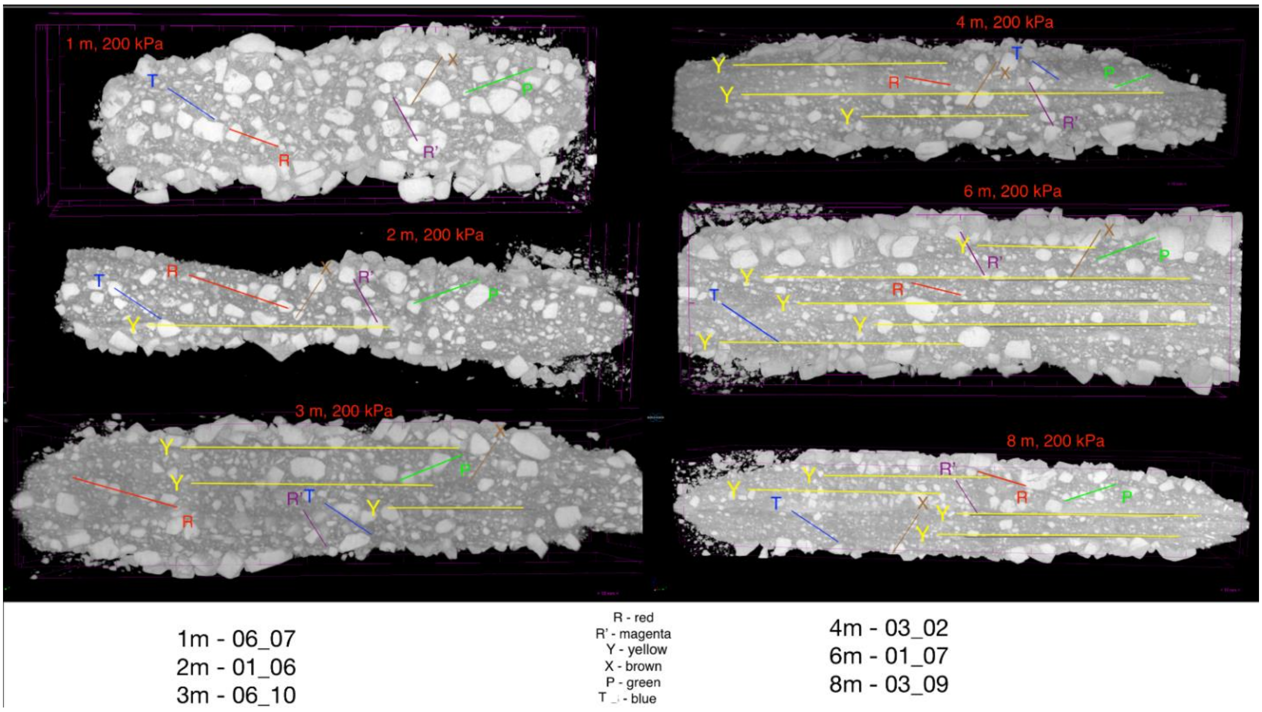


**Fig. 2.** Six types of Riedel shear structures can be recognized in terms of different shear displacements (1, 2, 3, 4, 6, 8 m) in present study. One interval in all the three-dimensional magenta boxes around the samples denotes 10 mm.

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## References

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