Shear Zone Deformational Trajectory-An Optical Analogy-Research Note

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Abstract: *Shear zones are tabular and usually elongate zones of strain produced by shearing forces on a rock. They are microscopic to regional scale domains across which displacement has taken place. They contain foliation sub-parallel to the principal plain of the strain ellipsoid. Their occurrences enhance rock permeability for ground water accumulation and flow. They also serve as avenues for accumulation of mineralizing fluids. Economically they are often exploited in quarrying and blasting operations. The present work is based on field observations and the literature; it demonstrates an analogy between features of tectonic refraction across shear zones and those of optical refraction. The structural (deformational) trajectory of shear zone is compared to the optical pathway of light ray as the latter passes from a dense to denser medium. It explains the structural mechanics behind the existence of tectonic (shear zone) refraction.*

Key Words: *Stress, tectonic,Shear zones,optical refractions,deformational trajectory,*

I. Introduction

Collins dictionary of geology (2011 edition) defines a shear zone as a tabular zone of rock showing evidence of shear stress in the form of crushing and brecciation by many parallel fractures. Hobb et al. (1976) describes a shear zone as a zone of large ductile shear strain with or without a component of shortening perpendicular to the zone. Passchier at al. (1990) describe it as relatively narrow planner zone of high ductile strain between less deformed wall rock, across which markers, such as layers or veins are displace. They go ahead to describe shear zone as ductile analogue of brittle fault zone. Hatcher Jr. (1995) says a shear zone is a zone of closely spaced, interleaving, anastomosing brittle faults and crushed rocks near the surface, or zone of ductile faults and associated mylonitic rocks at great depth.

Common to the descriptions by these authors are that the shear zone is tabular and has experienced strain by shearing forces, with the presence of crushed (brecciated) rock. The zone is sandwiched by less deformed wall rock.Ramsay and Huber (1983) categorize shear zone into the brittle and ductile types. The first type shows strain discontinuities across a plane, while the latter shows stain variation which may be continuous across the zone.

Ramsay (1980) presented two boundary conditions as attributes and geometric features of ideal shear zones viz. They are:

a. generally they have parallel sides
b. Displacement profiles along any cross section through a shear zone should be identical.

In shear zones mineral crystals or crystal aggregates are flattened and stretched along the axis of the zone into lenses which impart a foliational fabric to the rock. The boundary of the shear zone and wall rock is transitional. Originally planner or linear structures will experience extension or shortening depending their initial on orientation.Shear zones are economically important as pathways and accumulation avenues for mineralizing fluid. They also serve as planes of weakness in rocks which are often exploited in quarrying operations. When shearing stresses exceed the shearing resistance of the rock fracture results. Movement along the fractured plane causes fault development. Hence its common place to see shear zones and faults occur together in the field. Together with other factures they enhance rock permeability for ground water accumulation.Highly deformed rocks from ductile shear zones are called mylonites (Hobbs et al., 1976). Passchier et al. (1990) gave three high strain criteria for recognition of shear zones in gneiss terrains. There are: the presence of a strain gradient across the zone; i.e. strong

deformation at the centre to weakly or undeformed wall rock (Fig.1).

Fig.1. Typical shear zone in a rock (Internet source).

Secondly in undeformed host rock, the strain gradient results in a characteristic pattern of increasing intensity of foliation toward the shear zone and bending (refraction) of this foliation into the zone. Thirdly pre-existing veins or layering and foliation in the host rock are displaced along shear zone.

This work is based on studies/observations of shear zones in the field and the literature. It attempts to present some structural features of shear zones which are comparable to what is observed in refraction optics. In order words the deformational trajectory of shear zone is compared to the optical trajectory or pathway of light as it undergoes refraction (from a dense medium to a denser medium).The term deformational trajectory as used here connotes the pathway defined by alignment of deformed mineral grains across the shear zones.

The path of light as it passes from a fast medium to a slow medium bends towards the normal to the boundary between the two media. Fig.2 shows a simple refraction set up. The magnitude of bending depends on the indices of refraction of the two media. As the speed of light is reduced in slow (denser) medium, the wavelength is shortened proportionately. The frequency is unchanged; it is characteristic of the source of light and unaffected by the medium changes.
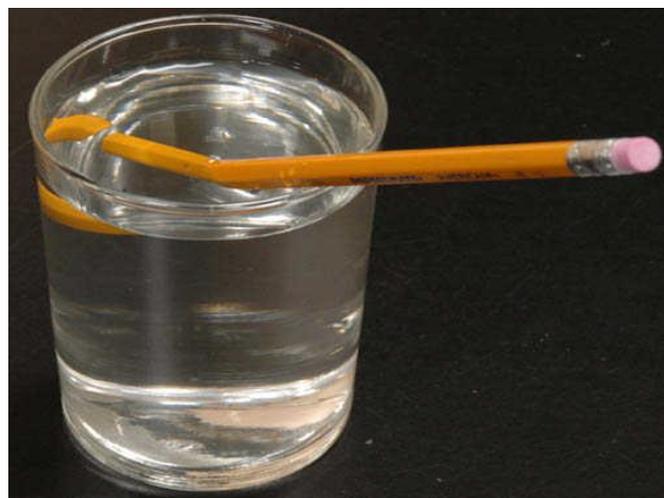
Fig.2.Asimple refraction set up (Internet source), showing the bending of light as it passes from a dense medium (air) to a denser medium (glass).

Ron Kurtus (2012) explains that the slowing of light speed through a denser medium is caused by electric fields in the material. The low speed of electromagnetic radiation as it passes through a transparent material such as glass or water is because of the effect of the electric fields surrounding the electrons and nuclei of the atoms in the material. These fields act as friction on the light wave impeding its propagation hence it slows down.In the following Figure the deformation path of a shear zone is traced following alignment of mineral crystals across it.The deformational path is also called structural trajectory.
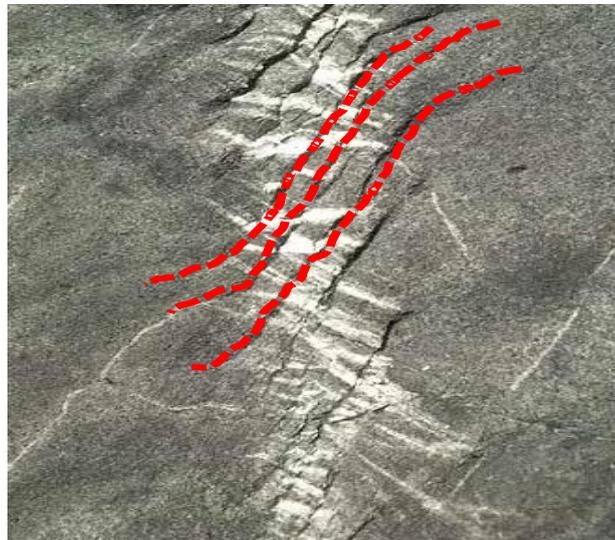
Fig.3. Deformational trajectories (red broken lines) across a shear zone. Notice the 'refraction' of the trajectories into the shear zone,(source of shear zone picture: internet).

The structural trajectory is seen to bend toward the shear zone and away from it from any direction.

II. Discussion/Conclusion

The bending of the structural trajectory across a shear zone is analogous to light to light ray traveling from a dense medium to a denser medium, and back to the dense medium. There is greater density of minerals grains within the shear zone because the minerals have undergone mechanical fragmentation during shearing. This is followed by concentration of mineral the grains, making the zone more densely packed than the unsheared adjoining rock. At the border/transition zone the shear force produce mechanical rotation of the mineral grains causing the bending appearance or "refraction" appearance. Drury (1987) describes deformation in a shear zone as involving angular relationships, so that linear features outside the shear system are seen to swing to it as shown in Fig.3.

The concentration of the minerals within the shear zone is because the rock is compressed maximally and perpendicularly by stresses while extension occurs perpendicularly to the direction of impact of the maximum stresses. The rock is consequently flattened on the plane of the shear zone. The 'refraction' of the deformational trajectory along the shear zone is an evidence of non-coaxial flow into the shear zone.There exist an optical analogy between shearing deformation in rocks as marked by the deformational trajectory which bends across the shear zone, and optical refraction of light, where the rays bend across the boundary of two media of different densities. **This is a scientific note!**

The following Table (1) compares the features of shear zone refraction and those of optical refraction.

Table 1:Features of shear zone refraction and optical refraction.

S/N	Shear Zone Refraction	Optical Refraction
1.	Involves change in deformational trajectory	Involves change in optical travel path
2.	Stretching of mineral aggregates along shear zone and shortening perpendicular to it.	Reduction in wavelength of light across denser medium with frequency of light unaffected.
3.	Rotation of mineral aggregates along boundary of shear zone, with fragmentation and concentration within shear zone.	Bending of light ray in dense medium due to slow speed is caused by frictional resistance of electric field of nuclei/electrons of atoms.
4.	Deformation path produced is reversible	Ray path is reversible.
5.	Deformation produced by shearing forces	No scientific records/reports of deformation.
6.	Deformation of mineral grains depends on hardness. Feldspars are fractured while quartz are plastically deformed	''

References

[1].   COLLINS DICTIONARY OF GEOLOGY 2011. (Internet-Linked). Harper – Collins 77-85 Fulham Place Road, London, W6 8jB.
[2].   DRURY, S.A. 1987. Image Interpretation in Geology. Allen & Unwin, London 176p.
[3].   HATCHAR, R.D. (JR) 1995. Structural Geology: Principles, Concepts and Problems (2ndEdition) Prentice Hall, New Jersey 525p.
[4].   HOBBS, B.E., MEANS, W.D., AND WILLIAMS P.F. 1976. An outline of Structural Geology John Wyley & Sons 5Hp.
[5].   PASSCHIER, C.W., MYERS, J.S., AND KRONER, A. 1990. Field Geology of high grade gneiss terrains. Springer – Verlag, 150p.RAMSAY, J.G. AND HUBER, M.I. 1983.The Techniques of Modern Structural Geology. Vol.2 Folds and Fractures Academic press.
[6].   RON K. 2012. WIKIPEDIA FREE ENCYCLOPEDIA (Internet material).

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