Coseismic Injectites At Stressed Ramps on the Naukluft Thrust, central Namibia

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MOTIVATION

Thrust ramps influence static stress change fields and can control the style of fault deformation and damage...

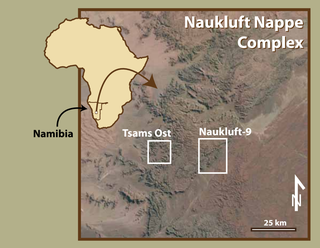
How do static stress change fields influence the style of fault rock deformation and off-fault damage during coseismic slip?

GOALS

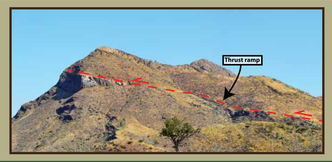
Compare static Coulomb Stress models with observed fault rock injectites on the Naukluft Thrust

Use observed injectite dimensions to estimate paleoearthquake magnitude

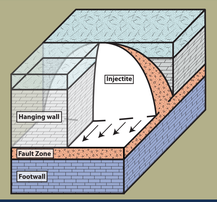
BACKGROUND



- **The Naukluft thrust is a ~500 Ma basal foreland thrust fault [1,2]**
- **Emplaced dolostone, quartzite, and shale sequences above limestone and shale.**
- **Far-travelled nappe transport: 50-80 km due southeast [3].**
- **Over ~200 km exposure [1].**



- The Naukluft Thrust ramps in the Naukluft-9 locality [4].
- Thrust ramps influence the static normal stress change during fault motion by focusing stress change gradients at inflection points[5].
- Sharper inflection points produce sharper stress change gradients [5].
- Along the length of the ramp, static normal stress change is in tension perpendicular to the ramp as the fault dilates to move past the ramp [5].



Fault injectites occur when coseismic stres in the fault exceeds the tensile strength of the wallrock. The wall rock fractures and *fluidized fault core material is emplaced into the fracture*

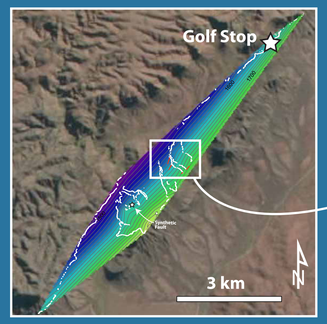
Examples of fault injectites include gouge injections and pseudotachylite injections

Methods

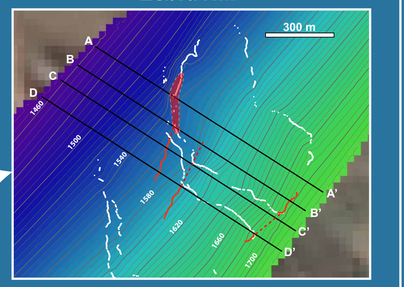
Two localities on the Naukluft Thrust were mapped using Trimble GeoXH GPS units. Fault surface topography was modelled from GPS data using a Natural Neighbor method. Cross sections of the interpolated fault surfaces were used to model the geometric influenced stress changes in the USGS Coulomb3 software.
These stress change models were compared with observed fault zone rocks, damage and injectites.

FAULT GEOMETRY AND STRESS CHANGE

Naukluft-9



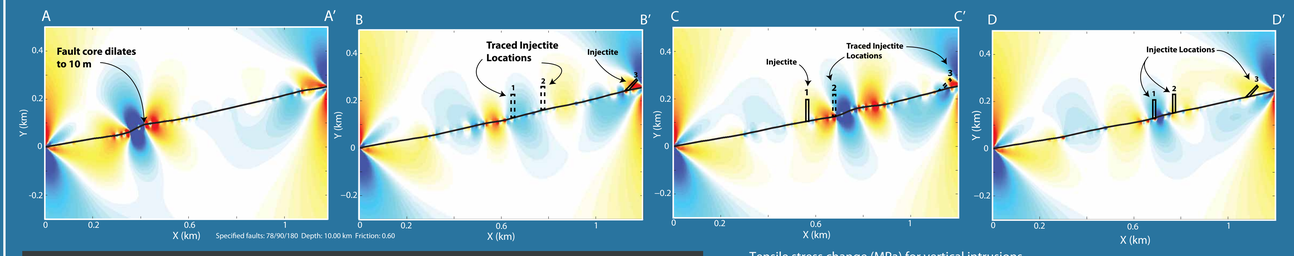
Zebra Hill



Here fault rock injectites and a zone of fault dilation are mapped relative to the modeled fault surface topography

Injectites have an average strike of ~030°, roughly perpendicular to hangingwall transport direction

Normal Stress Change (MPa) and Injectite Locations



A zone of fault dilation correlates with a sharp gradient between tensile and compressional stress change in A-A′

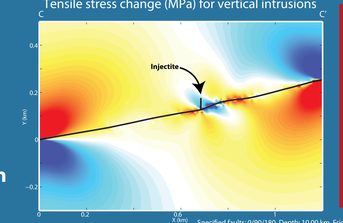
The extent of Injectite 2 traced to C-C′ is located at a zone of sharp tensile and compressional stress change gradients

Normal Stress Change for an idealized vertical intrusion on C-C′ places the injectite in a zone of tension

Tension — **Compression**

-7 — **7**

Tensile stress change (MPa) for vertical intrusions



Static stress changes, controlled by fault geometry, reinforce and localize dynamic stresses during coseismic slip where zones of compression work to squeeze fluids towards areas of tension and wall rock fracture

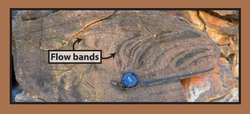
NAUKLUFT THRUST ROCKS AND INJECTITE MORPHOLOGY

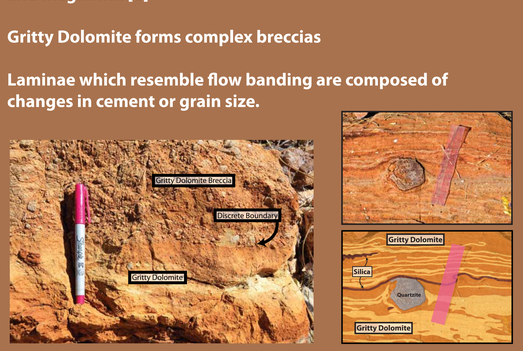
Gritty Dolomite

Granular fault rock was a slurry of super-critical CO2, dolomite grains, wall rock clasts, and neocrystalized dolomite, quartz, and magnetite [6]

Gritty Dolomite forms complex breccias

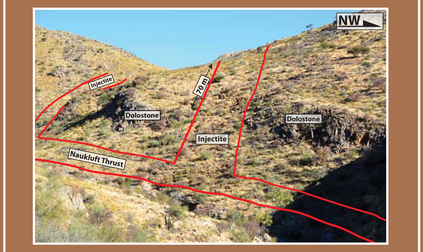
Laminae which resemble flow banding are composed of changes in cement or grain size.





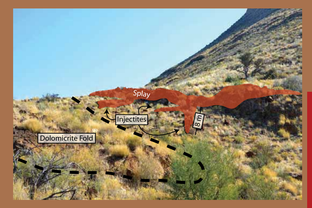
Zebra Hill Injectites

- **Generally tabular in shape, slight tapering towards the tip.**
- **Vertical extent 50 - 70 m from the fault plane**
- **Laminae parallel injectie walls**
- **Emplaced upsection into dolostone**



Golf Stop Injectites

- **Emplace downsection from a splay fault into shales and dolomicrite.**
- **~8 m in length with a sharp taper**
- **Gritty dolomite is red compared to elsewhere on the Naukluft Thrust**
- **Doubly-terminating quartz**



Here the Naukluft Thrust footwall is shale. Gritty dolomite forms an anastamosing network of small sills and dikes

Host lithology may be a major control on Injectite morphology

Where dolostone: large, tabular injectites

Where shale: anastamosing network

PALEOEARTHQUAKE MAGNITUDE

What can we learn about ancient earthquakes from injectites?

Gritty Dolomite is composed of neocrystallized dolomite, neocrystallized quartz and silica, magnetite, and wall rock inclusions [6].

This fault rock was a fluidized slurry supported by dissociated CO_2 [6]

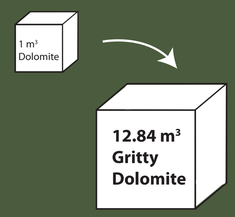
Frictional heating on the fault plane dissociated the CO_2 from a Dolo-mylonite laye r typically 5 cm thick [6]

Field data constrains injectite volume:

Height: 50 - 70 m
Width: 8 - 10 m
Length (into hillside): 220 m

What magnitude earthquake generates observed injectites?

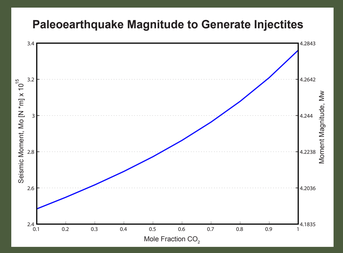
To calculate a relationship between a volume of Gritty Dolomite observed and a starting volume of Dolomite source rock the volume of CO_2 dissociated from 1 m^3 of dolomite at 50 MPa and 800 °C .



Using the above relationship with observed injectite volumes and the thickness of the dissociating layer (5 cm) the earhtquake slip patch is calculated.

Minimum energy to form injectite material

M_w ~ 4.2



BREAKING NEWS!

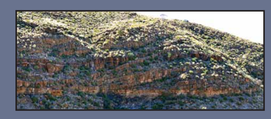
DOWNPLATING

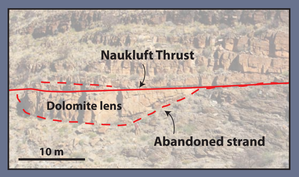
Underplating is a major process in subduction zones

Subduction erosion destroys material

Is this evidence of underplating's evil twin: Downplating?

At the Tsams Ost locality the Naukluft Thrust is low angle with a flat geometrthrust is low angle with a flat geometry. Deformation is accomodated through hanging wall folds and imbricate thrusts





***Downplating:** The fault abandons a lower, geomerically unfavorable strand and deformation continues upsection. A lens of hanging wall material is incorporated into the footwall.*

Questions:
Have you seen other field analogs of this process?

Has this process been reported before?

Bibliography

[1] Korn and Martin, 1959
[2] Ahredhent et al., 1978
[3] Martin et al., 1983
[4] Fagereng et al., 2014
[5] Kilsdonk and Fletcher, 1989
[6] Rowe et al., 2012

Acknowledgements

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