Stress orientation variability along the Hikurangi Subduction Margin (HSM): Insights from borehole image logging

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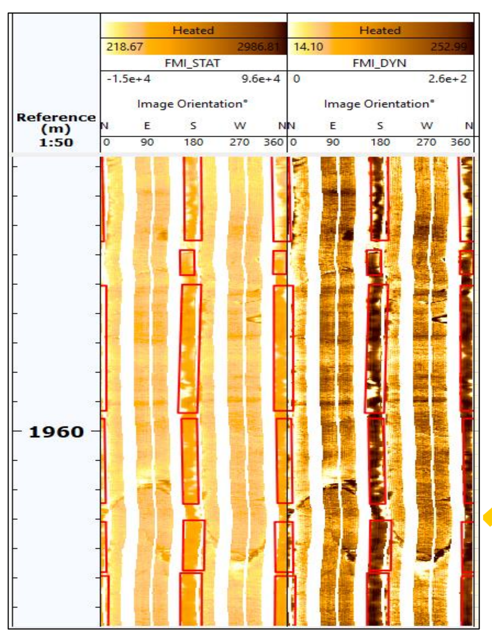
Why determining of stress is important?

- Determining principal stress orientation is crucial from the geohazard assessment point of view to improve the understanding of crustal deformation and try to establish a link with Slow Slip Earthquakes (SSEs) which may increase stress on the locked part of the subduction interface and trigger damaging earthquakes.
- Borehole image logs provide shallow deformation and stress regime in response to active subsurface deformation sources.

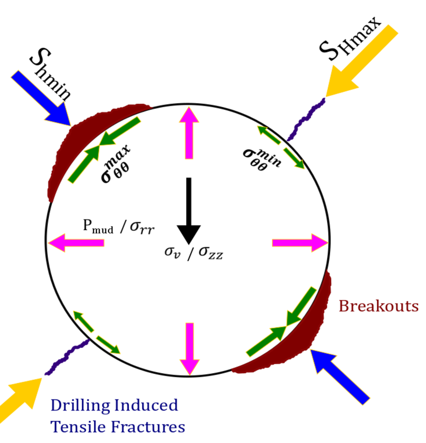
Methods and Data

- S_{Hmax} was determined from IODP 372 & 375 and industry borehole image logs.
- Local stress field perturbed during drilling due to the removed materials from the subsurface.
- When the stress concentration exceeds the rock strength, breakouts form as broad, parallel, poorly resolved conductive zones on opposite sides of the borehole's wall on resistivity image logs.
- Wellbore Breakouts (BOs) develop perpendicular to the present-day S_{Hmax} orientation .

a)

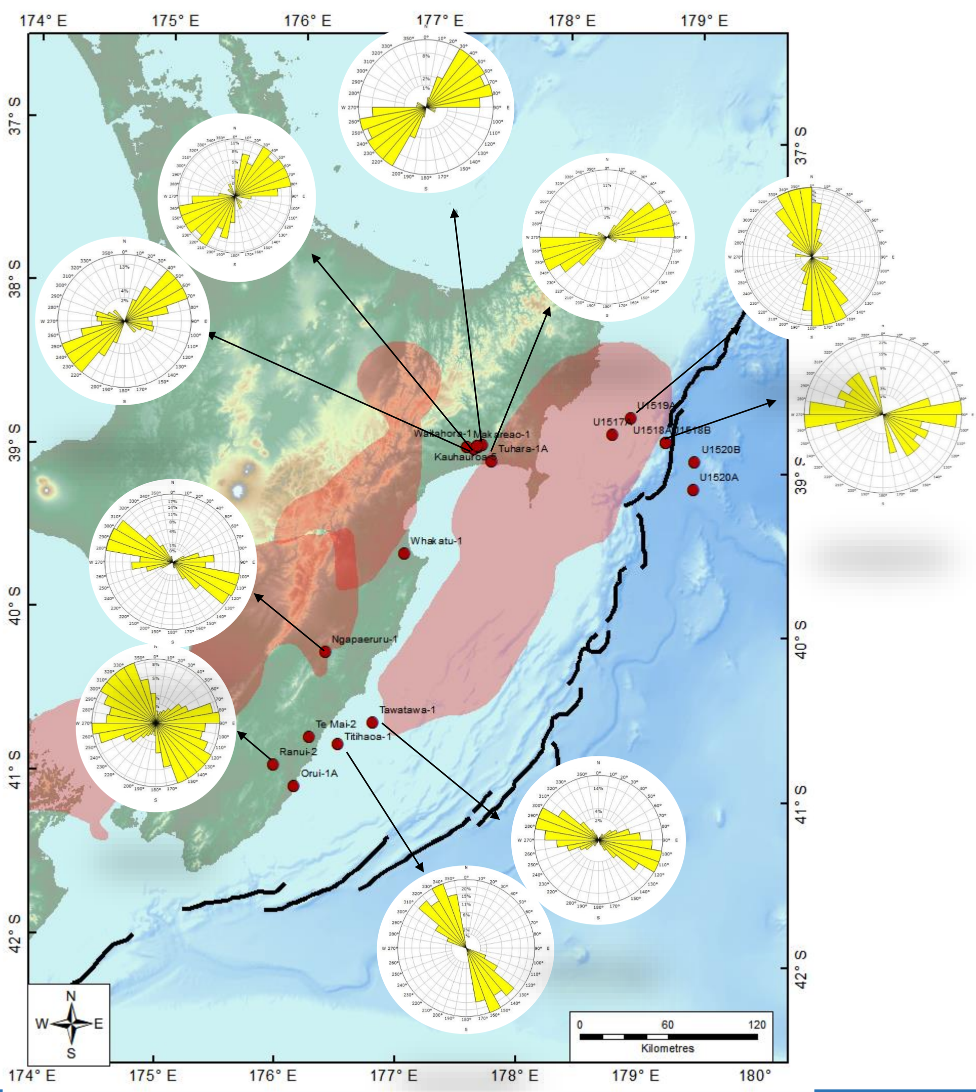


b)



a) Example of borehole breakouts from Tuhara-1A.
b) Schematic of borehole breakout analysis for S_{Hmax} and S_{hmin} orientation determination.

Overall Borehole Stress Pattern of HSM



Northern HSM:

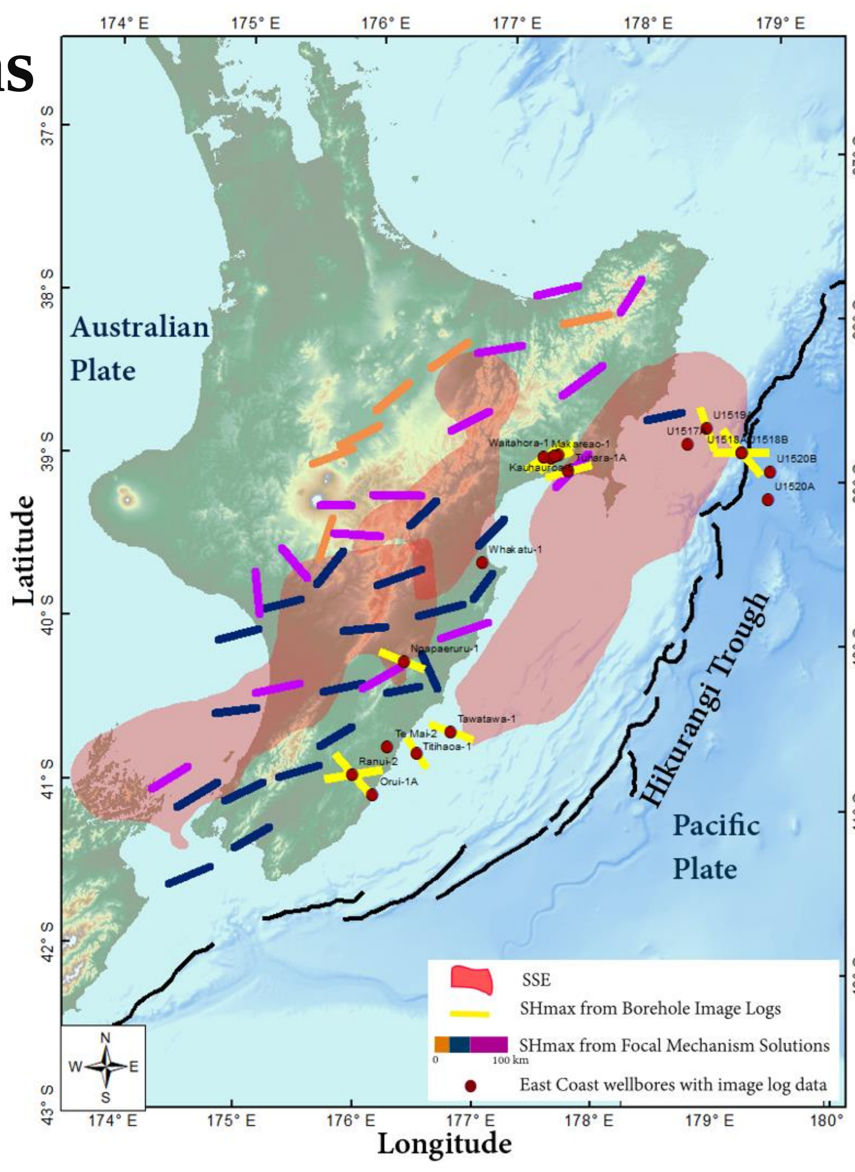
- Frontal thrust shows compression.
- Further landward stress orientation is NE-SW.

Southern HSM:

- Shallow S_{Hmax} is dominantly oriented NW-SE – suggesting the compression of the inner for-arc with a WSW-ENE component that matches with the strike of nearby dextral faults.

Large Scale Depth Variations

- Northern HSM – shallow borehole S_{Hmax} (< 3km) matches deeper S_{Hmax} orientations (60-100 km). derived from focal mechanisms (Townend et al., 2012).
- Regional stresses consistent with depth in northern HSM except over the offshore slow slip region.
- Spars S_{Hmax} direction determined form wellbore data suggests a disconnection from regional tectonics (ENE-WSW) in the offshore northern HSM where SSEs region source are located.
- Southern HSM – shallow borehole S_{Hmax} (< 3km) is more orthogonal to the HSM margin and nearly perpendicular to earthquake focal mechanism S_{Hmax} solutions (25-60 km).

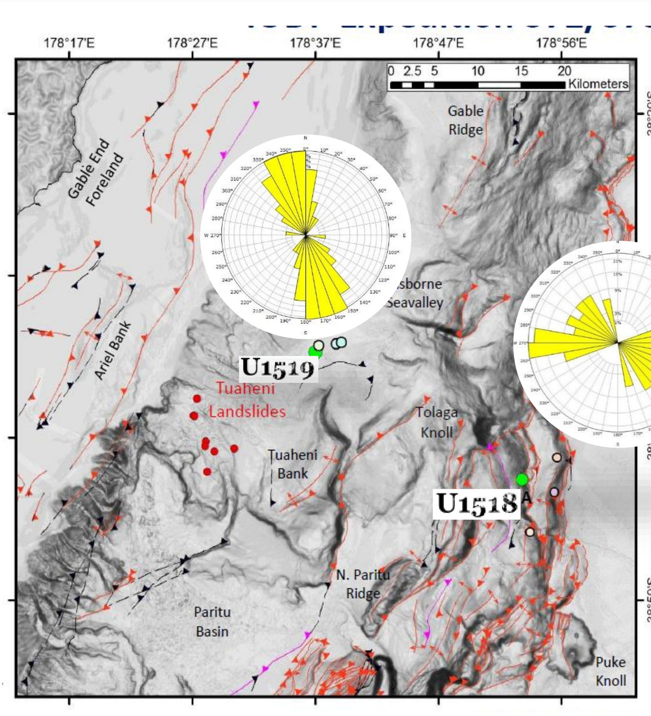


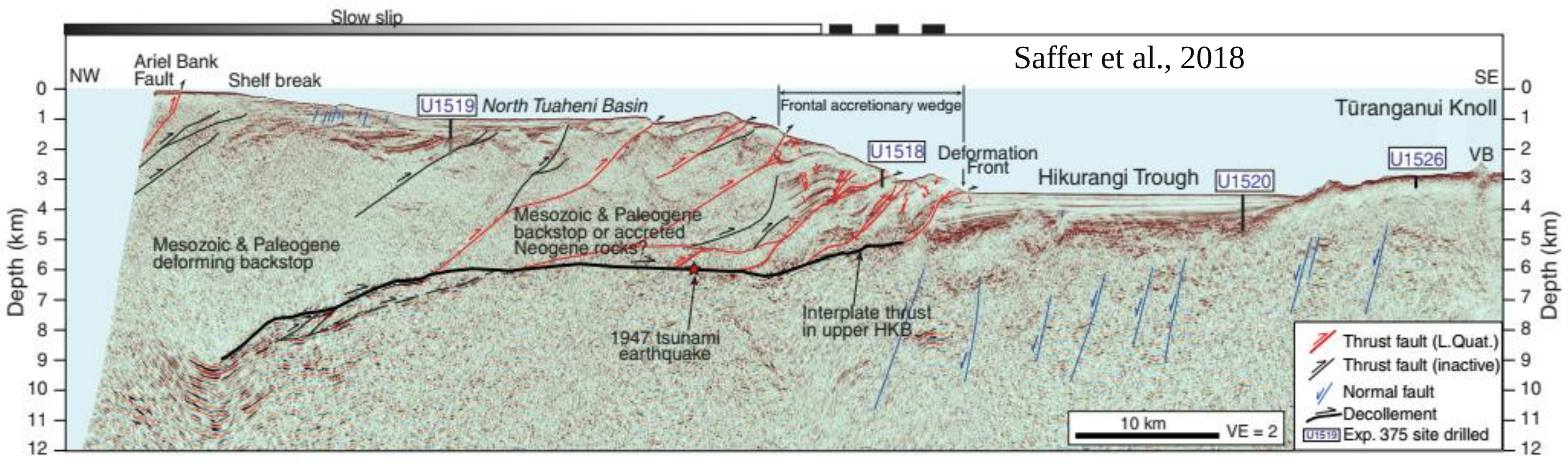
Future work

- Full analysis of image logs to determine stress magnitudes at shallow part of subduction zone.
- Analysis of shallow earthquake data at the East Coast of North Island to increase the certainty of our results.

Effect of Slow Slip?

- E-W S_{Hmax} at the frontal thrust shows regional tectonics operating there is compressional.
- NNW-SSE S_{Hmax} in the forearc suggests the overriding crust is disconnected from regional stress.
- Possibly due to decoupling of the plate interface in this region?





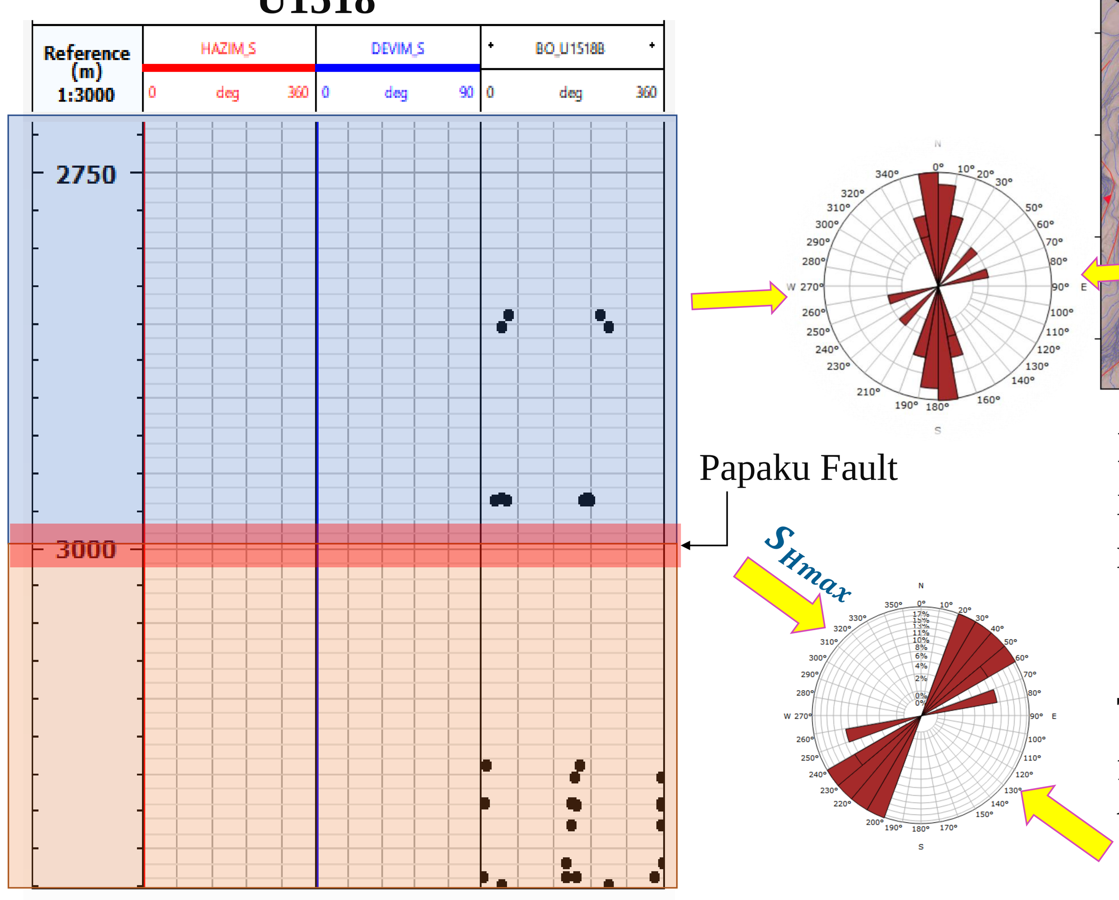
Saffer et al., 2018

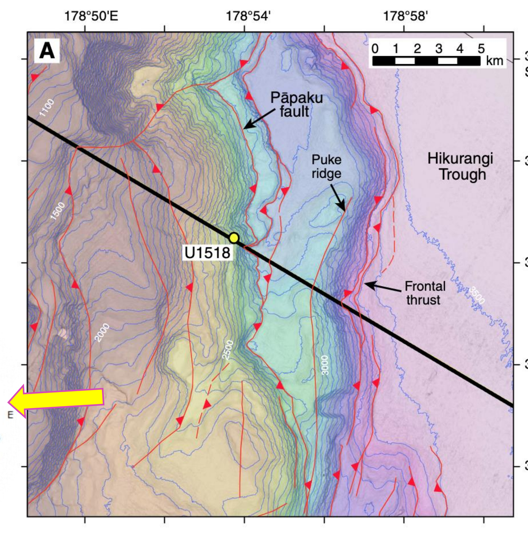
Depth-converted seismic Profile 05CM-04 showing locations and depths of sites drilled during Expedition 375, as well as structural interpretation. Star = projected location of March 1947 tsunami earthquake, VB = volcanic cone, and VE = vertical exaggeration.

Variation of S_{Hmax} Orientations with Depth

S_{Hmax} varies with depth in certain wells, including U1518 (frontal thrust) and Rauni-2 (southern Hikurangi Subduction Margin).

U1518



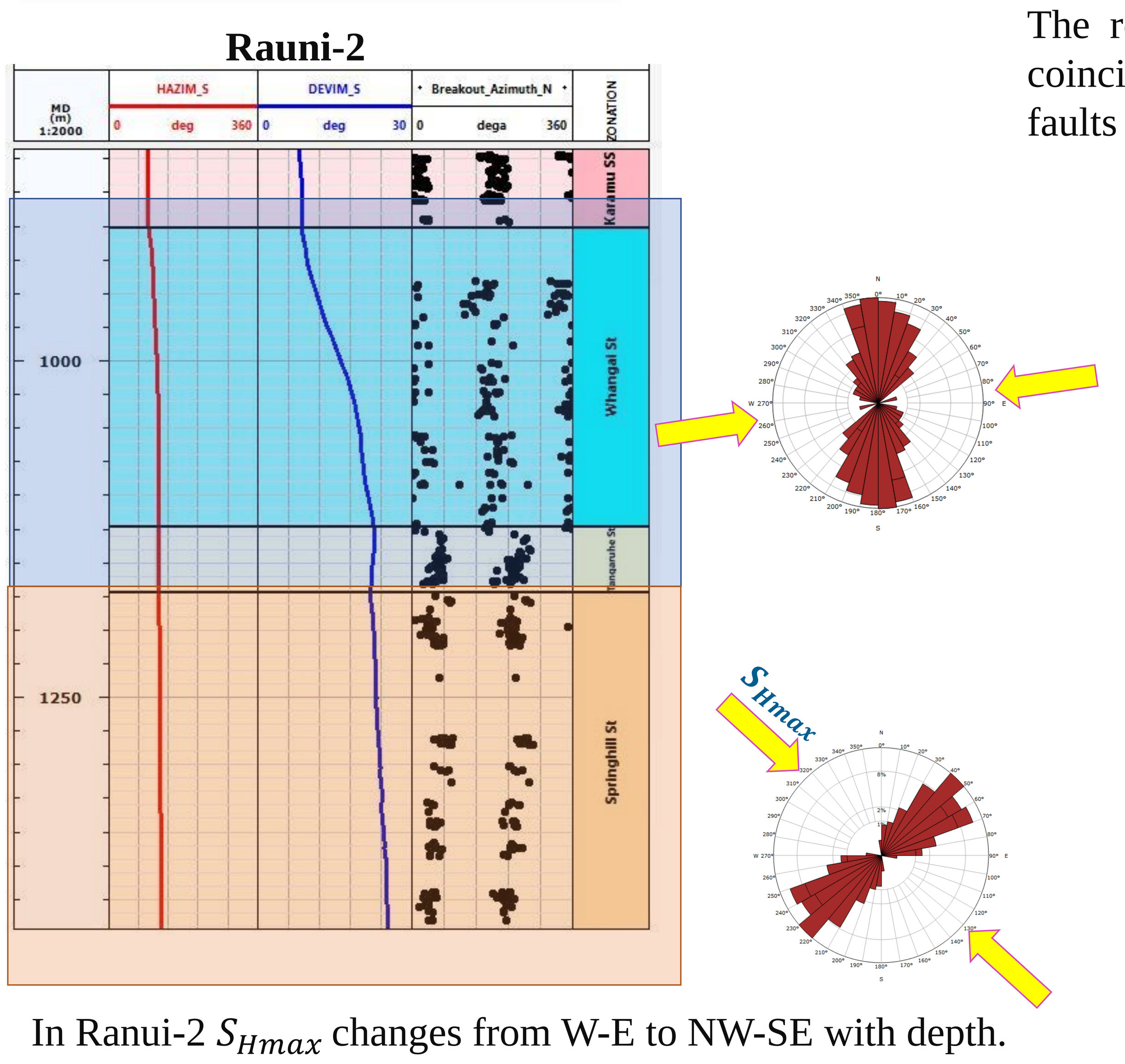


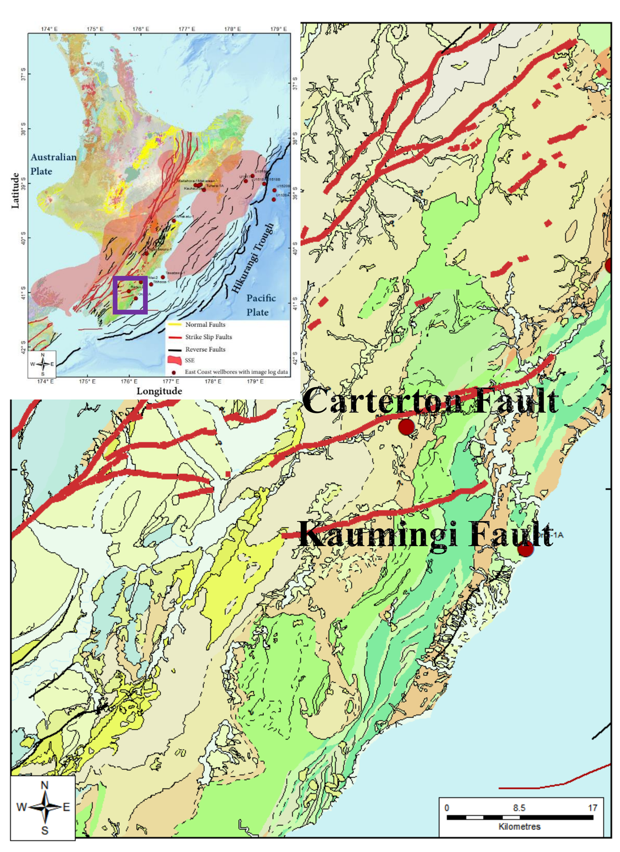
In IODP1518 S_{Hmax} is oriented E-W in the shallow part of the well, then rotates to NNW-SSE orientation.

The E-W S_{Hmax} orientation at the frontal thrust shows that the frontal thrust is in compression.

The rotation from W-E to NNW-SSE coincides with crossing active thrust faults at IODP 1518 site.

Rauni-2





In Ranui-2 S_{Hmax} changes from W-E to NW-SE with depth.

Deeper orientation match S_{Hmax} in other nearby wells.

Shallow E-W S_{Hmax} likely related to active strike-slip Carterton fault.

Deeper NW-SE S_{Hmax} may suggest a stress field perturbation caused by recent activity on nearby faults, a change in faulting regime with depth, rock mechanic changes or due to borehole deviation.

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References

Saffer, D.M., Wallace, L.M., Petronotis, K., and the Expedition 375 Scientists, 2018. Expedition 375 Preliminary Report: Hikurangi Subduction Margin Coring and Observatories. International Ocean Discovery Program. https://doi.org/10.14379/iodp.pr.375.2018

Townend, J., Sherburn, S., Arnold, R., Boese, C., & Woods, L. (2012). Three-dimensional variations in present-day tectonic stress along the Australia-Pacific plate boundary in New Zealand. Earth and Planetary Science Letters, 353–354, 47–59.