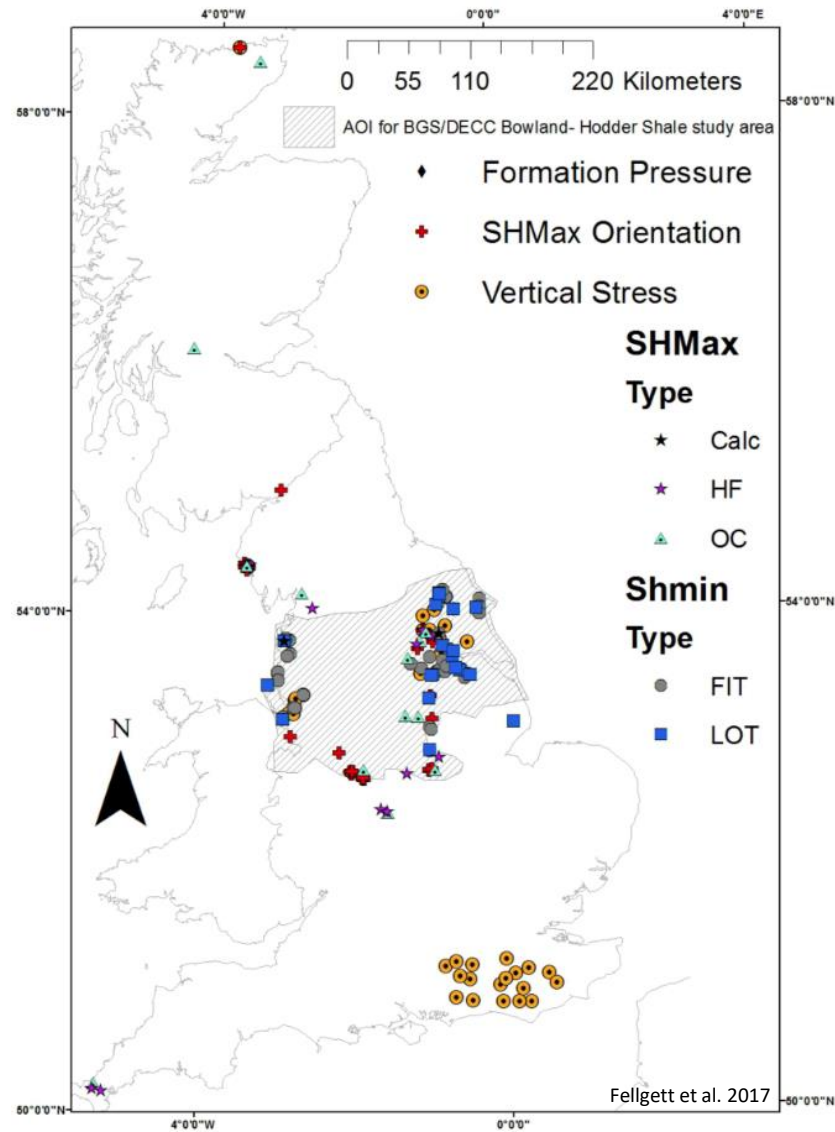


Andy Chadwick BGS

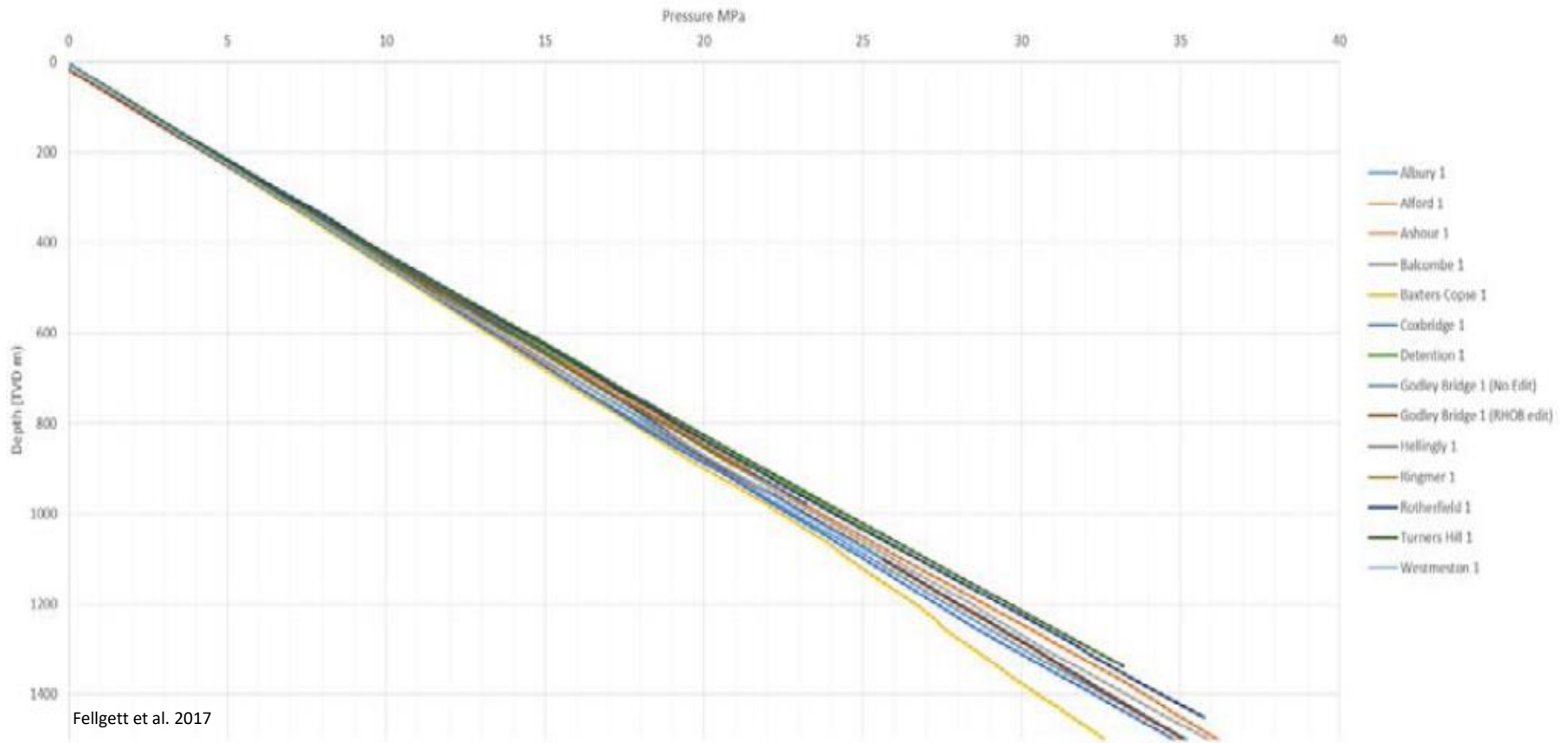
UK STRESS

UK *in situ* stress determinations



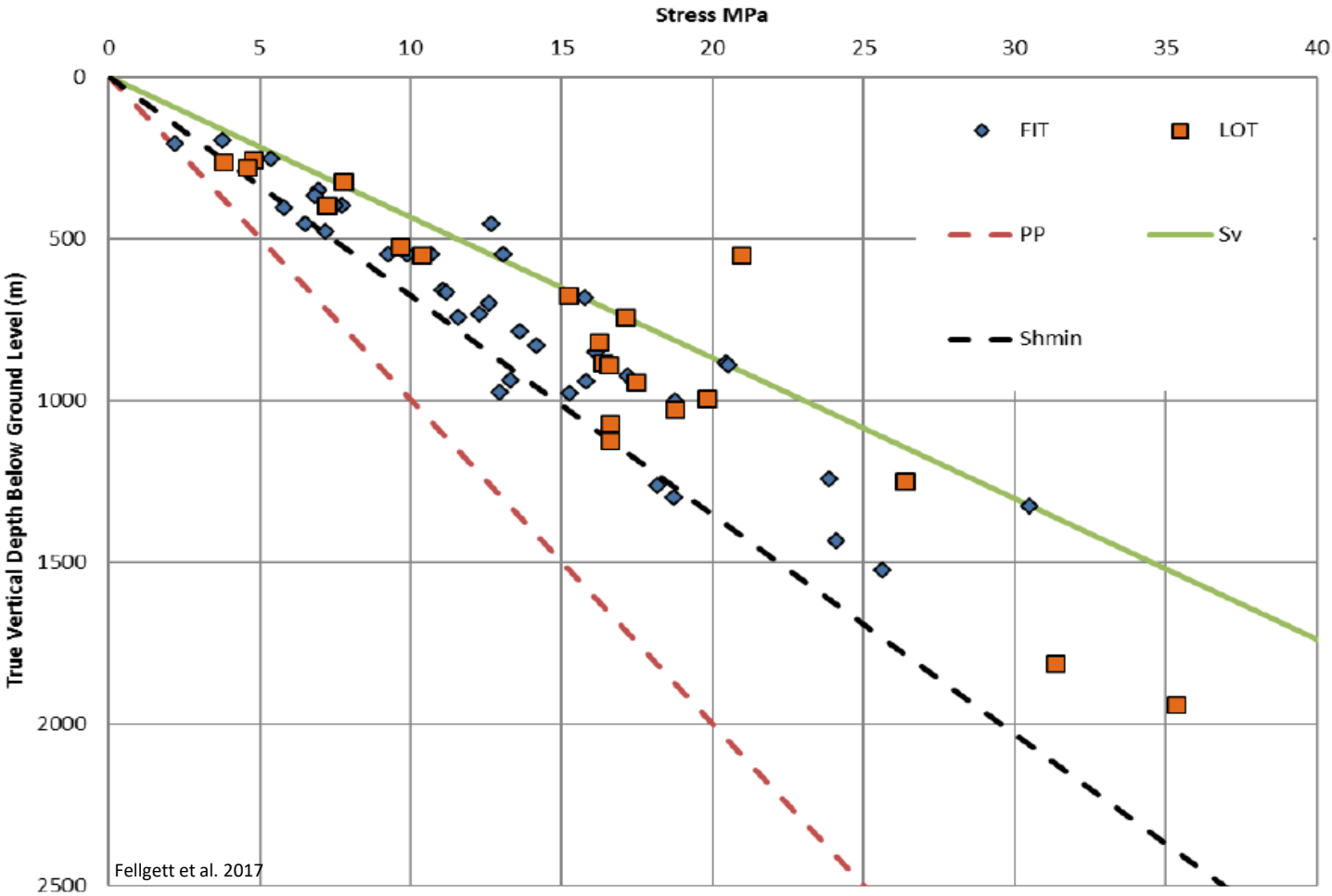
N.B. S_h data for SE England not currently worked up at BGS

Vertical stress (S_v) (Weald Basin)



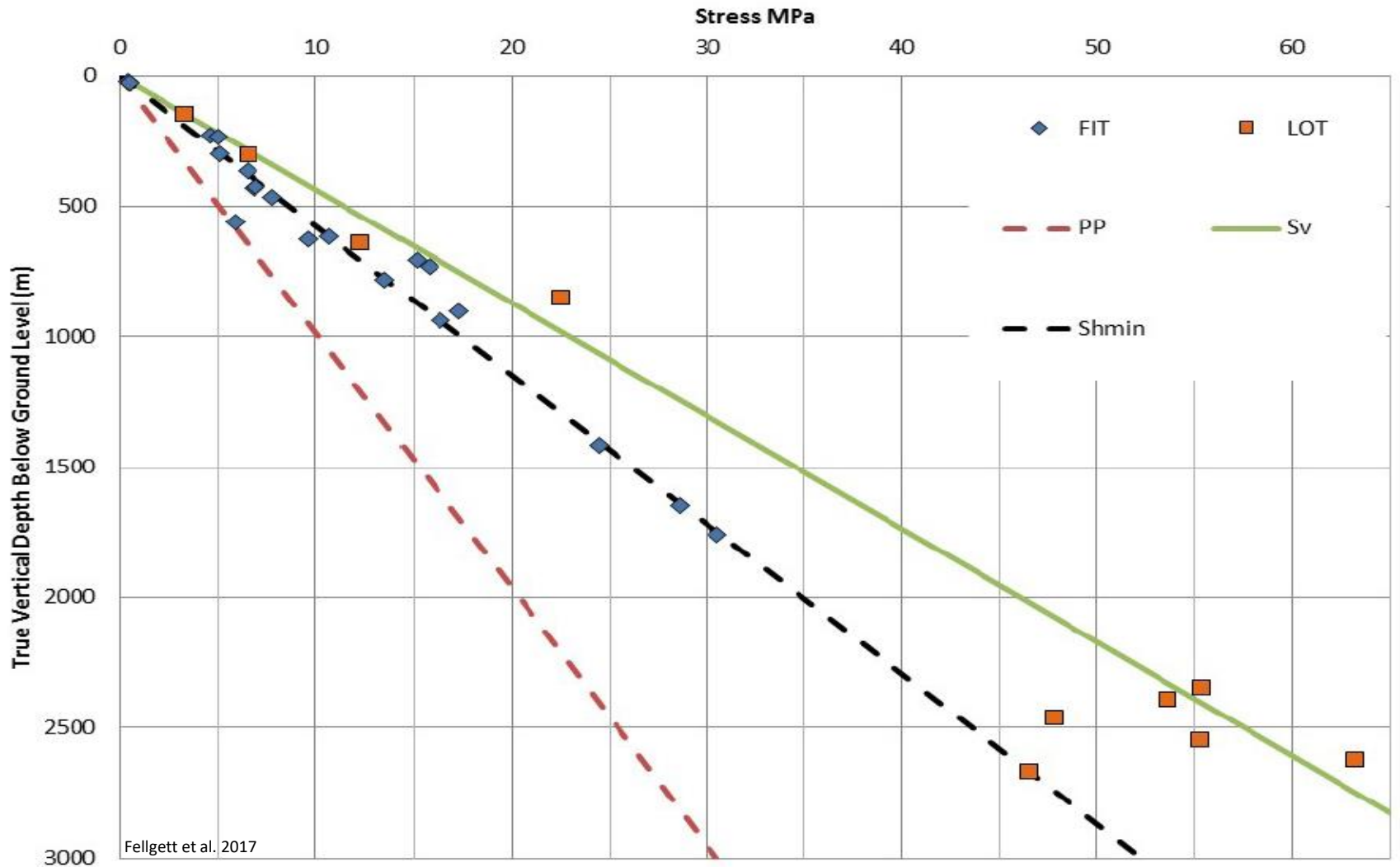
Vertical stress gradient 22 – 24 MPa/km (i.e. overburden densities 2200 – 2400 kgm^{-3})

Minimum horizontal stress (S_h) (E Yorkshire – N Nottinghamshire)



S_h gradient 14.7 MPa/km

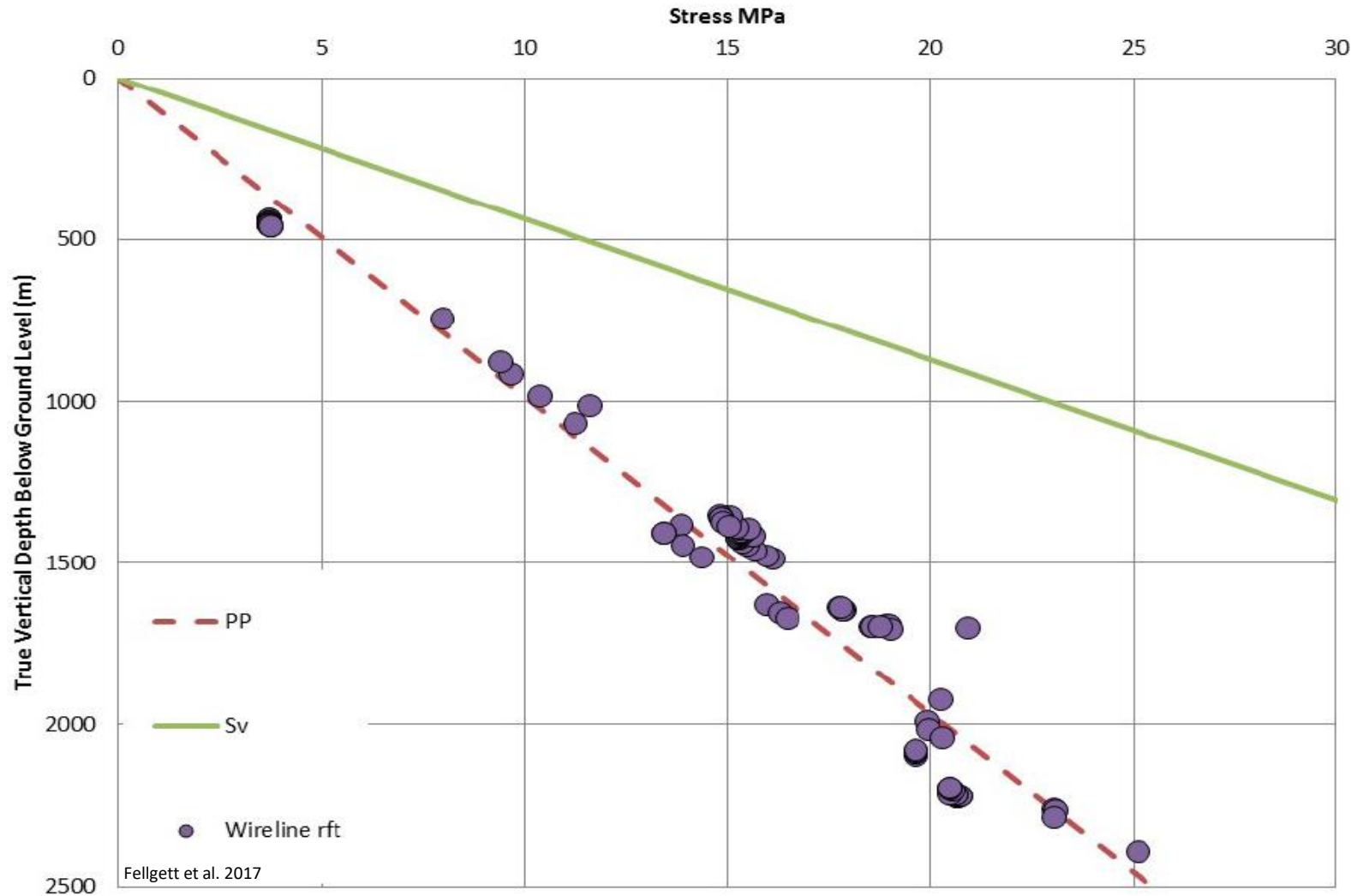
Minimum Horizontal Stress (S_h) (Lancashire – Cheshire)



Fellgett et al. 2017

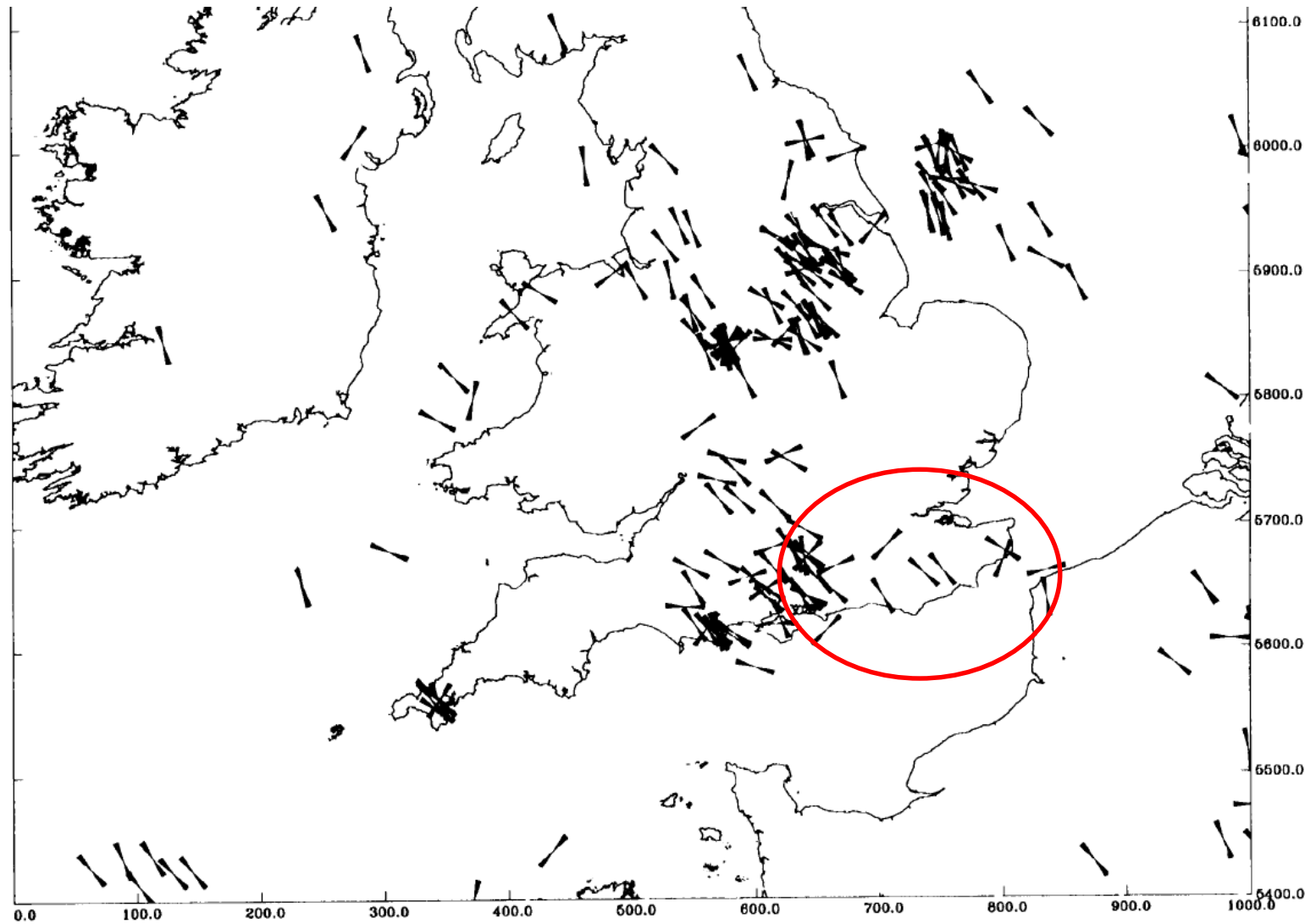
S_h gradient 17.3 MPa/km

Pore pressure (Lancashire, Cheshire, E Yorks, N Notts)



Pore pressure gradient is hydrostatic @ $\rho_w = 1019 \text{ kgm}^{-3}$

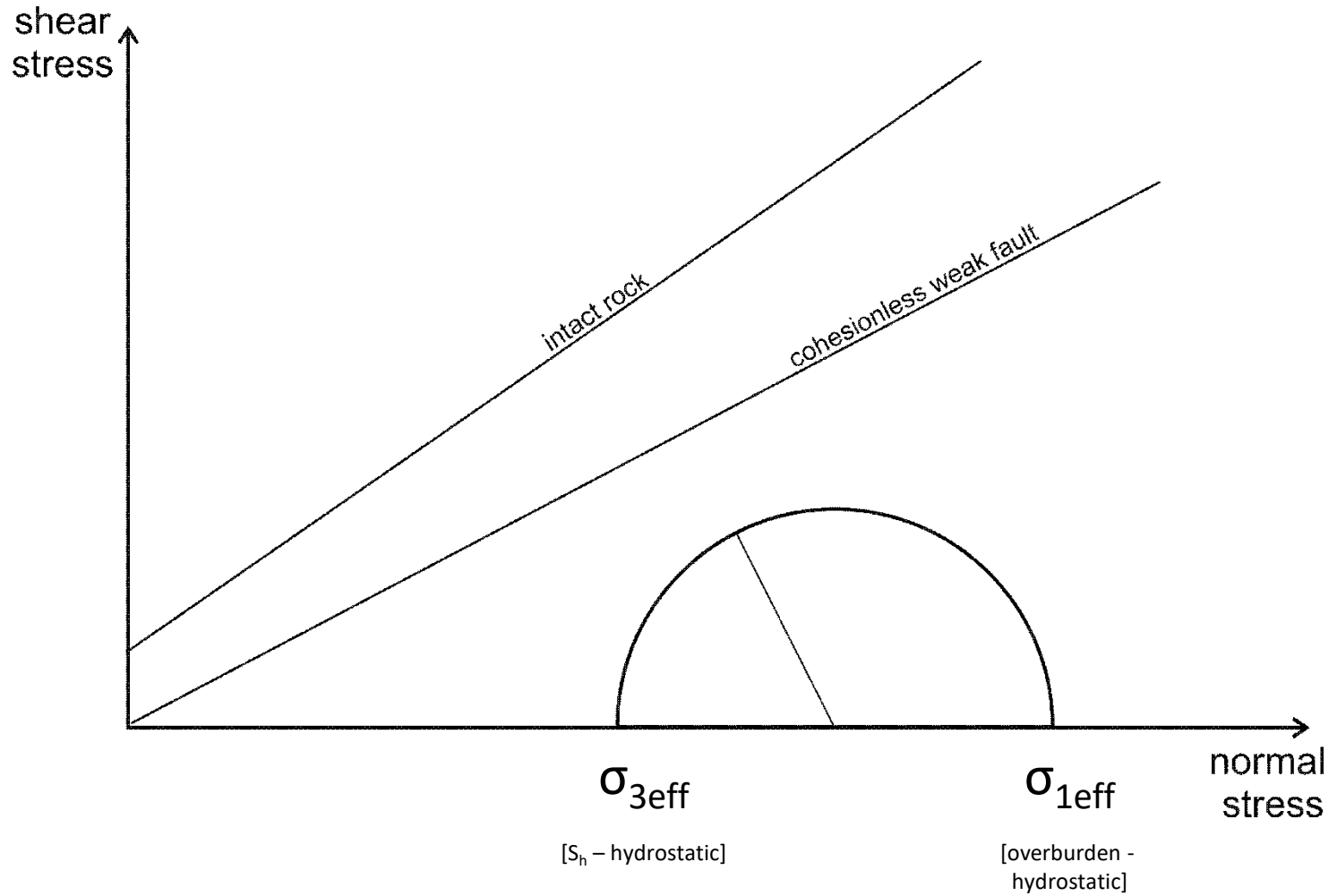
Maximum horizontal stress (S_H) directions



S_h perpendicular to S_H

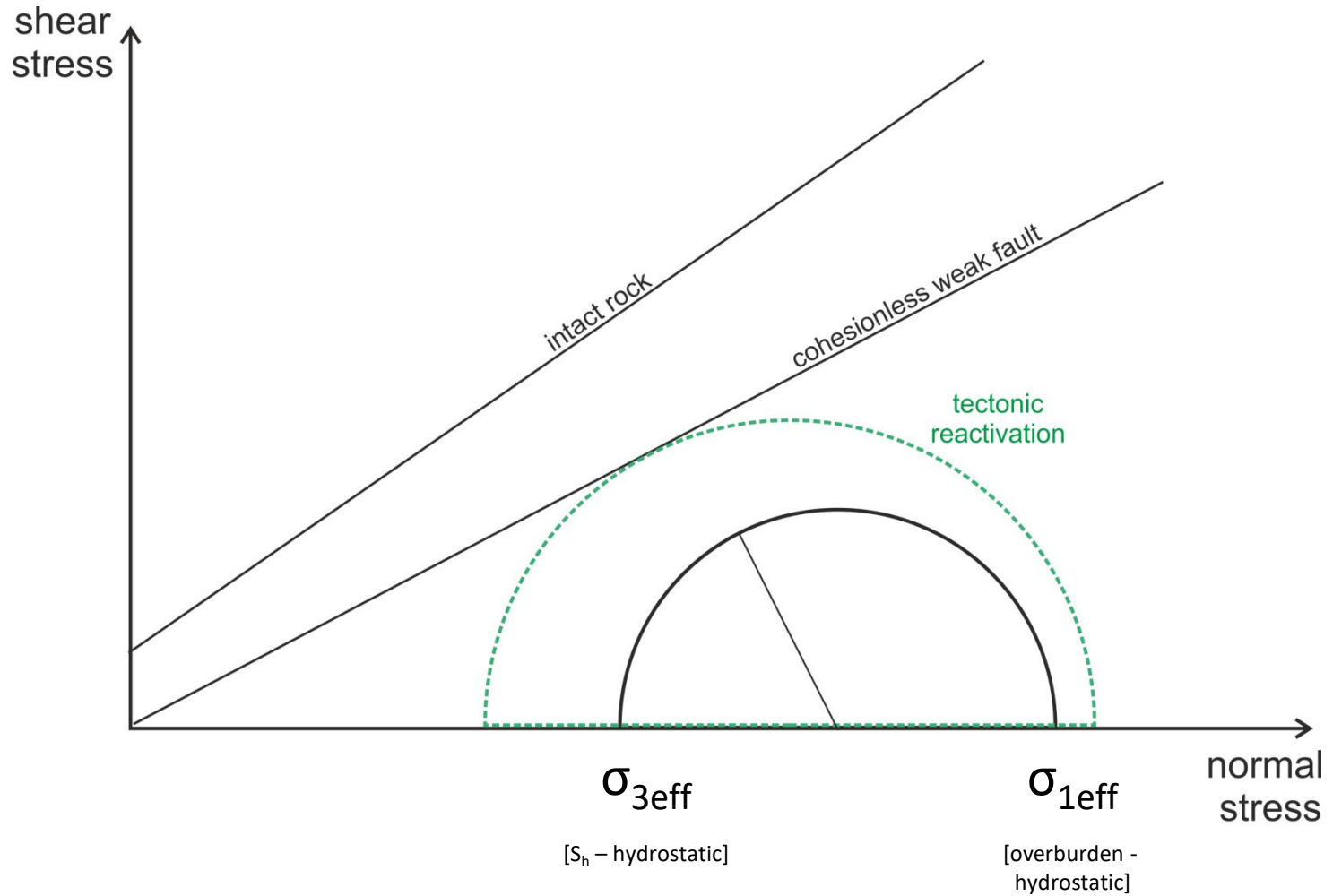
S_h generally ENE-WSW but local NW-SE orientations in SE England

In situ stresses



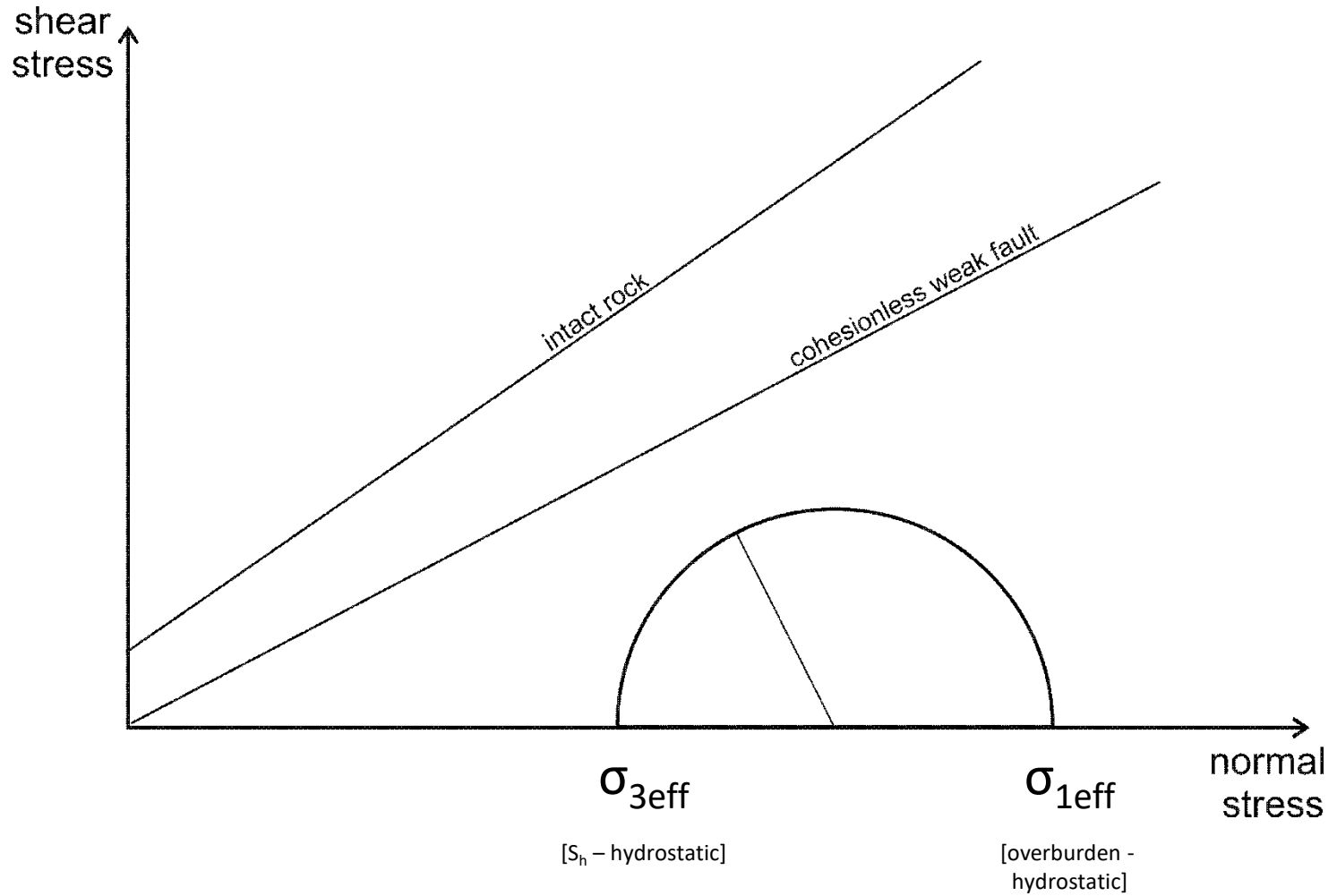
Stable fault

In situ stress change



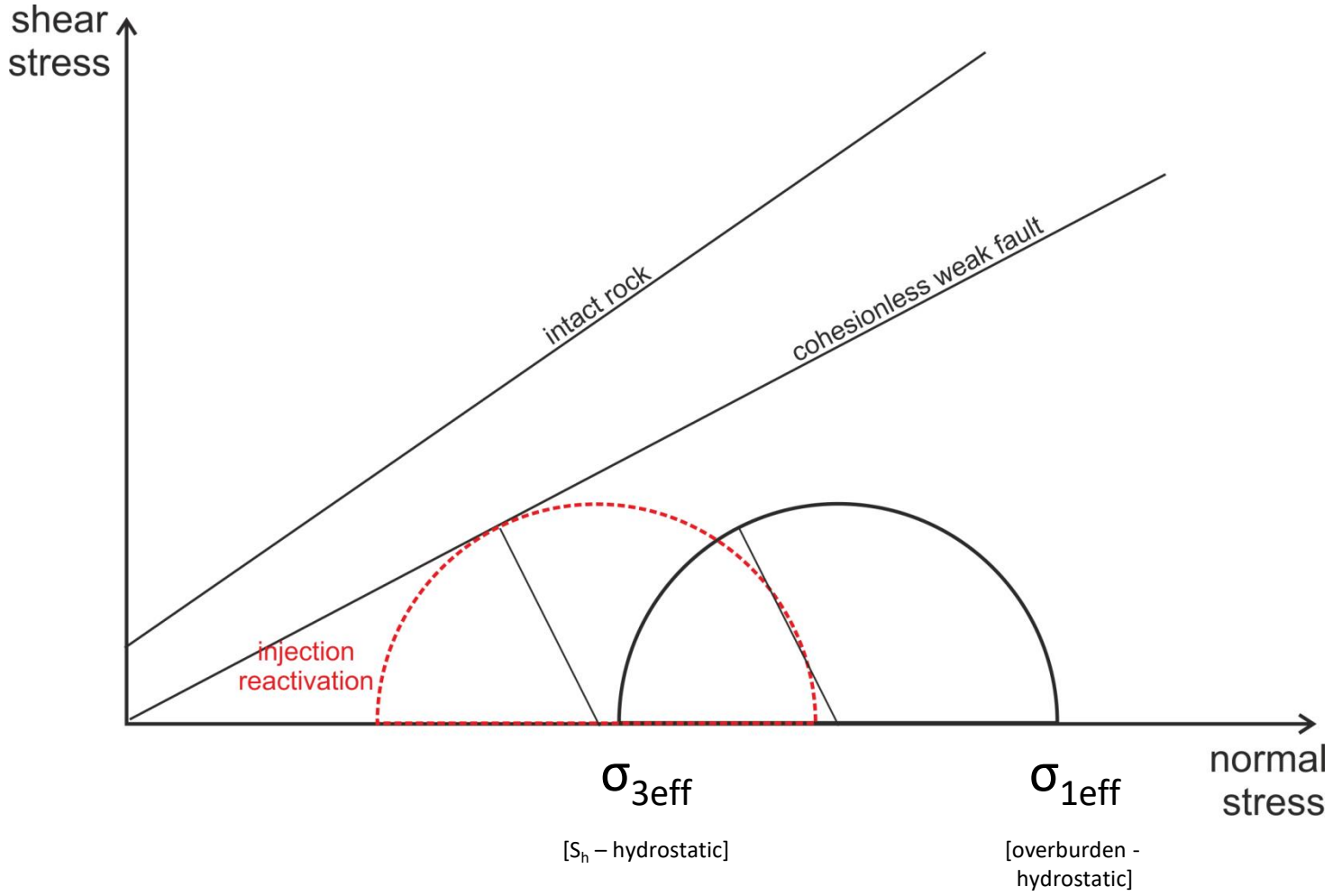
Tectonic fault reactivation of optimally-oriented fault

In situ stresses



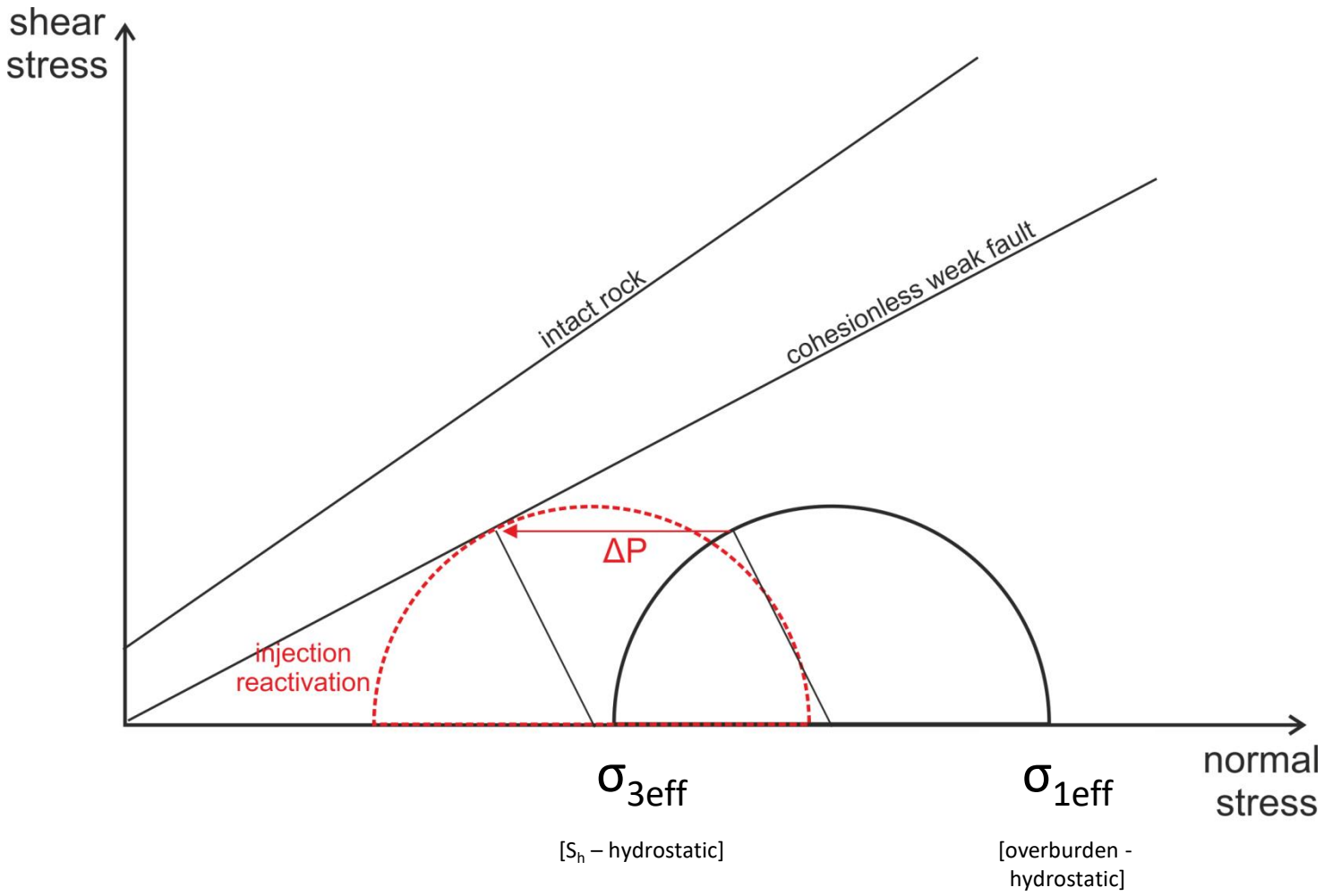
Stable fault

Reduction of effective stresses



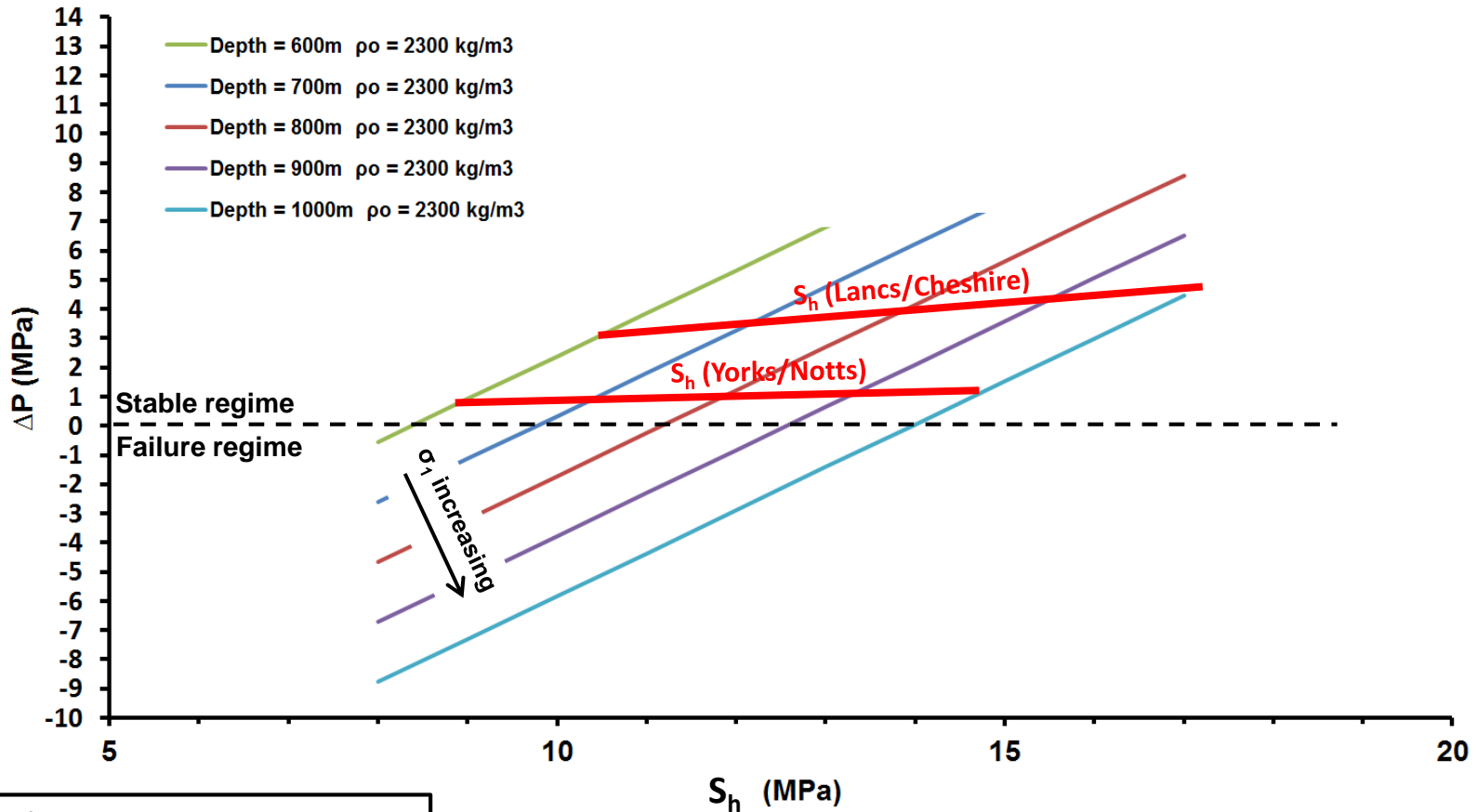
Fluid-pressure induced reactivation of optimally-oriented fault

Reduction of effective stresses



Fluid-pressure increase ΔP

Allowable pressure increase (ΔP) for variable S_v and S_h

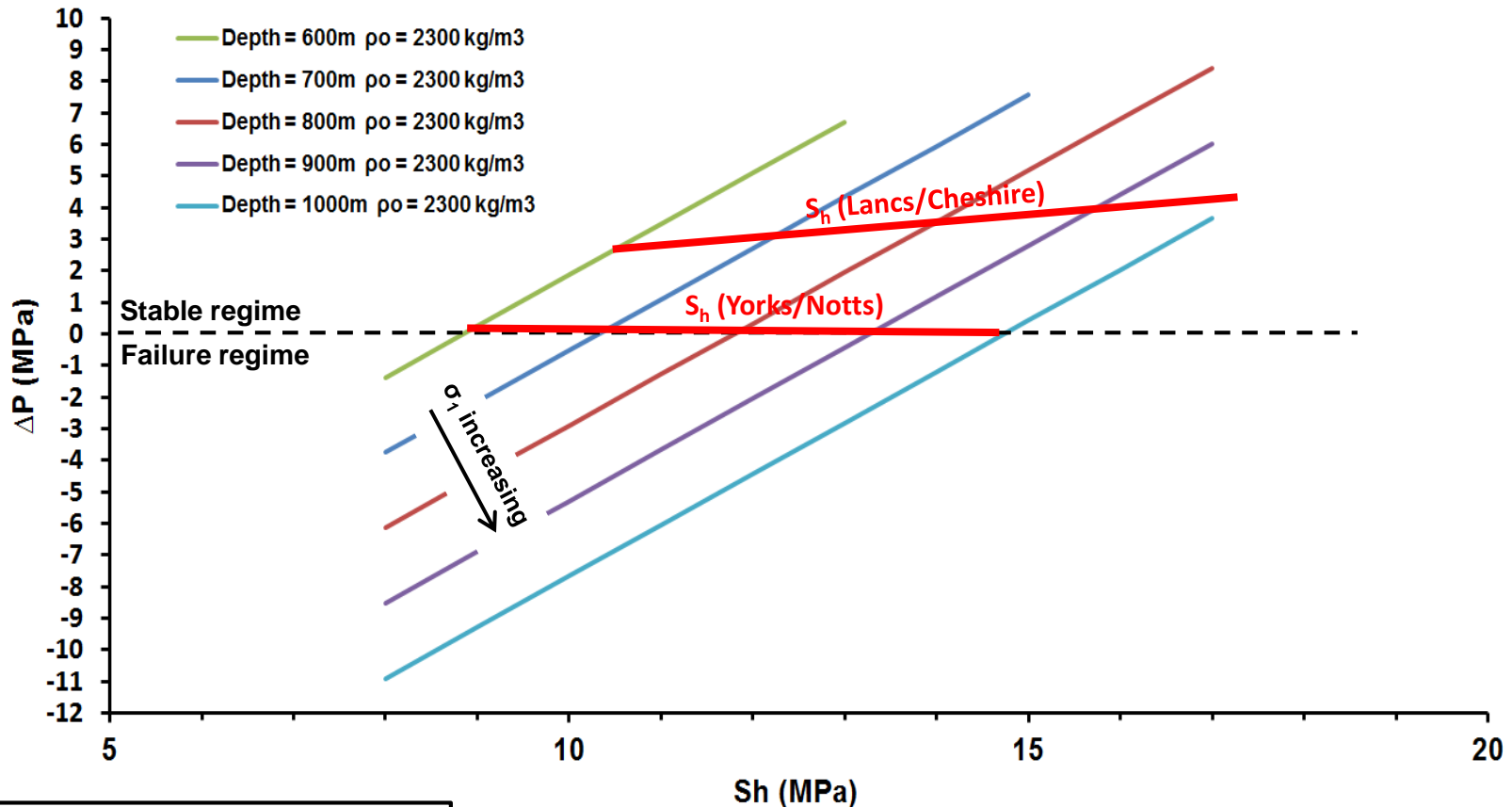


Variable fault depth
 Cohesionless fault
 Optimally-oriented
 Normal displacement (observed)
 $\mu = 0.6$
 $\sigma_1 = S_v$ (effective)
 $\sigma_3 = S_h$ (effective)
 $\sigma_3 = S_h$ (effective)
 Initial fluid pressure hydrostatic

Pressure increase $\sim 1 - 5 \text{ MPa}$ (10 - 50 bar) to induce slip on optimally-oriented fault

BUT fault reactivation very sensitive to magnitude of minimum horizontal stress (S_h)

Allowable pressure increase (ΔP) for variable S_v and S_h



Variable fault depth
 Cohesionless fault
 Optimally-oriented
 Normal displacement (observed)
 $\mu = 0.5$
 $\sigma_1 = S_v$ (effective)
 $\sigma_3 = S_h$ (effective)
 $\sigma_3 = S_h$ (effective)
 Initial fluid pressure hydrostatic

Pressure increase $\sim 0 - 4 \text{ MPa}$ ($0 - 40 \text{ bar}$) to induce slip on optimally-oriented fault

BUT fault reactivation very sensitive to magnitude of minimum horizontal stress (S_h)

Remarks

Optimally-oriented normal faults in 500 -1000 m depth range are close to critically-stressed given assumed values for σ_1 and σ_3

E-W normal faults are close to optimally-oriented for reactivation in the local stress regime ($S_v = \sigma_1$ and S_h oriented NW/NNW)

Local stress regime is unusual in UK - more commonly $S_v = \sigma_2$ (or more rarely σ_3) and S_h oriented ENE

Relatively small changes of *in situ* stress or fluid pressure will trigger reactivation

BUT significant uncertainty in principal stress magnitudes and directions