Varying least principal stress along lithofacies in gas shale reservoirs: effects of frictional strength and viscoelastic stress relaxation

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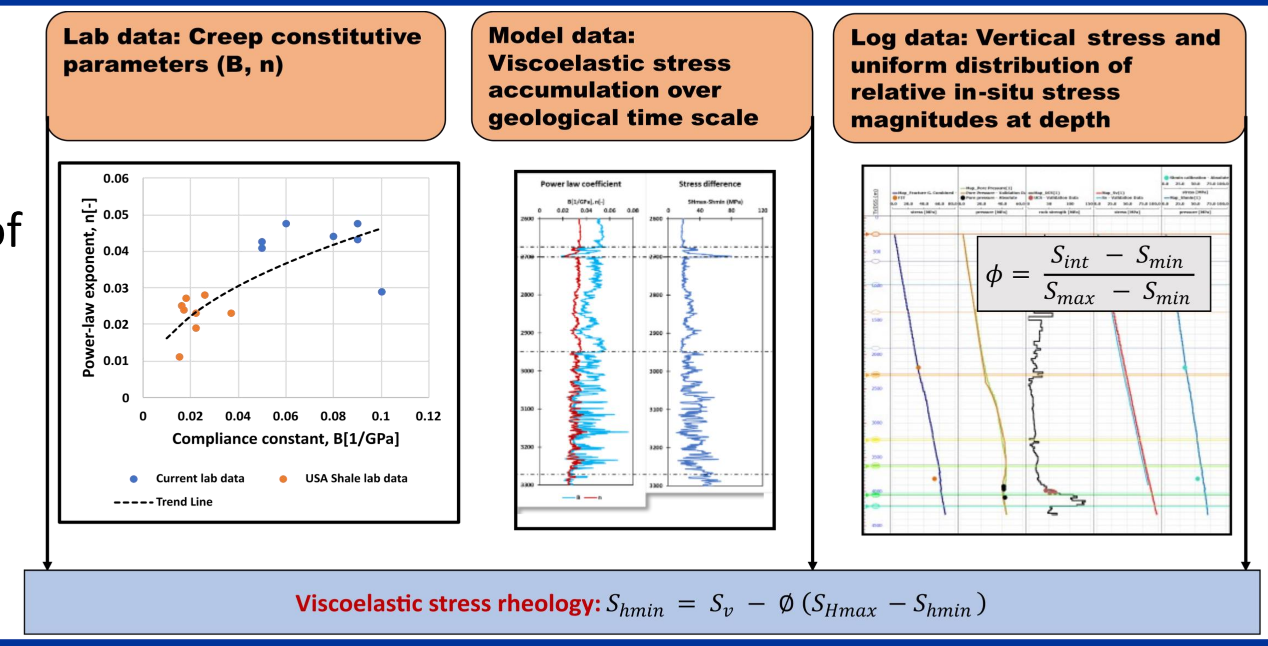
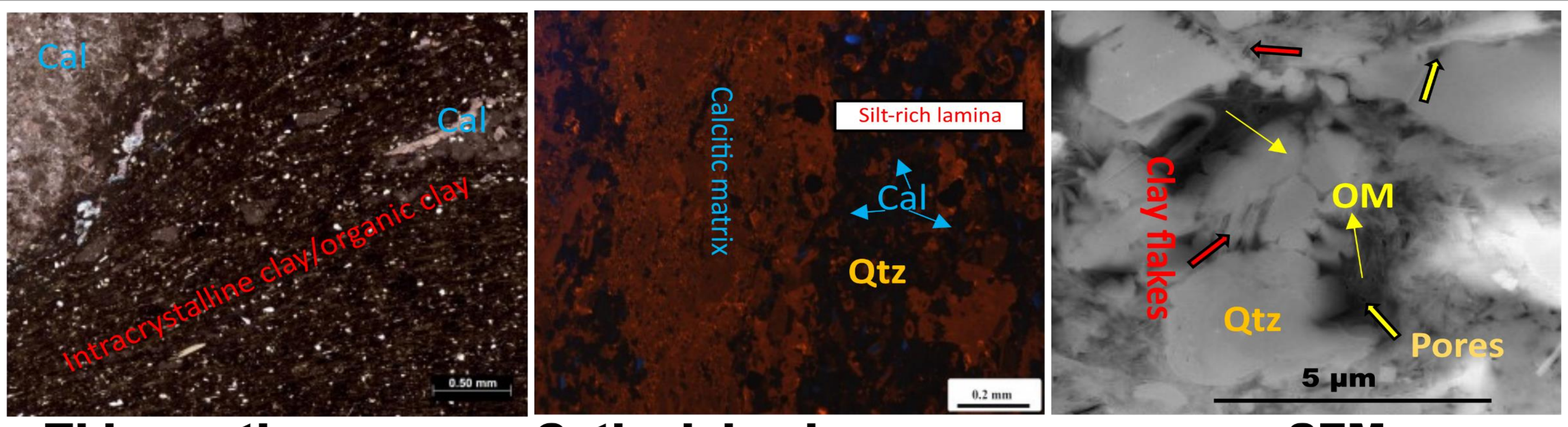
I. INTRODUCTION

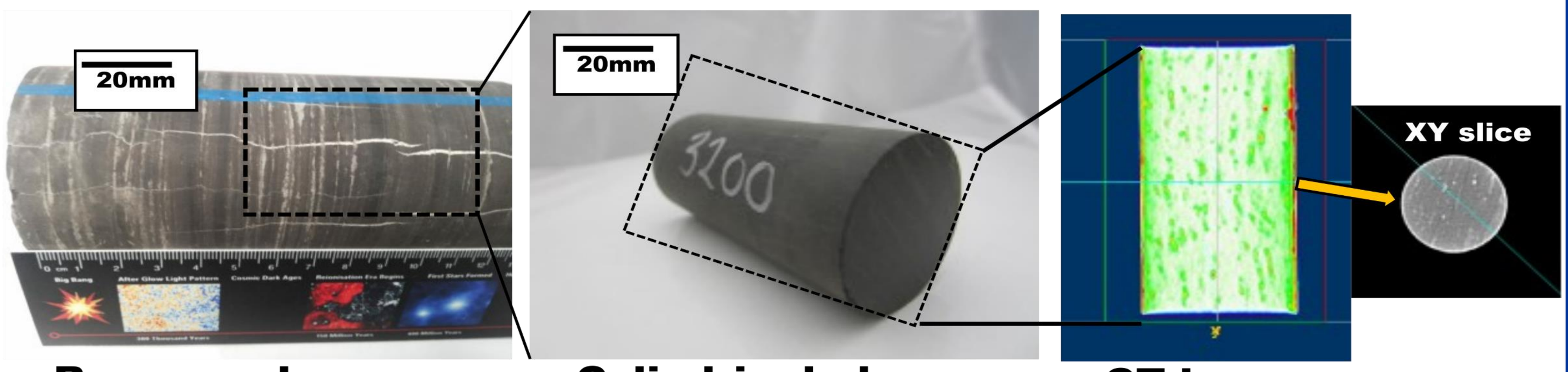
In unconventional gas shale reservoirs, it has been proven that **lithological layering** led to varying **least principal stress S_{hmin}** i.e., change in **stress regime** at depth. However, the fundamental mechanism responsible for this behavior is not clear. In this work, three hypothesis are considered: (i) **viscoelastic stress relaxation** (ii) **overpressure** (iii) **frictional strength** to evaluate layer-based stress profile. Multistage triaxial tests are conducted on samples from Goldwyer gas shale formations in Canning Basin to measure **creep deformation** and **frictional strength** properties along different lithological units (G-I to G-III). Further, pore pressure is estimated from wireline logs and tectonic stress accumulation is modelled through **viscoelastic rheology**. As a prototype these three factors are analyzed separately to investigate varying S_{hmin} magnitude in **Goldwyer** gas shale formation.

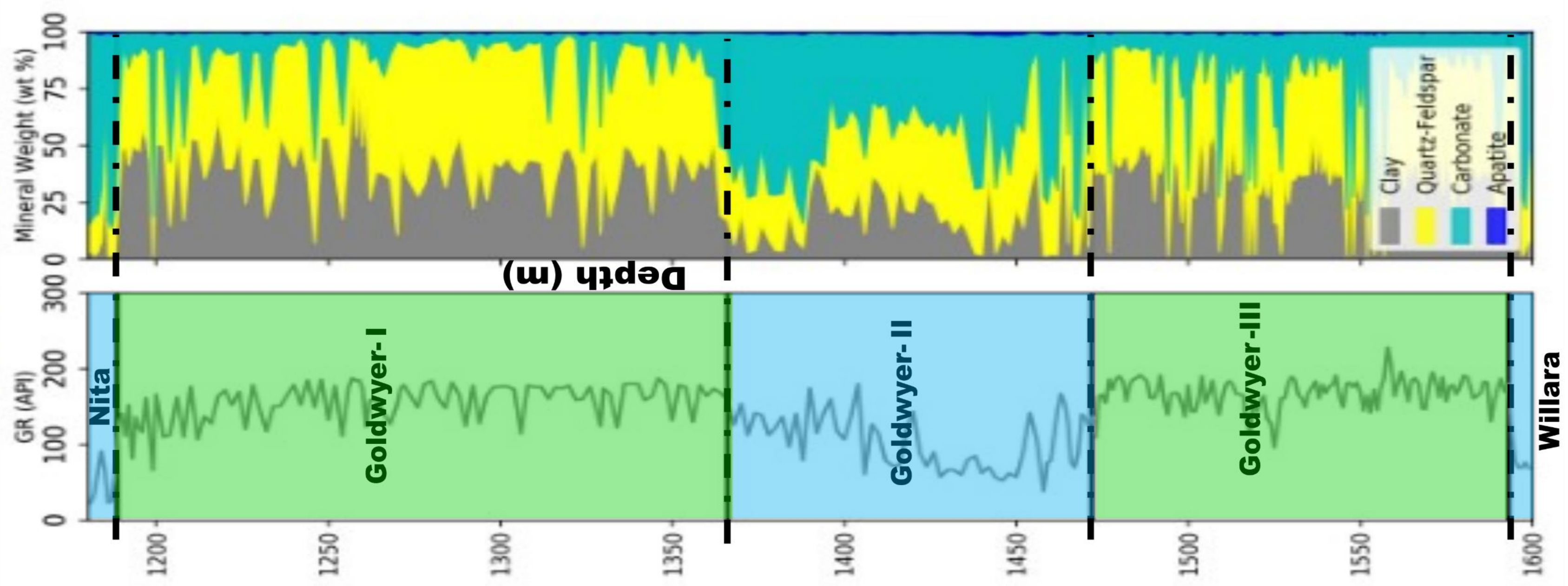
In-situ **horizontal differential stress** ($S_{Hmax} - S_{hmin}$) over a geological time scale of **300 Ma** with a constant strain rate of **4 x 10^{-19} s^{-1}** in the Goldwyer formations with viscoelastic rheology.



II. SHALE MATERIAL

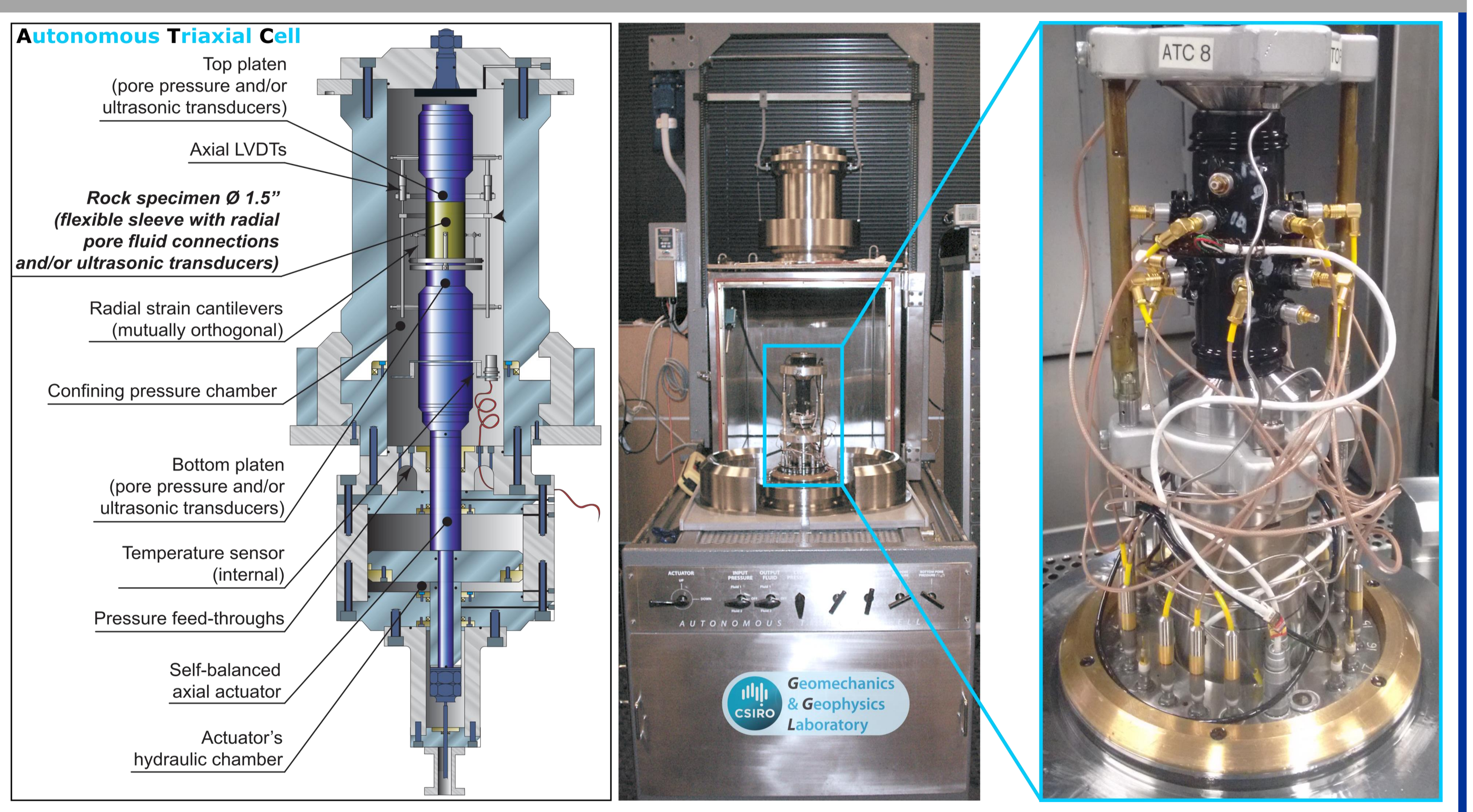


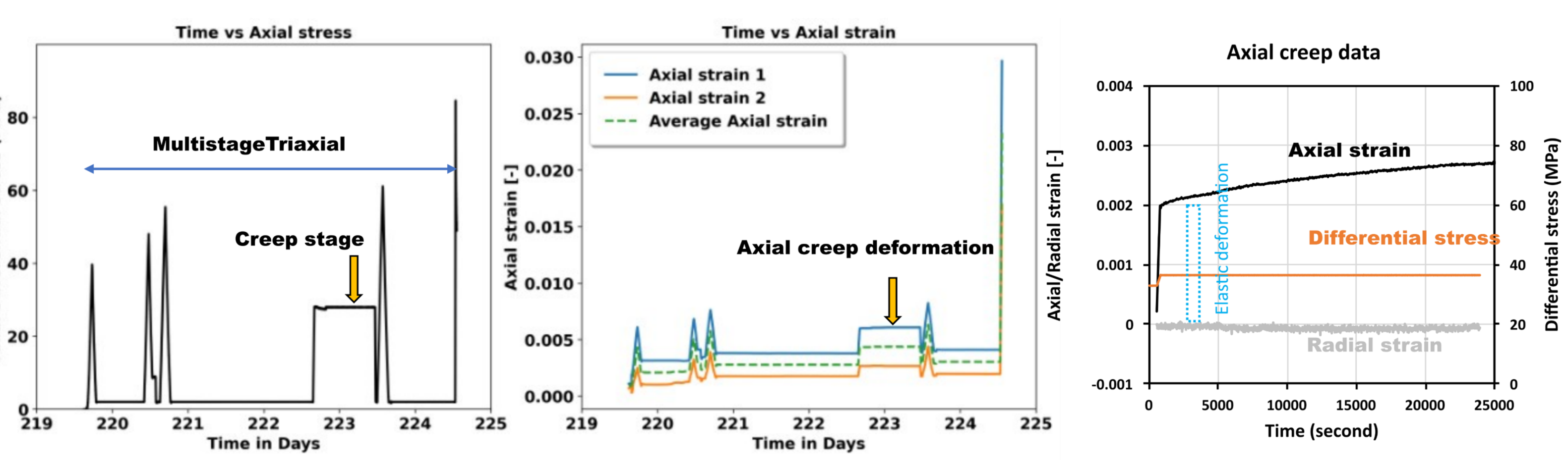


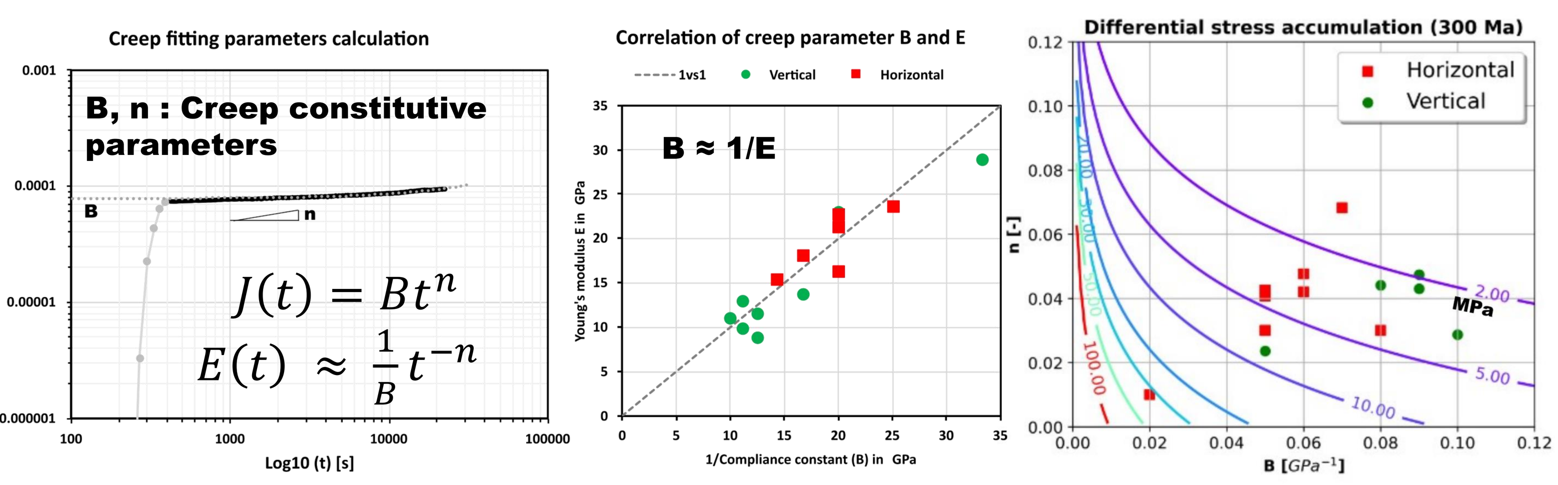


OM – Organic matter, Qtz – Quartz, Cal - Calcite, CT – Computer tomography, SEM – Scanning electron microscope, Pores – Meso pores network (100s nm range)

III. METHODS

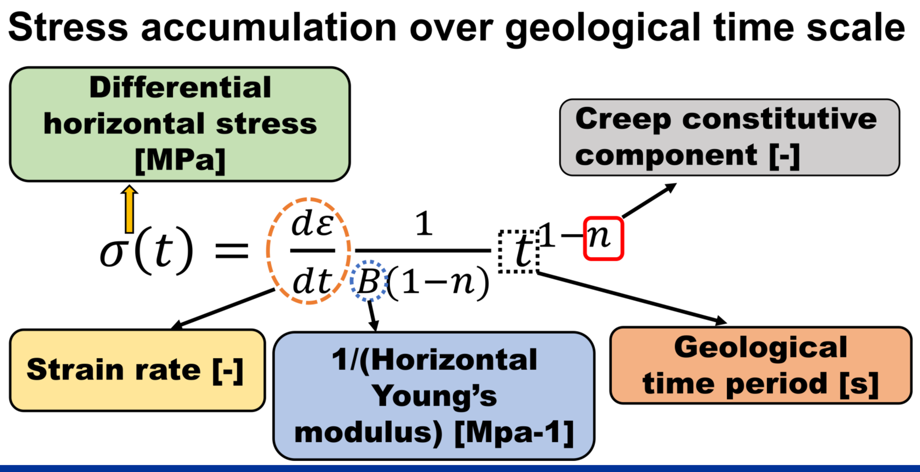






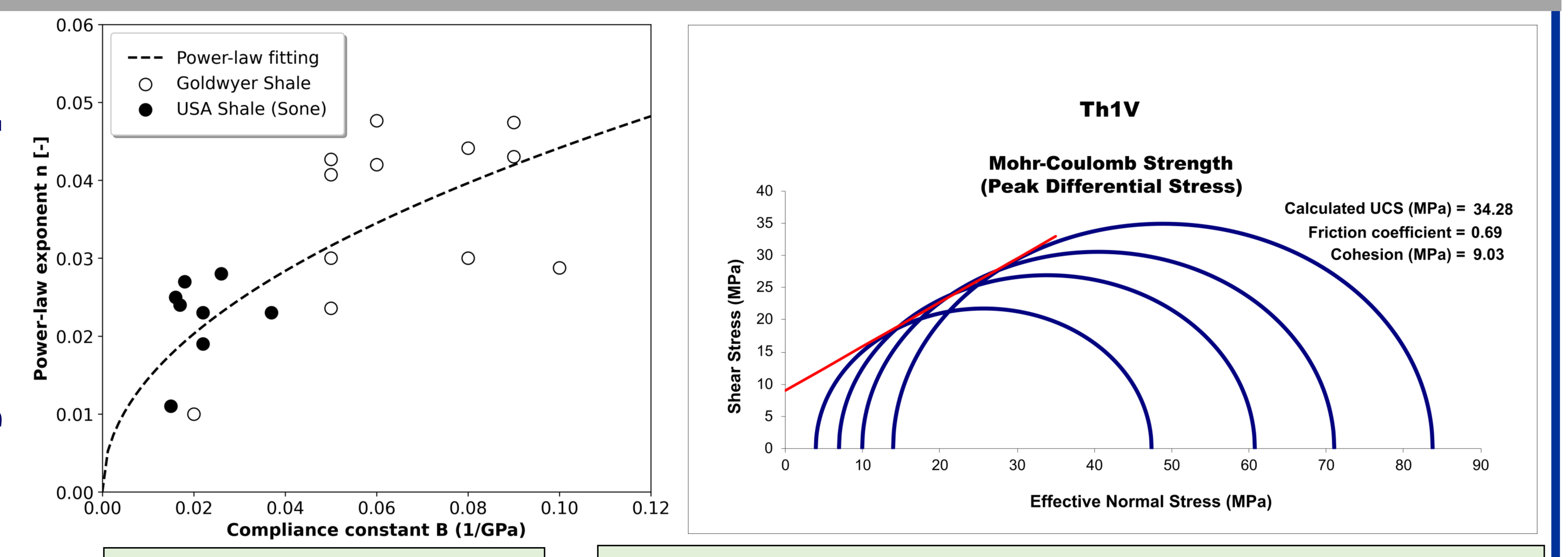
J(t) is the **creep compliance function** described by axial strain ε(t) per unit value of differential stress σ. Assuming linear viscoelasticity, **relaxation modulus E(t)** is defined as the reciprocal of J(t).

Stress accumulation over geological time scale



IV. RESULTS AND DISCUSSION

Mohr-Coulomb failure envelope & quantitative analysis of creep



Correlation of B and n | Rock strength properties - UCS, µ and cohesion

Frictional strength of faults governs the difference between maximum (σ_1) and least effective stress (σ_3) i.e., indirectly controls the **state of stress** at depth.

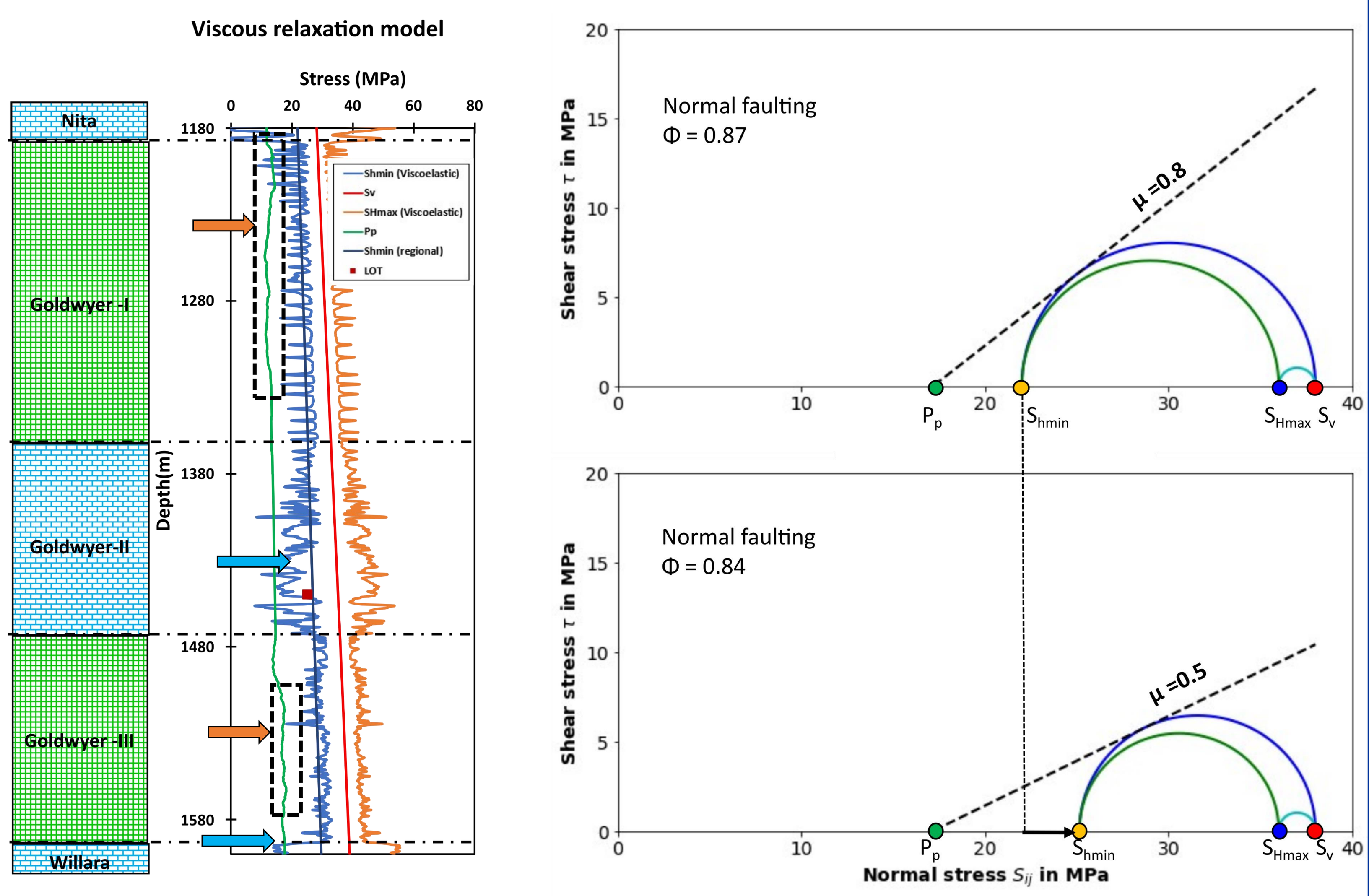
$$\frac{\sigma_1}{\sigma_3} = \frac{S_1 - P_p}{S_3 - P_p} = \left(\sqrt{\mu^2 + 1} + \mu\right)^2$$

where µ is the **friction coefficient**, and P_p is the pore pressure. Therefore, any variation of frictional properties lead to change in stress magnitudes across different lithological layers. S_{hmin} magnitude in the G-I and G-III units **remain close** to the vertical stress irrespective of the **elevated pore pressure**.

Pore pressure, S_{hmin} profile & frictional strength of the Goldwyer shale formation

Overpressure zone
Reduction in S_{hmin} magnitude

Decrease of frictional strength manifests in the increase of S_{hmin} magnitude



V. CONCLUSION

Layered **least principal stress** S_{hmin} magnitudes along different lithological layers in the Goldwyer gas shale comes from the combined effect of ***viscous stress relaxation*** and change in ***frictional properties*** of differing lithologies of the Goldwyer shale formation (units G-I to G-III). Elevated ***pore pressure has*** negligible effect on the observed layer-based S_{hmin} profile.

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