STRESSES THROUGH SEDIMENTARY STRATA – TECTONIC STRAINS

Sedimentary strata are generally laid in marine or lacustrine environments and built up as a series of layers. Where the strata remains fairly horizontal and not too contorted or faulted, the vertical stress (σ_v) is essentially due to self-weight and can be calculated on the basis of 0.025 MPa/m depth or an effective stress of 0.015 MPa/m depth. Assuming the rock is laterally constrained, such that there is no allowable strain in the horizontal plane, the horizontal effective stress due to self-weight ($\sigma'_{h/sw}$) can be calculated using the following equation (1):

$$\sigma'_{h/sw} = \sigma'_v \left(\frac{\nu}{1-\nu}\right) \quad (1)$$

where ν is Poisson's ratio.

In practice, the horizontal stresses are very seldom equivalent to this. Part of the reason is that this equation represents a simplified elastic model which does not account for creep processes. More generally, there are other components that are due to horizontal effective tectonic stress ($\sigma'_{h/tec}$), which is generated by tectonic movements. This may be due to tectonic plate loading, but is more frequently due to local structural conditions such as anticlines and synclines.

The major and minor principal effective tectonic stresses, $\sigma'_{h/tec/1}$ and $\sigma'_{h/tec/2}$, are calculated as:

$$\sigma'_{h/tec/1} = \sigma_1 - \sigma_{h/sw} \quad (2)$$

$$\sigma'_{h/tec/2} = \sigma_2 - \sigma_{h/sw} \quad (3)$$

It is desirable, regionally, to consider the strain caused by tectonic movements, rather than focusing on stress fields. Stresses vary with the modulus of the rock; the stiffer the rock, the more stress it carries for a given strain. Using the values of tectonic stress calculated from Equations 2 and 3, the components of tectonic strain can be calculated as follows:

$$\varepsilon_{tec/1} = \frac{\sigma'_{h/tec/1} - \nu\,\sigma'_{h/tec/2}}{E} \quad (4)$$

$$\varepsilon_{tec/2} = \frac{\sigma'_{h/tec/2} - \nu\,\sigma'_{h/tec/1}}{E} \quad (5)$$

To examine the average tectonic strain for a group of stress measurements, Sigra rotates the principal strains into direct N-S & E-W strain and shear strain components to find the mean of these. The principal tectonic strains and their direction may be calculated from these three mean strains. If tectonic strains are relatively uniform between adjacent stress measurements they may be used to calculate stresses in rock of varying stiffnesses, and Poisson's ratios where stress measurements have not been made. This process is the reverse of that used to derive the tectonic strain.

In these cases, the horizontal stress due to overburden is calculated according to Equation 1. The effective stresses due to tectonic strain may be calculated using the following equations:

$$\sigma'_{h/tec/1} = \frac{E}{1-\nu^2}\left(\varepsilon_{tec/1} + \nu\,\varepsilon_{tec/2}\right) \quad (6)$$

$$\sigma'_{h/tec/2} = \frac{E}{1-\nu^2}\left(\varepsilon_{tec/2} + \nu\,\varepsilon_{tec/1}\right) \quad (7)$$

The principal effective stresses are calculated by adding the horizontal stress due to self-weight to the above figures.

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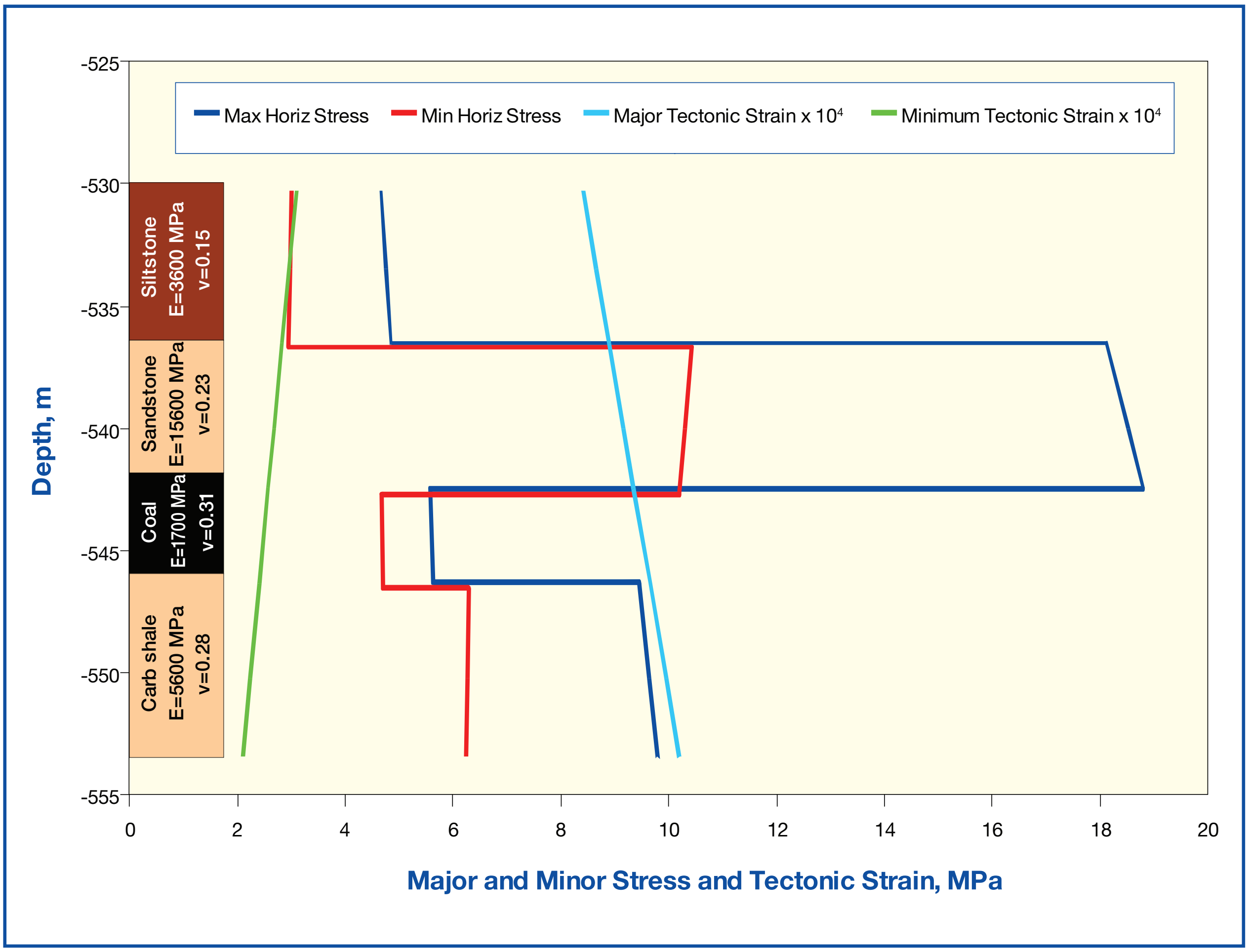

The above figure shows an example of a layered sedimentary strata with varying stiffnesses and Poisson's ratios. The rock is subject to gradually varying tectonic strains. The major tectonic strain, increasing with depth, indicates some features of a possible anticline, while the minor tectonic strain shows the reverse trend. The stiffness of the strata varies considerably and so, correspondingly, do the stresses.

Vertical variation in tectonic strain are indications of unconformities. Faulting may often be detected by lateral variations in tectonic strain. Faults are invariably locations of stress relief and normally faulted zones generally show very low to negative tectonic strain.