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Paleo stress analysis of reverse reactivated normal faults.

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In inverted basins with reverse reactivated normal faults, only a selection of faults will be reverse reactivated. A problem with recognizing reverse reactivated faults (inverted faults for short) is, that not all the inverted faults can be recognized as such on seismic. A normal fault with an original throw of 100 m, that has been inverted 40 m, will show a normal throw of 60 m and no visible inversion component. North Sea seismic lines illustrate this effect. However, although this is a limitation in the recognition of inverted faults, this is not the reason for partial inversion. A geomechanical reason is, that steep normal faults, with a dip of about 60° can only be inverted if the dip along which the upward moving fault block moves (the effective dip) is in the range of less than 45° and more than 15°. For effective dips outside this reverse reactivation range, the fault will not move but the matrix will eventually brake along a new low angle reverse fault, if the magnitude of the horizontal stress is high enough. A geomechanical analysis, based on Mohr circle constructions, will be used to demonstrate this property.

Subsequently, the property can be used to determine the paleo stress that was responsible for the inversion. Imagine two visibly contemporaneously inverted normal faults with slightly different strike orientations. The faults must have been reactivated by the same horizontal stress. For each of the faults the reactivation range can be determined by using a standard stereonet construction. The intersection of a normal fault with a vertical plane parallel to the orientation of the maximum horizontal stress (the reactivation stress) is the effective dip. Since that fault has been inverted, the orientation of the maximum horizontal stress must be in the reactivation range. The same holds for both faults. Given that the two faults have slightly different strikes, the reactivation ranges are also slightly differently oriented, however, both ranges must contain the same reactivation stress orientation. Overlying both reactivation ranges results in an overlap, which includes the reactivation stress and gives a reliable estimate of the orientation of the paleo reactivation stress. If more inverted faults can be used, the precision of the paleo stress analysis improves.

Having determined the strike orientation of the reactivation stress, it is now possible to use the result to determine which normal fault will have been inverted, even if the inversion component is not clearly visible.

The large stress increase that is associated with reverse reactivation can be correlated with the formation of a sealing cataclastic gouge. This was the main topic of the fault seal prediction studies for which the paleo stress analysis was developed. The technique has been successfully applied to inverted areas in the North sea, where it was used as part of fault seal prediction studies and could be verified with pressure data.

An advantage of this technique is, that it can be applied on the basis of seismic without the need for large data sets or well data. However, having rock mechanical rock properties available will of course improve the precision of the analysis.