STRESS HISTORY ANALYSIS FROM 3D RESTORATION OF FAULTS: INITIAL RESULTS AND IMPLICATIONS FOR FAULT REACTIVATION AND HYDROCARBON LEAKAGE IN THE TIMOR SEA REGION, AUSTRALIA

A. Gartrell and M. Lisk
CSIRO Petroleum, Australian Resources Research Centre, 26 Dick Perry Avenue, Kensington, WA 6151, Australia

Fault reactivation subsequent to hydrocarbon charge is a primary risk to seal integrity. In the Timor Sea, fault reactivation related to late Tertiary collision of the Australian continent with the Banda Island Arc is thought be responsible for the common occurrence of breached traps. Quantification of fault reactivation risk by analysing the in situ stress tensor has been reasonably successful in explaining patterns of leakage in the region (Castillo et al., 2000; de Ruig et al., 2000; Hillis, 1998; Mildren et al., 1994). However, these analyses rely on the assumption that the contemporary stress field has not changed significantly since the onset of hydrocarbon charge.

Two main stages of late Tertiary collision at Timor have been recognised (Charlton et al., 1991;Hillis, 1991;Woods, 1994). The first stage occurred in the Late Miocene (8 Ma) when transitional Australian continental crust reached the subduction system. Rapid uplift and deformation resulted, as sediments on the Australian Plate margin were accreted into the collision complex. The second stage occurred when true continental crust entered the subduction system in the mid-Pliocene. The Timor Trough evolved as a foredeep basin in response to imbricate thrust loading on the Australian margin during this event. The two collisional events are manifested in discrete fault reactivation events (e.g. at Oliver; Woods, 1994) and examples of extensional (dip-slip normal), transtensional (oblique-slip normal) and strike-slip (transcurrent) fault reactivation patterns are observed in seismic data throughout the Timor Sea. It seems unlikely to expect that the stress field has remained constant during this complex multi-staged collisional process through to the present day. A more complete understanding of fault reactivation history and associated leakage of hydrocarbons, with a better match to the observational data, may therefore be gained from analysis of palaeo-stress conditions.

Fault slip data can be used to derive a reduced palaeo-stress tensor, which describes the orientation of the principal stresses and the stress ratio, R = (s2-s3)/(s1-s3). The parameter R defines the shape of the stress ellipsoid and can be used to characterise the stress regime (extensional, compressional, strike-slip, transtensional, transpressional; (Angelier, 1994). Determination of the full stress tensor, which includes stress magnitude, requires knowledge of friction and failure parameters, and the depth of overburden.

The problem with using fault slip inversion techniques in an offshore petroleum exploration context is that fault slip data (e.g. slickensides) cannot be measured directly from seismic data and faults are rarely sampled by coring. However, 3D seismic data often enables good definition of footwall cut-off, hangingwall cut-off and fault plane geometries. Slip directions can be obtained by matching footwall and hangingwall cut-offs during 3D structural restoration of a given fault. Inversion of the fault-slip data can then be performed in order to estimate palaeo-stress conditions.

Initial palaeo-stress determinations have been made for the Skua area of the southern Vulcan Sub-basin using fault-slip inversion methods. 3D restoration and fault-slip inversion of the Rowan Fault, which was reactivated during the Late Miocene, indicate that an extensional stress regime existed at this time. s1 is shown to have been vertical, with s2 oriented approximately E-W and an R value of around 0.4 is calculated.

The palaeo-stress result contrasts with present day stress measurements in the Timor Sea region that generally indicate strike-slip or mixed strike-slip/extensional (transtensional) mode stress regimes (depending on locality) in which s2 is vertical, s1 is horizontal and oriented approximately 060°-240° (Castillo et al., 2000;Hillis, 1998). A local exception occurs in the Nancar Trough, where a significant change in the structural grain of the rift faults (E-W oriented) is associated with a swing in the orientation of s1 to approximately 015°-195° (Castillo et al., 2000).

The present-day NE-SW orientation of sHmax (i.e. s1 at present) is thought to be primarily related to stress focusing at the continent-continent collision occurring in New Guinea (Coblentz et al., 1998). The Late Miocene E-W trend of sHmax (i.e. s2 in the Late Miocene) is more consistent with the present day sHmax orientation of areas on the North West Shelf situated further south of the collisional zone (e.g. Northern Carnarvon Basin). Hence, the changes in the orientations and magnitudes of the principal stresses observed in the Timor Sea may represent the generation of increasing horizontal stress at the New Guinea collisional zone.

Tectonic processes aside, a late Tertiary extensional phase helps explain the range of reactivation styles observed in the Timor Sea region. When combined with charge histories, the variation in stress regimes indicated by this early work adds the possibility of a new layer of complexity to fault reactivation and associated leakage histories in the Timor Sea. However, this additional complexity may be necessary in order to obtain more accurate analysis of fault reactivation related leakage scenarios and risks in the region.

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