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Reprint of: Comparison of modern fluid distribution, pressure and flow in sediments associated with anticlines growing in deepwater (Brunei) and continental environments (Iran)☆

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ABSTRACT

Differences in fluids origin, creation of overpressure and migration are compared for end member Neogene fold and thrust environments: the deepwater region offshore Brunei (shale detachment), and the onshore, arid Central Basin of Iran (salt detachment). Variations in overpressure mechanism arise from a) the availability of water trapped in pore-space during early burial (deepwater marine environment vs arid, continental environment), and b) the depth/temperature at which mechanical compaction becomes a secondary effect and chemical processes start to dominate overpressure development. Chemical reactions associated with smectite rich mud rocks in Iran occur shallow (~1900 m, smectite to illite transformation) causing load-transfer related (moderate) overpressures, whereas mechanical compaction and inflationary overpressures dominate smectite poor mud rocks offshore Brunei. The basal detachment in deepwater Brunei generally lies below temperatures of about 150 °C, where chemical processes and metagenesis are inferred to drive overpressure development. Overall the deepwater Brunei system is very water rich, and multiple opportunities for overpressure generation and fluid leakage have occurred throughout the growth of the anticlines. The result is a wide variety of fluid migration pathways and structures from deep to shallow levels (particularly mud dykes, sills, laccoliths, volcanoes and pipes, fluid escape pipes, crestal normal faults, thrust faults) and widespread inflationary-type overpressure. In the Central Basin the near surface environment is water limited. Mechanical and chemical compaction led to moderate overpressure development above the Upper Red Formation evaporites. Only below thick Early Miocene evaporites have near lithostatic overpressures developed in carbonates and marls affected by a wide range of overpressure mechanisms. Fluid leakage episodes across the evaporites have either been very few or absent in most areas. Locations where leakage can episodically occur (e.g. detaching thrusts, deep normal faults, salt welds) are sparse. However, in both Iran and Brunei crestal normal faults play an important role in the transmission of fluids in the upper regions of folds.

1. Introduction

In the early days of hydrocarbon exploration the identification of surface anticlines associated with oil seeps, contains the implicit understanding that anticlines are sites of focused fluid flow, where some fluids are at least temporarily trapped, and others escape to the surface. As reviewed by Evans and Fischer (2012), today we understand that a very complex interplay exists in folds between fluids, stratigraphy, stages of fold development and fold style. Fluids

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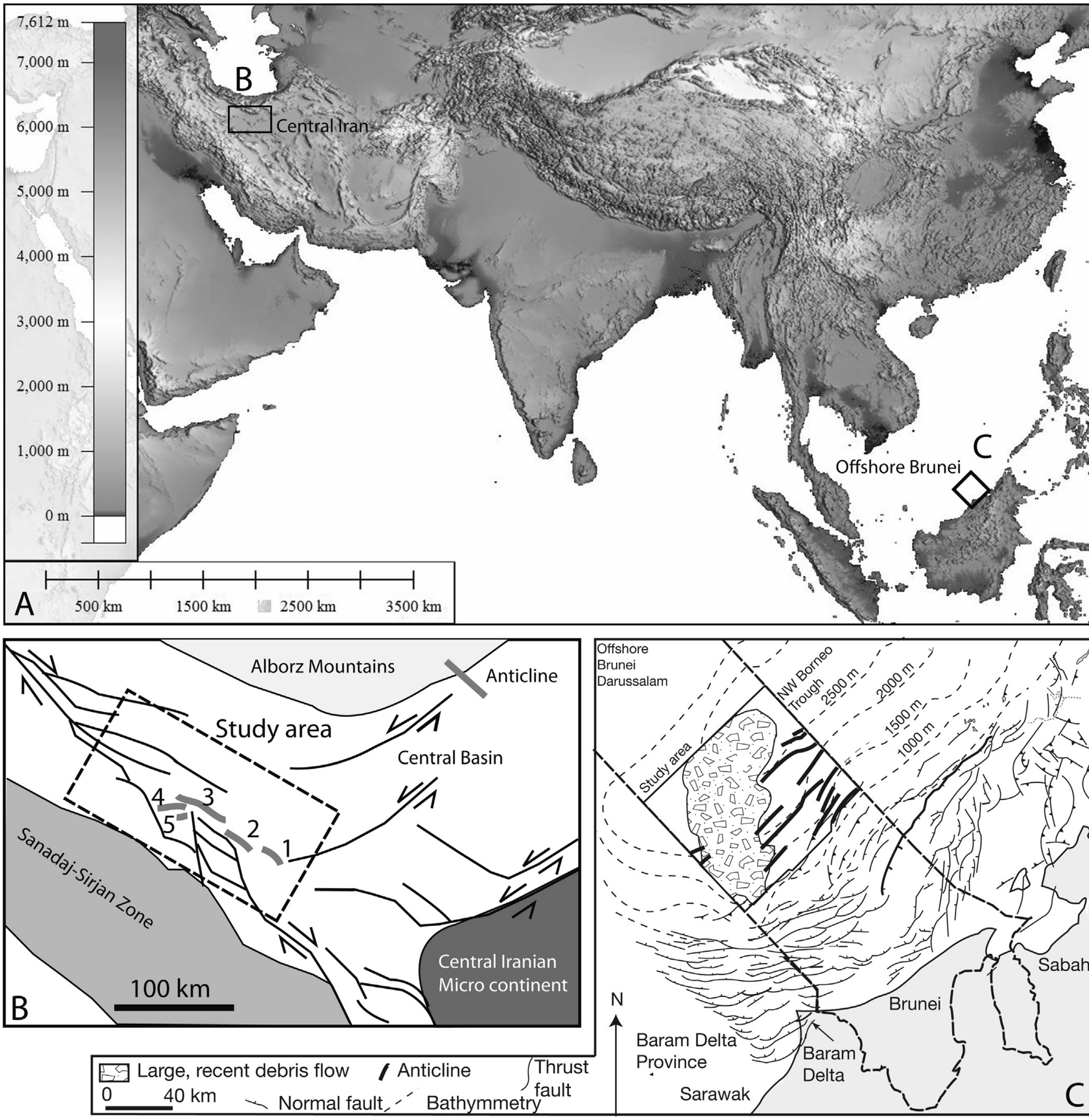

Figure 1. Location maps for the study areas. A) Regional map, B) Central Iran, C) Brunei. 1 = Silak Anticline, 2 = Sarajeh Anticline, 3 = Alborz Anticline, 4 = Mil-Zangar Anticline, 5 = Yazdan Anticline.

comprise three key properties: temperature, pressure and chemical composition, each of which is controlled by a number of processes. These properties can vary considerably even around a single fold (Evans and Fischer, 2012). Fluids exert an effect on rock strength, (by permitting pressure solution and other chemical reactions to occur, stiffening the rock by depositing cements, and reducing rock strength by overpressure) and impact structural style. Conversely the structural and stratigraphic permeability architecture influences the location of fluids and fluid migration pathways (e.g. Sibson, 1996, 2005). These fluid pathways typically involved downward percolation of meteoric waters through fractures, and upwards movement of warm fluids (particularly along thrusts, e.g. Barker et al., 2000; Beaudoin et al., 2011). Fluid filled zones, predominantly in fractures, are commonly transient features and evidence for their existence is likely to be lost if cements are not deposited. So, while understanding the development of folds by studying veins is very important and allows the sequential development of fold–fluid relationships through time to be determined (e.g. Barbier et al., 2012; Beaudoin et al., 2012; Evans and Fischer, 2012), it is also important to study active folds, and to understand how fluids are distributed at a snapshot in time of fold and thrust development. For example the modern relationships between