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Integrated hydroacoustic flares and geomechanical characterization reveal potential hydrocarbon leakage pathways in the Perth Basin, Australia

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ABSTRACT

Geoscience Australia (GA) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducted a marine survey including monitoring hydroacoustic flares in order to understand the natural leakage pathways in the offshore northern Perth Basin. 186 hydroacoustic contacts were encountered and classified and thirty two were interpreted as possible seeps or expulsion of gases from the subsurface. The contacts were typically distributed above areas of interpreted subsurface faulting. In the survey site Da (15 km^2), nine probable seeps and sixteen other contacts were interpreted and are aligned with a fault segment (A2) interpreted on 2D seismic reflection data. The segment A2 is part of a major N–NNW trending fault system intersecting the sedimentary sequence from the near seabed to the Permian units, including the Kockatea Shale source rock located in the oil window. Evaluation of the stress state on the fault segment A2 suggests that it is not critically stressed and therefore not likely prone to reactivation and dilation and vertical leakage under the modelled stress field. We propose that fault segment A2 acts as a baffle delimiting a migration pathway in the wall rock and permitting hydrocarbons generated from the source rock to overcome capillary entry pressures of the overlying marginal seals. The interpreted seeps could therefore be associated with intraformational vertical migration in the wall rock focused by the faults.

1. Introduction

The Perth Basin comprises depocentres and structural features formed in an obliquely-oriented extensional rift system on Australia's southwest margin during the Palaeozoic to Mesozoic breakup of eastern Gondwana (Crostella and Backhouse, 2000; Jones et al., 2011). The basin has had a complex, multi-phase history of extension and reactivation, and regional tectonic events that affected basin evolution and controlled sedimentation include: (i) Early to Middle Permian rifting followed by Middle to Late Permian uplift and Late Permian to Early Jurassic subsidence, (ii) Early to Middle Jurassic rifting followed by Middle to Late Jurassic subsidence, (iii) Late Jurassic to Early Cretaceous rifting followed by Early Cretaceous uplift and Early Cretaceous to Cainozoic subsidence, (v) local Miocene reactivation and inversion (Jones et al., 2011; Rollet et al., 2013).

Exploration drilling in the offshore northern Perth Basin has discovered residual oil and gas accumulations (i.e. current accumulation with palaeo-oil column, Jones and Hall, 2002; Kempton et al., 2011) and breached accumulations (i.e. dry closure with palaeo-oil column, Kempton et al., 2011) typically within Permian sandstone reservoirs overlain by the regional Triassic Kockatea formation source rock and seal. Kempton et al. (2011) validated the offshore extension of the Triassic petroleum system sourced from the oil-mature source (i.e. Early Triassic Kockatea Shale). The high incidence of palaeo-oil and residual columns, however, suggests that trap integrity and especially fault-seal represents an important risk factor for preservation of oil (Langhi et al., 2012).

In order to understand the natural leakage pathways a Geoscience Australia (GA)-Commonwealth Scientific and Industrial Research Organisation (CSIRO) survey was conducted in the

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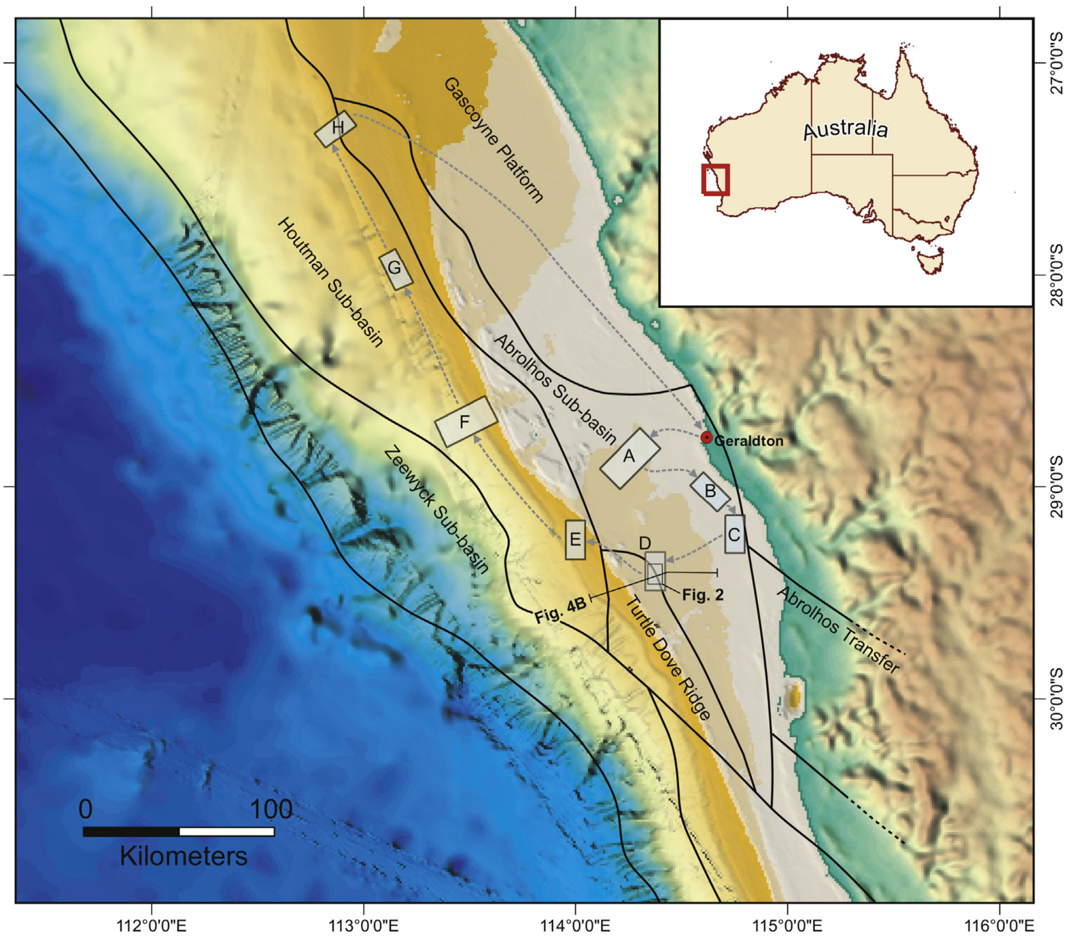

Figure 1. Structural elements of the study area in the offshore northern Perth Basin. Topography shown in the background. The GA-CSIRO survey route is shown with the grey dotted line; the eight detailed survey areas (A–H) are shown with grey boxes.

offshore northern Perth Basin (Fig. 1) aiming to identify and characterize natural hydrocarbon seepage through an integrated survey. This survey included characterization of acoustic signatures in the water column using echo sounder and side scan sonar, seafloor bathymetry and acoustic backscatter, sub-bottom profiling, water column and sediment sampling and ROV deployment. The survey extent encompassed an offshore area from 27.2151 to 29.5194 South latitude, 112.7503–114.7544 East longitude with eight detailed survey areas (A–H, Fig. 1). The Area D was selected to test for evidence of fluid seepage at sites of seafloor seismic amplitudes brightening above large depocentre-bounding faults on the western margin of the Abrolhos Sub-basin where a possible stratigraphic trap was interpreted in a thick basinal succession of high amplitude continuous reflectivity interpreted as a lowstand clastic basin fan complex of the Dongara Sequence (Rollet et al., 2013). Also, SAR anomalies where recorded in the area.

Many previous studies of hydrocarbon seeps have used acoustic methods to detect hydroacoustic flares in the water column indicative of expulsion of gases from the subsurface (e.g., Greinert et al., 2006; Sahling et al., 2008; Talukder et al., 2013). In this survey water column hydroacoustic flares were monitored using a split beam Simrad EK-500 echo sounder operating at 38 and 120 kHz and a single beam Simrad EA-500 echo sounder operating at 12 kHz. This data was logged and processed using Echoview (Myriax, Hobart, Tasmania), with acoustic plume locations, descriptions and interpretations exported to a database and geographical information system (GIS) on board the vessel.

During the survey of the eight areas (Fig. 1), and including transits between them, 186 echo-sounder hydroacoustic flares were encountered and classified. Thirty-two of these flares were interpreted as possible seeps or expulsion of gases from the subsurface. The interpretation was based on a number of prerequisite criteria such as; number of acoustic soundings, vertical orientation in the water column, morphology, spatial orientation to the seafloor and also relationship to seafloor morphological features typically associated with cold seeps (Talukder et al., 2013). Hydroacoustic flares were not ubiquitous in all areas however where observed they typically were distributed above areas of interpreted N–S subsurface faulting.

In this short communication we will present echo-sounder results and investigating the relationship between the subsurface structures and the possible mechanism controlling the natural seepage in site Da, a NE–SW oriented c. 15 km^2 survey area (29.4060–29.4601 DD South latitude114.3234–114.3702 DD East longitude).

2. Echo-sounder contacts

26 echo-sounder contacts were imaged over an approximately 22 h period over the survey site Da (Fig. 2). Nine vertical hydroacoustic flares from the seabed with vertical extents to for greater