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Pockmark development in the Petrel Sub-basin, Timor Sea, Northern Australia: Seabed habitat mapping in support of CO_2 storage assessments

W.A. Nicholas [a,*], S.L. Nichol [a], F.J.F. Howard [a], K. Picard [a], H. Dulfer [b], L.C. Radke [a], A.G. Carroll [a], M. Tran [a], P.J.W. Siwabessy [a]

[a] Marine and Coastal Geoscience Group, Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia
[b] Regional Geology & Mineral Systems Group, Geoscience Australia, GPO Box 378, Canberra, ACT 2601, Australia

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ABSTRACT

The extent to which fluids may leak from sedimentary basins to the seabed is a critical issue for assessing the potential of a basin for carbon capture and storage. The Petrel Sub-basin, located beneath central and eastern Joseph Bonaparte Gulf in tropical northern Australia, was identified as potentially suitable for the geological storage of CO_2 because of its geological characteristics and proximity to offshore gas and petroleum resources. In May 2012, a multidisciplinary marine survey (SOL5463) was undertaken to collect data in two targeted areas of the Petrel Sub-basin to facilitate an assessment of its CO_2 storage potential. This paper focuses on Area 1 of that survey, a 471 km^2 area of sediment-starved shelf (water depths of 78 to 102 m), characterised by low-gradient plains, low-lying ridges, palaeo-channels and shallow pockmarks. Three pockmark types are recognised: small shallow unit pockmarks 10–20 m in diameter (generally <1 m, rarely to 2 m deep), composite pockmarks of 150–300 m diameter formed from the co-location of several cross-cutting pockmarks forming a broad shallow depression (<1 m deep), and pockmark clusters comprised of shallow unit pockmarks co-located side by side (150–300 m width overall, <1 m deep). Pockmark distribution is non-random, focused within and adjacent to palaeo-channels, with pockmark clusters also located adjacent to ridges. Pockmark formation is constrained by AMS ^{14}C dating of in situ mangrove deposits and shells to have begun after 15.5 cal ka BP when a rapid marine transgression of Bonaparte Shelf associated with meltwater pulse 1A drowned coastal mangrove environments. Pockmark development is likely an ongoing process driven by fluid seepage at the seabed, and sourced from CO_2 produced in the shallow sub-surface (<2 m) sediment. No evidence for direct connection to deeper features was observed.

1. Introduction

The geological storage of carbon dioxide (CO_2) in offshore sedimentary basins has the potential to complement the use of marine renewable energy in reducing the input of carbon into the environment. However, because of the heterogeneity among sedimentary basins and their geological settings the suitability and characterization of proposed target sites for CO_2 storage needs to be explored on a case-by-case basis (Hovorka et al., 2004; Gough and Shackley, 2005; Holloway, 2007; Gibson-Poole, 2009; Carpenter et al., 2011). For the marine environment, this requires integrated mapping of seabed environments and the subsurface geology to identify locations of potential and past leakage, and the relationship of seabed environments to storage reservoirs.

Buoyant fluids are expressed at the seabed through focused fluid flow, commonly resulting in the formation of mineralised chimneys in the subsurface, and pockmarks at the seabed (Van Rensbergen et al., 2007). Such fluids consist of liquid and gas which may contain hydrocarbons, and can be sourced from hydrocarbon reservoirs, water-saturated sedimentary rock, mineral-related brines, and groundwater. In sedimentary basins the gaseous phase is most commonly the hydrocarbon methane (CH_4). Non-thermogenic gases may be produced biogenically through the breakdown of organic matter, or abiogenically from dissolving bicarbonate (HCO_3^-) (Horita and Berndt, 1999). Pockmarks are common in areas with thick accumulations of Holocene sediment, in shallow marine (continental shelf) environments (Judd and Hovland, 2007). They are of particular interest because of their possible contribution to catastrophic gas venting (gas blowouts), slope failure, relationships to earthquakes, and because of the development of significant seep-related habitats (e.g. bioherms, reefs, etc.). More recently, because of the interest in

* Corresponding author. Tel.: +61 2 6249 9672.
E-mail address: tony.nicholas@ga.gov.au (W.A. Nicholas).

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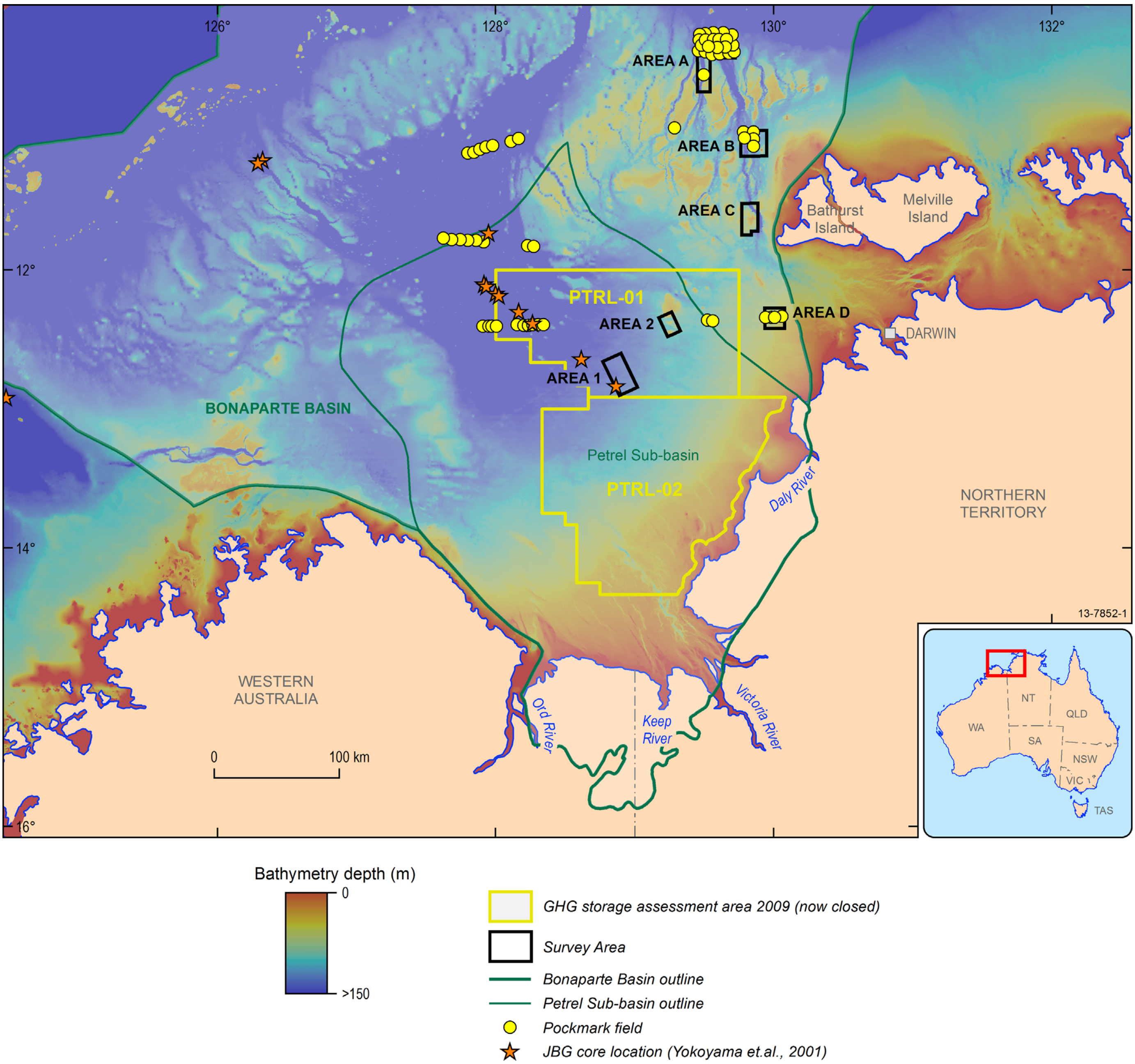

Fig. 1. Location of the study area (Area 1) set within semi-enclosed Joseph Bonaparte Gulf. The Petrel Sub-basin, located within the Bonaparte Basin underlies Joseph Bonaparte Gulf. Also illustrated are the locations of former Greenhouse Gas storage assessment areas (now closed) Petrel 01 and 02. Areas A–D are from previous surveys undertaken by Geoscience Australia in collaboration with AIMS (SOL4934, SOL117).

carbon sequestration in the sub-surface marine environment, the presence of fluid-related structures at the seabed has become a key factor in understanding the sub-surface plumbing system in sedimentary basins.

The Australian Government, through Geoscience Australia, is undertaking integrated seabed mapping surveys focused on the seabed and shallow subsurface to help reduce uncertainties associated with storing CO_2 in Australia's offshore basins. These studies form part of a large body of work being undertaken under the National CO_2 Infrastructure Plan (NCIP). These seabed mapping surveys have two linked aims: (i) the collection of data from the seabed and shallow (<100 m) subsurface environments to determine if there is evidence for seepage to the seabed, and; (ii) characterisation of seabed habitats for their ecological function and significance.

In May 2012, Geoscience Australia undertook a marine survey (SOL5463/GA0335) of the seabed and shallow subsurface geology in two targeted areas of the Petrel Sub-basin (Area 1 and Area 2), in Joseph Bonaparte Gulf, northern Australia (Carroll et al., 2012; Fig. 1). The survey was undertaken in collaboration with the Australian Institute of Marine Science (AIMS) on board the AIMS research vessel, *R. V. Solander*. The survey in the Petrel Sub-basin forms part of the Australian Government's National Low Emission Coal Initiative (NLECI), which aims to accelerate the development and deployment of low-emission coal technologies involving carbon capture and the geological storage of CO_2.

Pockmarks play a central role in understanding fluid flow from the sub-surface to the seafloor. Therefore the objectives of this paper are to present results, describe the geomorphology, and provide an interpretation of seabed geomorphic features from Area 1 of marine survey SOL5463. We also assess those features, in particular pockmarks, for their potential as indicators of past or active fluid flow, and the implications for CO_2 storage of their presence.