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Research paper

New style of honeycomb structures revealed on 3D seismic data indicate widespread diagenesis offshore Great South Basin, New Zealand

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ABSTRACT

In the Great South Basin, within the Eocene section, at time-depths around 700–900 ms two way time below the seafloor, unusual features are observed on 3D seismic data closely associated with polygonal faults. The features, referred to as honeycomb structures (HS), cover an area of ~600 km^2, are packed circular, oval, to polygonal depressions 150–400 m across in plan view and several to 10 + m in amplitude. Polygonal faults rapidly die out at the Marshall Paraconformity, which is overlain by the Oligocene Penrod Formation. Hence the polygonal faults are inferred to have formed prior to the Marshall Paraconformity, and they cross-cut HS features. Consequently the top of the HS probably formed at burial depths of around 375–500 m, which is their decompacted depth below the paraconformity. The interval containing HS is about 125 m vertical thick. There are several possible origins for the HS. The most probable is related to bulk contraction of the sediment volume accompanied by fluid expulsion, which suggests a diagenetic origin, in particular the opal-A/CT transition. There are actually two polygonal fault systems (PFS) present in the area. The Southern Tier 1 PFS lies laterally to the HS and overlaps with it. The Northern PFS (Tier 2) lies above the HS, appears to be independent of the HS, and formed in the upper 200–300 m of the sediment column. The Tier 1 PFS probably formed by shear failure related to the same diagenetic effects that caused the HS.

1. Introduction

In the Great South Basin (GSB), New Zealand (Fig. 1), the post-rift, bathyal upper Eocene marl-prone interval imaged on 3D seismic data has revealed the presence of extensive polygonal fault systems (PFS) with cell sizes typically in the range of 400–1000 m (Figs. 2 and 3). In some areas overlapping with the polygonal faults is a new type of seismically imaged feature (Figs. 4 and 5). These features are most strikingly seen on amplitude time and horizon slices. They form fields of circular, oval and polygonal shapes about 150–400 m across that are closely spaced (centre to centre distances are typically in the range of 180–400 m), cover an area in excess of 600 km^2 and affect a zone tens of metres thick (Fig. 3). These features, like larger-scale density inversion or differential compaction structures described by Davies et al. (2009) and Davies and Cartwright (2007) have a 'bubble wrap' appearance in plan view (Fig. 5). However, the features described here in some particularly well imaged areas have a polygonal, commonly hexagonal planform morphology rather than exclusively circular (Fig. 4). Hence, we refer to these structures here as honeycomb systems (HS) following Maczak (2014).

Circular to polygonal features present in sediments can be caused by a wide variety of processes including: dissolution and collapse associated with karst, patterned ground (e.g. lithalsas) related to periglacial processes, biological growths in mound fields, diagnetically-triggered polygonal faults (including juvenile or sub-seismic scale polygonal faults), fluid escape features (e.g. pockmarks), soft sediment deformation by compaction/loading, and diagenetic changes such as opal A-opal CT transition and calcite/aragonite dissolution (e.g. Isaacs et al., 1983; Hesse, 1990; Kessler

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and Werner, 2003; Berndt, 2005; Gay et al., 2006; Cartwright, 2007; Judd and Hovland, 2007; Meadows and Davies, 2007; Moss and Cartwright, 2010; Moss et al., 2012; Howarth and Alves, 2016). This paper describes for the first time the nature of the HS features, discusses their likely origin, and relationship with adjacent, superimposed polygonal fault systems (PFS).

2. Geological setting

The Great South Basin lies offshore, SW of New Zealand's South Island (Fig. 1). It formed as an intra-continental basin during Jurassic-Cretaceous and Late Cenomanian-Turonian extension associated with Gondwana breakup and separation of Australia, Antarctia and Zelandia (Beggs, 1993; Cook et al., 1999; Cox and Sutherland, 2007; Grobys et al., 2009; Uruski, 2010). The Santonian period represents the start of a prolonged period of transgression and subsidence in the GSB area, accompanied by drowning of earlier terrestrial and near-shore environments (Uruski, 2010, Fig. 6). This transgression culminated in widespread deposition of the organic-rich shales of the Waipawa Formation during the Paleocene-Eocene Thermal Maximum (Nicolo et al., 2007; Killops et al., 2000).

The upper part of the Late Cretaceous to top Eocene section comprises the post-rift subsidence phase, while the Oligocene and Neogene marks continued subsidence during a time that regionally in New Zealand is characterized by compression and onset of the Tonga-Kermadec subduction (Sutherland et al., 2010; Bache et al., 2012). The four sedimentary units that comprise the succession in the GSB are the Hoiho (Late Cretaceous, syn-rift), Pakaha (Late Cretaceous-Eocene post-rift, shale dominated), Rakiura (Eocene, marl-dominated), and Penrod (Oligocene-Neogene) groups (Fig. 6). For the shallow features discussed in this paper the Late Eocene is the key period. This period follows a transition from widespread deposition of organic-rich shales during the Paleocene-Eocene thermal maximum to deltaic progradation associated with a major Early Eocene lowstand (Nicolo et al., 2007; Killops et al., 2000). The Early Eocene delta progradation is seen in the SW part of the study area (Fig. 7). Deepwater (mesopelagic) conditions were established during the Middle-Late Eocene, and significant reworking by currents of sediments produced widely developed contourite deposits (ExxonMobil Exploration Company, 2010). The Rakiura Group is subdivided into the shale-dominated Laing Formation and the marl-dominated Tucker Cove Formation. These formations are lateral equivalents where the Tucker Cove Formation grades into the Laing Formation passing to the NW, but generally the Tucker Cove Formation overlies the Laing Formation.

The Eocene-Oligocene boundary is the regional Marshall Paraconformity (Figs. 7 and 8), which from DSDP studies is related to the onset of the Antarctic Circumpolar Current (Kennett et al., 1975; Carter, 1985; Fulthorpe et al., 1996; Lever, 2007). Above and below the Marshall Paraconformity are contourite deposits, and overlying it are drift sheets (Uruski and Ilg, 2006, Fig. 8). Today the study area lies

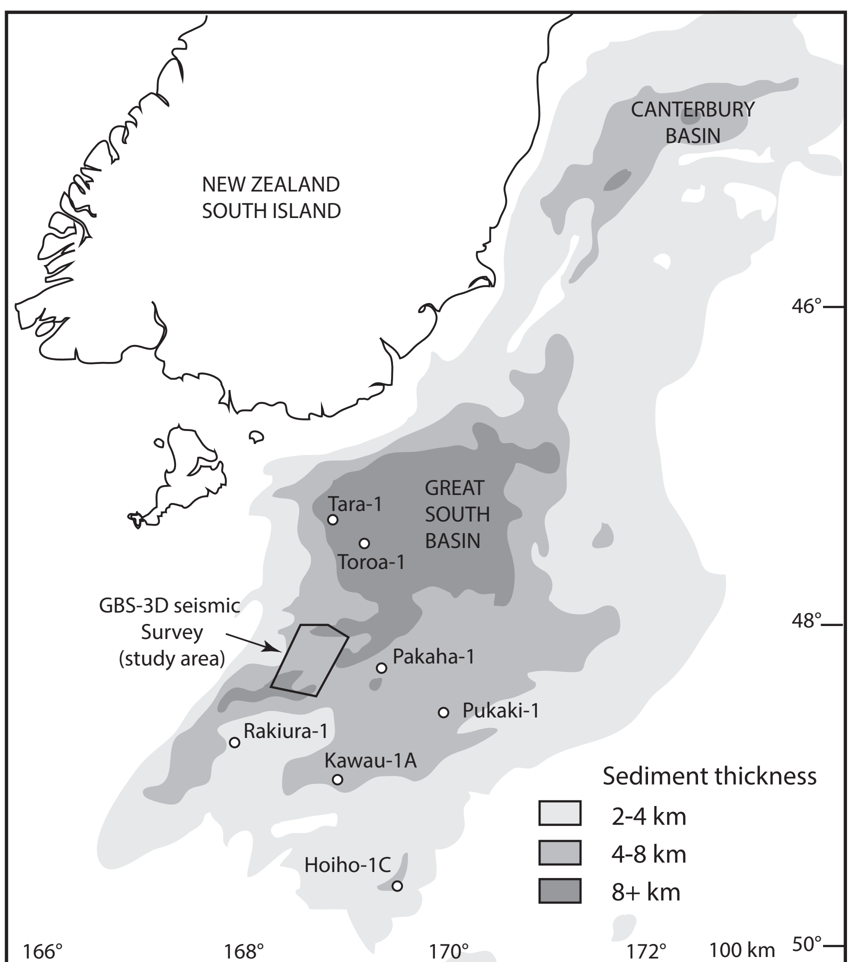

Fig. 1. Location map for the study area in the Great South Basin, New Zealand.