Journal of Structural Geology 79 (2015) 31–41

Contents lists available at ScienceDirect

Journal of Structural Geology

journal homepage: www.elsevier.com/locate/jsg

Paleo stress contribution to fault and natural fracture distribution in the Cooper Basin

H. Abul Khair*, D. Cooke, M. Hand

Australian School of Petroleum, University of Adelaide, 5005, Australia

ARTICLE INFO

Article history:
Received 3 October 2014
Received in revised form
7 July 2015
Accepted 11 July 2015
Available online 15 July 2015

Keywords:
Paleo-stress
Discrete fracture network
Geomechanics
Fault network
Elastic dislocation

ABSTRACT

The contribution of the unconventional reservoirs to the global oil and gas production made it important to address the main factors that control high production from these reservoirs. Hydraulic fracturing that intersect natural fractures results in a high stimulated rock volume and high production. Over a decade of effort to use elastic dislocation and different types of restoration to predict fracture network didn't succeed fully in addressing this factor.

We used image log fractures and fault network within an iterative boundary element method (iBEM3D) to predict the paleo-tectonic events and the fracture network in the Cooper Basin. The methodology was able to predict only the major tectonic events that occurred after the deposition of the Cooper Basin sediments and contributed to the formation of the natural fractures. As the methodology does not include fault elastic properties, fracture orientations near the faults showed unrealistic results and should not be considered as indicative for the actual natural fractures.

The main trend of the Cooper Basin fractures was attributed to post Triassic inter-seismic relaxation after major tectonic compressional events, which resulted in a normal fault stress regime. However, the current day stress regime is believed to be also a major factor in forming some of the natural fractures. Hunter Bowen orogeny in the Late Triassic contributed less to the existing fractures. Whereas, Cainozoic compressional forces played no role in the formation of the Cooper Basin natural fractures.

1. Introduction

Mapping fractures from image logs and cores is considered the most accurate way for determining the fracture density at the well bore location in one dimension (1D). However, detecting fractures in the subsurface between wells is a major challenge for the oil and gas companies, and was approached by researchers in different ways such as stochastic models (e.g. La Pointe and Hudson, 1985), seismic attributes (e.g. Chopra and Marfurt, 2007; Abul Khair et al., 2012), amplitude versus offset (AVO) (e.g. Schoenberg and Sayers, 1995), magnetotellurics (e.g. Thiel et al., 2012), and different types of restoration (e.g. Abu Khair et al., 2013a, 2013b). The majority of the fractures in any basin rocks are products of the main paleo-tectonic events affected that particular basin.

Over the last couple of decades, geologists sought to understand the tectonic history of faulted and fractured regions by relating slip along faults, together with the orientation, to the state of the stress at the time of displacement (e.g. Anderson, 1942; Price, 1966; Okada, 1985; Mandl, 1988; Maerten, 2000). The rapid increase in the availability of three dimensional (3D) fault geometries and their slip distribution encouraged the development of complex geometric, kinematic, stochastic, and geomechanical methods to determine the paleo-tectonic events and the spatial distribution of its related paleo-stress magnitudes. These methods are based on different algorithms which aim to restore the existing natural geological structures through inverse and forward problem solving.

Recently, a three dimensional iterative boundary element method (iBEM3D) was introduced by Maerten et al. (2014) for modelling complex geological structures. The methodology is based on the use of the theory of angular dislocation and superposition to model 3D discontinuities in elastic, heterogeneous, isotropic whole or half space. It involves running thousands of iterations that include different stress regimes and different stress magnitudes to forward model the current structures and calculate paleo-tectonic events responsible for generating them. A detailed description of the methodology will be discussed in details later.

The Cooper Basin in South Australia (Fig. 1), has been one of the

* Corresponding author.
E-mail address: Hani.abulkhair@adelaide.edu.au (H. Abul Khair).

http://dx.doi.org/10.1016/j.jsg.2015.07.007
0191-8141/

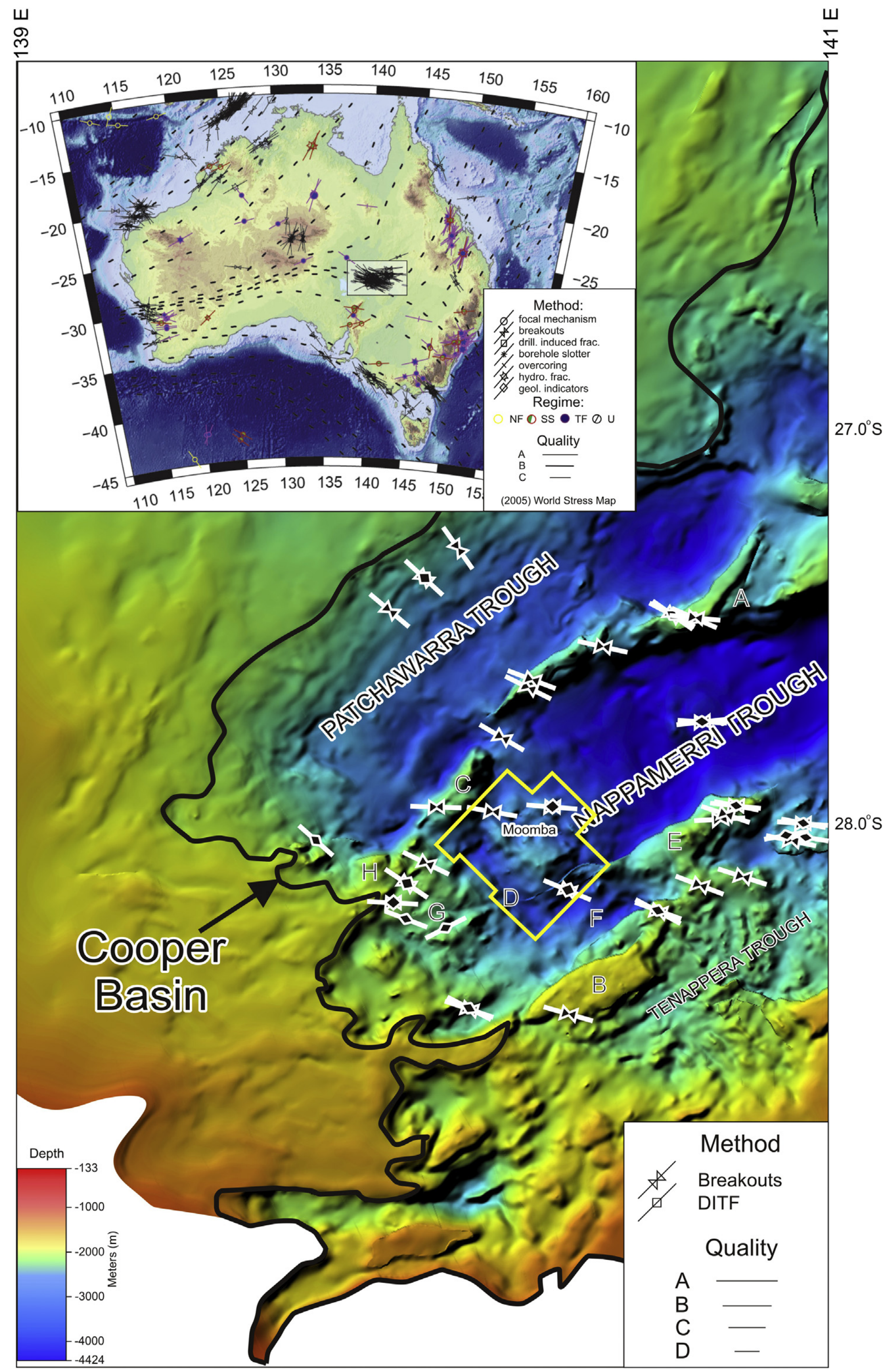

Fig. 1. Top Warburton Basin (Pre-Permian Basement, seismic horizon Z) in the Cooper Basin (Modified after NGMA, 2009). Map shows NE–SW major troughs separated by ridges. Study area is located at the southwestern termination of the Nappamerri trough (Moomba-Big Lake 3D seismic cube outlined in yellow). A: Innamincka Ridge; B: Murteree Ridge; C: Gidgealpa – Merrimelia Ridge; Wooloo Trough; E: Della-Nappacoongee Ridge; F: Allunga Trough; H: Warra Ridge. Top left: Australian stress map (Modified after Hillis and Reynolds, 2000 and Heidbach et al., 2010), SH indicated in black lines. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

major oil and gas producers from its Permian tight sands since last century. However, shales in the Cooper Basin are now attracting attention as target for oil and gas production following the enormous shale production in North America. In the current study, we use the iBEM3D technique to construct the paleo-stress state during the major paleo-tectonic events for the Cooper Basin. This in