Marine and Petroleum Geology 59 (2015) 593–610

Contents lists available at ScienceDirect

Marine and Petroleum Geology

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

Research paper

Validation of lateral fluid flow in an overpressured sand-shale sequence during development of Azeri-Chirag-Gunashli oil field and Shah Deniz gas field: South Caspian Basin, Azerbaijan

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ARTICLE INFO

Article history:
Received 24 November 2013
Received in revised form
10 July 2014
Accepted 20 July 2014
Available online 28 July 2014

Keywords:
Azerbaijan
South Caspian Basin
Shah Deniz
Azeri-Chirag-Gunashli
Pliocene Productive Series
Lateral fluid flow
Tilted fluid contacts
3D basin modeling

ABSTRACT

Data collected over the past 15 years from exploration, appraisal and production in the offshore South Caspian Sea validates the previously developed model of lateral fluid flow from the overpressured basin center to the basin margins within the sandstone aquifers of the Pliocene Productive Series. Specifically, new data confirm the predictions that 1) although both sandstones and shales are overpressured, sandstones are generally less overpressured than shales, 2) there is a lateral, regional gradient in sandstone overpressure, decreasing from the basin center to the basin margin and 3) the impact on the pressure field from local features such as mud volcanoes or local faults is limited. Additional pressure data, combined with regional seismic mapping, suggests variations in lateral fluid flow in different stratigraphic intervals. These data show that the less continuous sandstones of the upper and lower Productive Series are closer to the surrounding shale pressures as they are less well connected to the basin margin outlet, whereas, continuous sandstones in the middle Productive Series show the highest amount of lateral pressure transfer from the basin center and are therefore at lower pressures than the surrounding shales. Pressure data from development wells at the Azer-Chirag-Gunashli oil field and the Shah Deniz gas-condensate field reveal local variations in sandstone and shale overpressure resulting from the lateral pressure transfer affect (Traugott and Heppard, 1994; Traugott, 1996; Swarbrick and Osborne, 1998; Yardley and Swarbrick, 2000). Across large, high relief structures, well-connected sandstones transmit fluid pressures from the adjacent, deep overpressured synclines into the shallower crest of the structure. Pressures in sandstones decrease updip along a hydrostatic gradient (0.433 psi/ft). The pressure gradient in the shales however, will change according to the shale overpressure gradient. In the South Caspian Basin the overpressure gradient in the shales varies between 0.6 and 0.9 psi/ft. Therefore, the relative overpressure between the sandstones and shales varies along structural dip. There are a number of important implications to exploration, appraisal, and development because of large scale lateral fluid flow. Lateral fluid flow has consequences for the sealing capacity of sandstone reservoirs and the variable position of hydrocarbon –to- water contacts around a structural accumulation. This requires each sandstone–shale couplet be considered separately for pore pressure prediction. Basin-scale 3D models were constructed to better understand the implications of basin-scale fluid flow within and between individual reservoirs at each structure.

1. Introduction

The South Caspian Basin (SCB) has regained a prominent position in global oil and gas production. Developments at Azeri-Chirag-Gunashli (ACG) and Shah Deniz (SD) in the offshore Azerbaijan (Fig. 1) have resulted in export of large quantities of oil and gas. These developments produce from the Pliocene Productive

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http://dx.doi.org/10.1016/j.marpetgeo.2014.07.019
0264-8172/

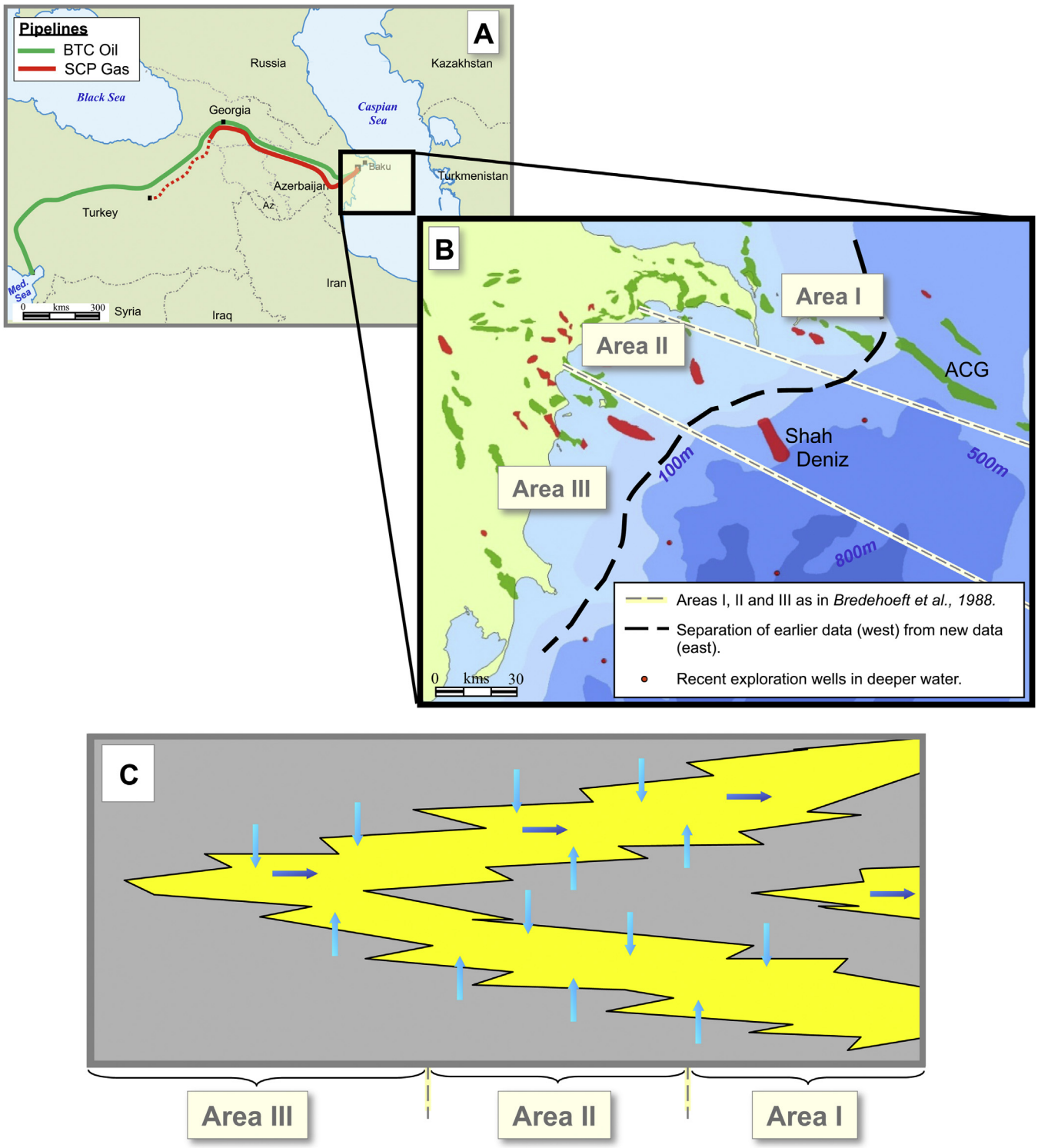

Figure 1. A. Map of Caspian region showing oil and gas export pipelines of the Baku-Tblisi-Ceyhan oil pipeline (BTC) and South Caucasus gas pipeline (SCP). B. Bathymetry of north-western South Caspian Basin showing location of recent oil and gas developments and exploration wells. Azeri-Chirag-Gunashli oil field (ACG) and Shah Deniz gas field (SD) represent major new offshore developments with over one hundred and fifty new wells drilled. Also shown on map are Areas I, II, and III as defined in Bredehoeft et al. (1988) and extent of original data set. C. Schematic stratigraphic model of Bredehoeft et al. (1988), summarizing lateral fluid flow model of South Caspian Basin. Area I displays highest sandstone to shale ratio and the least amount of overpressure. Area III displays the lowest sandstone to shale ratio and the highest amount of overpressure. Area II is intermediate between the extremes.

Series (PS) reservoirs (Fig. 2) further offshore and in deeper water than had been penetrated previously (Wethington et al., 2002; Reynolds et al., 1998).

Hydrocarbons have been produced from PS reservoirs for over 150 years, both onshore and then in shallow water extensions of onshore fields. In Bredehoeft et al. (1988), Buryakovsky and Javanshir (1983), Javanshir (1985) the authors interpreted data collected from these onshore and near shore developments and concluded that sandstones in the SCB act as lateral conduits for fluid flow from the overpressured basin centre to the margins of the