PETROLEUM EXPLORATION AND DEVELOPMENT
Volume 43, Issue 4, August 2016
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: PETROL. EXPLOR. DEVELOP., 2016, 43(4): 602–610.

RESEARCH PAPER

Quantitative analysis of the effect of salt on geothermal temperature and source rock evolution: A case study of Kuqa foreland basin, Western China

WU Hai[1, 2,*], ZHAO Mengjun[1, 2], ZHUO Qingong[1, 2], LU Xuesong[1, 2], GUI Lili[1, 2], LI Weiqiang[3], XU Zuxin[2]

1. Key Laboratory of Basin Structure and Hydrocarbon Accumulation, CNPC, Beijing 100083, China;
2. PetroChina Research Institute of Petroleum Exploration & Development, Beijing 100083, China;
3. School of Geosciences, Yangtze University, Wuhan 430100, China

Abstract: There develop two sets of thick salt in the Kuqa foreland basin, the impact of salt thickness on geothermal temperature and thermal evolution of source rock was analyzed using transient thermal modeling method based on the two dimensional seismic profile from west to east of the basin and the related boundary condition. The results indicate that: (1) the change of salt plies will not have different impact on geothermal temperature when the total thickness of the salt body is constant; (2) the geothermal temperature of formations above the salt will increase about 0.3–0.6 °C/100 m, while the subsalt geothermal temperature will decrease about 0.6–1.0 °C/100 m in the west of the basin; the geothermal temperature of formations above the salt will increase about 1.9–2.3 °C/100 m, while the subsalt geothermal temperature will decrease about 0.2–2.6 °C/100 m in the east of the basin; (3) the value of vitrinite reflectance will be lagged about 0.02%/100 m averagely in the west of the basin, and will be lagged about 0.05%/100 m in the east. As the thermal conductivity of salt is negatively correlated with temperature, the salt body in the east has a shallower burial and lower geothermal temperature, so its overall thermal conductivity is higher, causing the changing rates of geothermal temperature and R_o are higher than the west. A case study of Dina 2 condensate field of Kuqa foreland basin indicates that the charge time of hydrocarbon there lagged about 7.5–9.0 Ma because of the delayed source rock thermal evolution caused by the salt, matching well with the formation period of trap, which is favorable for the late accumulation of hydrocarbon in this area.

Key words: salt; conductivity; geothermal temperature; source rock; thermal evolution; basin modeling; Kuqa foreland basin; Tarim Basin

Introduction

The studies on salt concentrate on the characteristics of its traps and seal before. The strong ductility of salt could have a big influence on hydrocarbon migration and accumulation, causing the formation of favorable prospects in the suprasalt, subsalt, intrasalt and the flank area[1–3]. In the 1930s, it was found that the presence of salt in the sedimentary basin would modify the geothermal field[4], the impact area is about 2–3 times the salt diameter[5–6]. The anomaly of the geothermal is caused by high thermal conductivity of salt[7]. The thermal conductivity of salt tested in the lab is 2–4 times higher than other kinds of sedimentary rocks (sandstone and mudstone etc)[8–9], and the presence of matrix and fluid would make its thermal conductivity 10–30 times higher than other kinds of sedimentary rocks[10–11].

The presence of salt would cause higher geotherm in the suprasalt area, lower geotherm in the subsalt area compared with the area without salt, and the shape of salt would also have widely different effect on geotherm[8]. Mello[8] made several salt models such as cylindrical, single peak and double peak, salt mushroom, and salt sheet models based on different shapes of salt bodies, simulated their impact on geotherm under the steady state heat flow, and concluded that some elements, including the burial depth, shape and size of salt bodies would influence the geothermal changing degree. Moreover, the anomaly geothermal field will make the thermal evolution of the suprasalt source rock advance, and the thermal evolution of the subsalt source rock delay, enlarging hydrocarbon generation window. In addition, the quartz cementation starts from 80 °C, and the cementation rate will increase exponentially with the increase of temperature[12–15], so the presence

Received date: 31 Aug. 2015; **Revised date:** 22 May 2016.
* **Corresponding author.** E-mail: wuhai2012@hotmail.com
Foundation item: Supported by the China National Science and Technology Major Project (2016ZX05003-002); the PetroChina Science and Technology Development Project (2016B-0502).

of salt will slow down the cementation rate in subsalt layers, which is favorable for the preservation of porosity.

The geothermal field anomaly studies before were based on simplified theoretical salt models or drilling stem test temperature, which could hardly reflect the real geological situation and only allowed qualitative analysis due to the restriction of salt burial depth[8,16]. In this study, based on the two dimensional seismic profile from west to east of Kuqa foreland basin, transient heat flow method was used to simulation and quantitatively analyze the effect of salt on the geotherm and thermal evolution of source rock, and further discuss its significance in the formation of oil and gas reservoir.

1. Geologic setting

The Kuqa foreland basin was developed from the Permian to Quaternary and it belongs to rejuvenated foreland basin[17–18] or inheritance foreland basin[19–20]. It have two sets of thick salt layers each in the west and east of the basin (Fig. 1). The salt layer in the west is in the Paleogene Kumugeliemu Formation, with a thickness from 100 to 3000 meters, and more than 3000 meters in local areas, and is thickest in Well Dawan1—Tubei4—Keshen2 area; the salt layer in the east is in the Neogene Jidike Formation, and is thickest in Well Dongqiu8—Dongqiu5—Dina03 area, with the thickness exceeding 2700 m in Well Dongqiu8. The source rock of the basin mainly includes the subsalt Triassic lacustrine mudstone and Jurassic carbonaceous mudstone, but large in burial depth, the source rock has been rarely encountered in drilling, making it difficult to study the source rock directly[21].

2. Construction of the geologic model

2.1. Simplified salt model

When the salinity of saline lacustrine basin change from low to high and to low again, the sediments deposited would follow a regular sedimentary sequence, i.e. sand-shale-dolostone-gypsiferous-salt-halite-salt-gypsiferous-dolostone-shale-sand from bottom to top[22], sometimes, there would be a thin limestone layer before the deposition of dolomite[22]. As there are several this kind of sequences in Kuqa basin, there are some clastic layers (mudstone) interbedded in the main salt layers, which has been found in core observation. The occurrence of multiple thin mudstone layers adds difficulty to the geologic model building and description of salt layers, so before thermal simulation, it is necessary to analyze whether the variation of layer number will have a different impact on the geothermal field when the total thickness of salt is fixed.

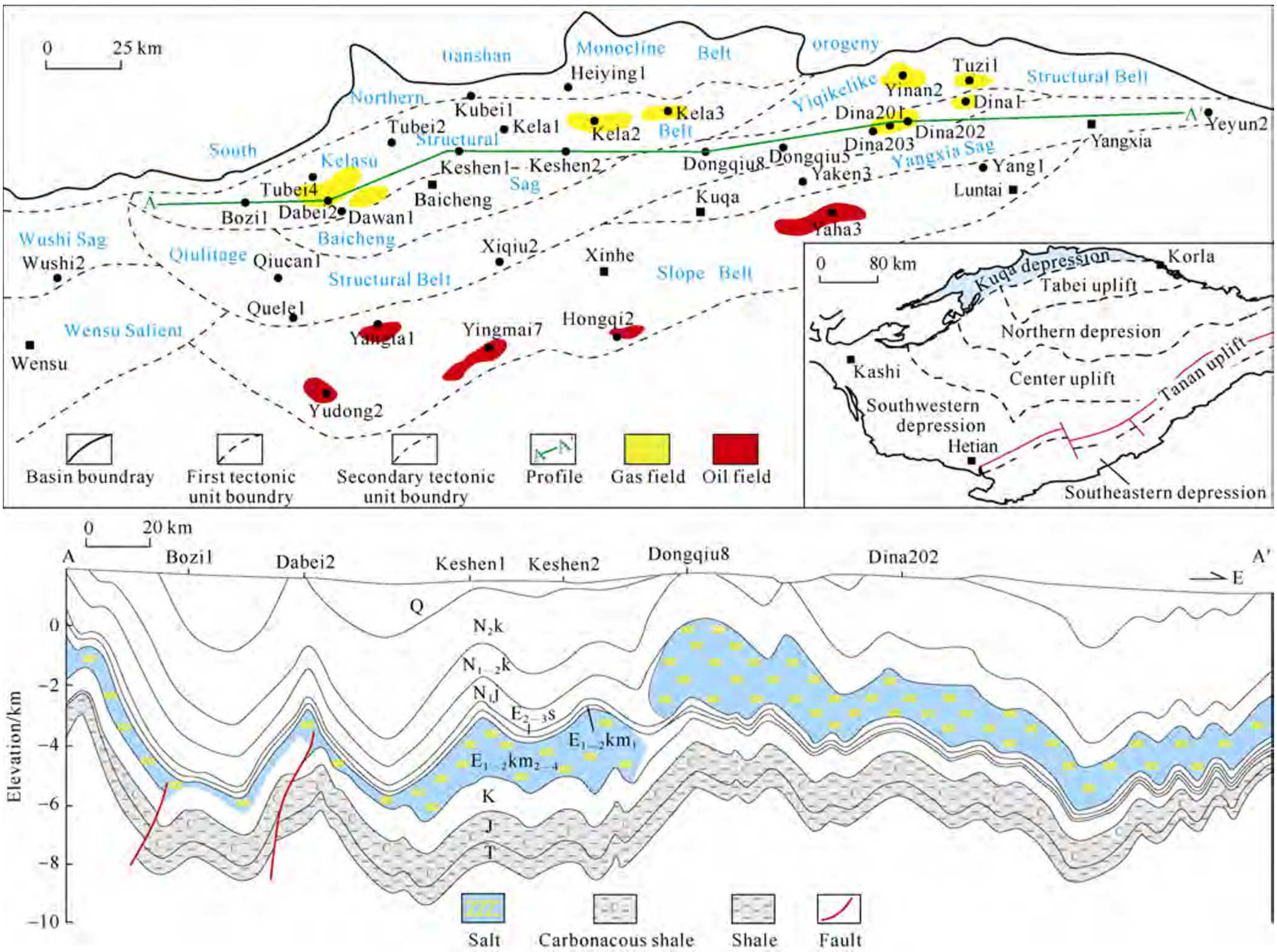

Fig. 1. Structural units and geologic profile of Kuqa foreland basin. N_2k—Kuqa Formation, $N_{1-2}k$—Kangcun Formation, N_1j—Jidike Formation, $E_{2-3}s$—Suweiyi Formation, $E_{1-2}km$—Kumugeliemu Formation.