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Paleo-heat flow evolution of the Tabei Uplift in Tarim Basin, northwest China

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ABSTRACT

The paleo-heat flow evolution of the Tabei Uplift in the Tarim Basin is investigated based on burial and thermal history reconstruction of 14 wells and using basin modeling. Numerous geological parameters, such as, temperature data and missing sediment thickness by erosion were used in the modeling. The basin model was calibrated using 460 measured vitrinite reflectance ($\%VR_o$) and vitrinite-like maceral reflectance ($\%VLMR_o$) values to constrain the validity of the maturity model. The heat flow history of the Tabei Uplift, Tarim Basin shows the following characteristics: (1) the highest paleo-heat flow was predicted to have occurred in the Early Ordovician as 65 ± 5 mW/m^2, and gradually decreased to 55 ± 5 mW/m^2 during the Late Carboniferous; (2) a thermal kick was modeled to have occurred in the Permian as suggested by an abrupt rise in the heat flow; (3) the heat flow gradually decreased since the Triassic; (4) the present day heat flow was predicted to be as low as 38 mW/m^2. This heat flow history honors the geologic and tectonic evolution history of the Tabei Uplift and is suggested as the best case heat flow model.

1. Introduction

The Tarim Basin is one of the most petroliferous basins of China. The Tahe Oilfield is situated in the southern slope of the Ackule High within the North Yarim Uplift (Fig. 1) (Kang and Kang, 1996; Zhang, 1999, 2003; Zhou et al., 2001; Li and Xu, 2004; Wang et al., 2008). The Tarim Basin is considered to be a typical "cool" basin (Wang et al., 1995a, 2000). Zhang and Liu (1992) studied the thermal gradient and heat flow of the basin based on geo-temperatures and spectral logs and suggested an average gradient of 2.0 °C/100 m. Wei (1992), Wang et al. (1995b,c, 1999) and Liu et al. (2004) studied the heat flow of the Tabei Uplift (the northern uplift of the Tarim Basin), Tazhong areas and other main structure units on the basis of geothermal gradient and measured thermal conductivities of rock samples. Xie and Zhou (2002) calculated the Cambrian–Ordovician paleo-temperature using pyrolysis kinetics simulation experiments on samples from the Tacan1 well. Qiu and Wang (1998), Qiu et al. (2006) estimated that the geothermal gradient in TZ12 well ranges from 2.4 to 3.0 °C/100 m by using free radical concentrations of kerogen determined by Electron Spin Resonance (ESR) spectrometry. However, the previous studies were mainly based on temperature data from measurements of rock thermal conductivities of limited samples. These studies were primarily focused on present day thermal regime, gradients and heat flow, mainly in the Tazhong, Luntai and Yarim areas of the Tabei Uplift. However, systematic research on the heat flow history of the Tabei Uplift, especially in the Tahe Oilfield area, has not been conducted.

The link between the evolution history and the paleo-heat flow of the basin was established from the Sinian to the present day by some authors, who identified four thermal episodes in the Tarim Basin (Pan et al., 1996; Li et al., 2000, 2005). In this study, the evolution of the heat flow history in the Tabei Uplift was evaluated, using 1-D basin modeling of 14 wells. The primary input data include the paleo-surface temperature, paleo-sea-level and depth, unconformities, missing sediment thickness during the erosion periods, and geological properties of sediments. A total of 460 vitrinite reflectance ($\%VR$) and vitrinite-like maceral reflectance ($\%VLMR_o$) values measured from 14 wells were used as maturity indicators to calibrate the model. The study provides a thermal approach to the tectonic behavior of the Tabei Uplift and helps to establish a link between the tectonic events and the heat flow history.

2. Regional geological setting

The Tarim Basin, located in the southern Xinjiang Uygur Autonomous Region, northwest China, is one of the world's largest

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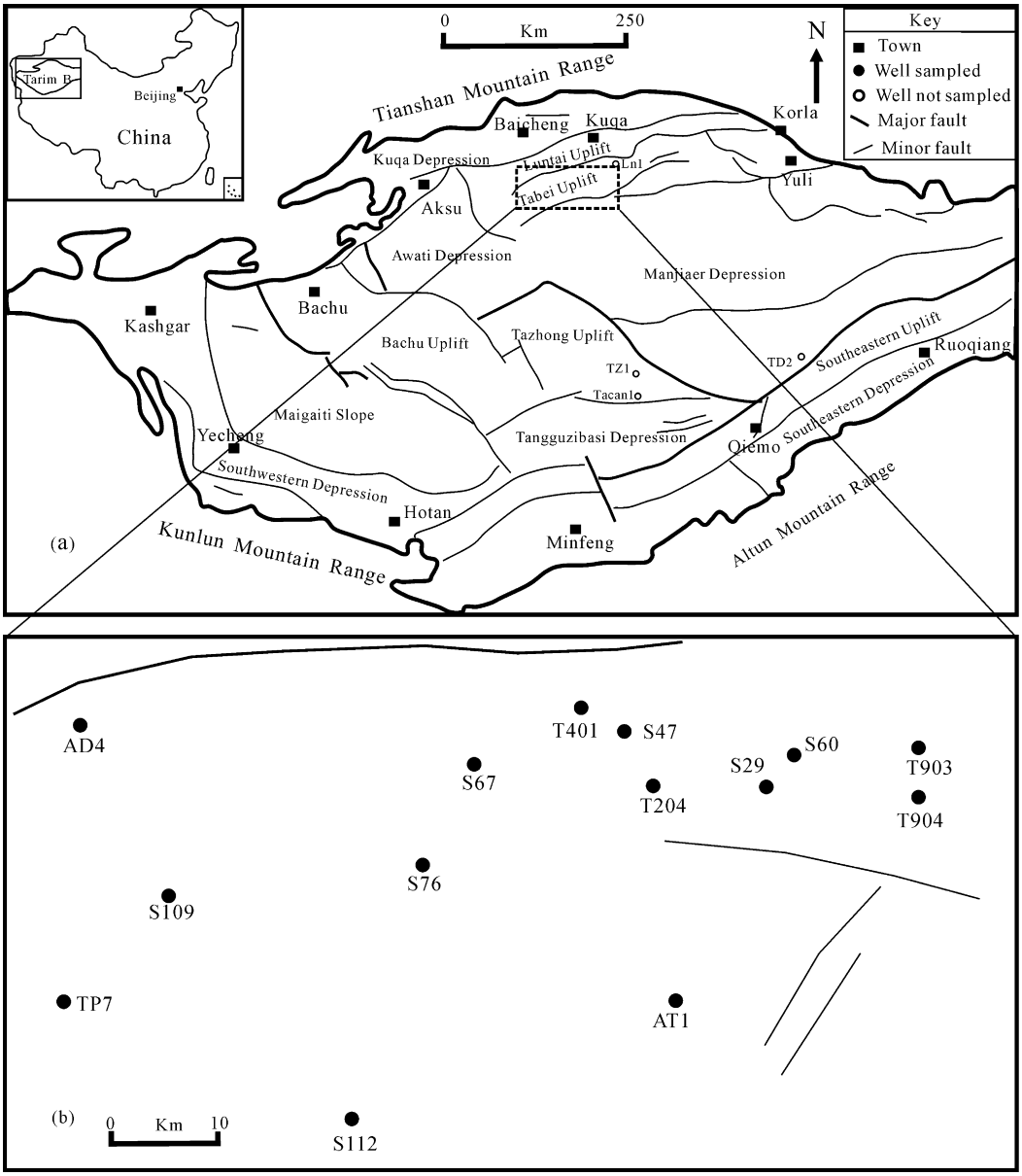

Fig. 1. Map showing the locations of the modeled wells in the Tabei Uplift, Tarim Basin, and major tectonic terrains.

frontier basins, with an area of 560,000 km^2 (Fig. 1). Detailed geological characteristics of the entire Tarim Basin have been summarized by many authors (e.g. Li et al., 1996; Jia and Wei, 2002; Zhang and Huang, 2005). It is a Palaeozoic cratonic basin, overlain in the south and north by Mesozoic–Cenozoic foreland depressions (Li et al., 1996). Fluctuating crustal activity has resulted in multiple unconformities (Jia and Wei, 2002; Zhang and Huang, 2005), causing the basin to form several tectono-stratigraphic entities (Fig. 1).

The Tabei Uplift is located in the northern part of the Tarim Basin (Fig. 1). The Tahe Oilfield lies in the southern part of the Tabei Uplift and is bounded by the Manjiaer and Awati depressions to the south (Fig. 1). A total of 6500–9500 m thick sedimentary sequence, comprising Cambrian to Tertiary strata, rests on the Archaean and Proterozoic crystalline basement (Zhang, 1999; Jin et al., 2008; Wang et al., 2008).

The Cambrian stratigraphic sequence consists mainly of tidal, platform and platform-margin marls, mudstones and carbonates/evaporites. The overlying Lower Ordovician section is primarily composed of platform dolomite and argillaceous limestone, whereas the Middle–Upper Ordovician interval is composed of platform and marginal slope-shelf carbonate sediments (Kang and Kang, 1996; Jin et al., 2008). The Middle–Upper Ordovician sequence can be subdivided into four formations, including the Yijianfang (O_2yj), Qiaerbake (O_3q), Lianglitage (O_3l) and Sangtamu (O_3s) formations from bottom to top.

The O_2yj formation consists mainly of wackestone, bioclast packstone and intraclast packstone. The O_3q and O_3l formations are composed of micrite limestone with thin clay interlayers. The O_3s formation is comprised of siliciclastic mudstone and sandstone. The black/dark-gray Ordovician mudstones and mud-rich limestones, particularly in the Manjiar Sag, are the major source rocks for the Ordovician reservoirs (Graham et al., 1990; Zhang and Huang, 2005; Wang et al., 2008).

The Sinian to Quaternary sequence is well preserved in the cratonic region, reaching up to 14 km in thickness in the Manjiaer Depression (Huang et al., 1999). The stratigraphy (Fig. 2) of the Tarim Basin consists of several marine, continental and transitional deposits. The Palaeozoic strata were deposited almost entirely in