



## Research paper

# Fault system impact on paleokarst distribution in the Ordovician Yingshan Formation in the central Tarim basin, northwest China



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## ARTICLE INFO

## Article history:

Received 5 January 2015

Received in revised form

4 November 2015

Accepted 20 December 2015

Available online 22 December 2015

## Keywords:

Tarim basin

Yingshan formation

Fault system

Paleokarst

Carbonate reservoir

## ABSTRACT

The paleokarst-unconformity at the top of the Ordovician Yingshan Formation in the central Tarim basin was exposed to air for at least 10 Ma, providing favorable conditions for the later formation of high-quality reservoirs. During the karstification process, the fault system plays an important role in controlling the development of paleokarst. This study characterized the fault system through the paleokarst features on the northern slope of the Tazhong High and examined in detail the impacts of the fault system on paleokarst distribution. Formation Micro-Imager logs and seismic curvature change rate were used for characterizing the fault system in different scales. The results revealed three sets of faults in this region. Cross-cutting relationships, unconformities, and relation between faults and karstification indicate Mid-to-Late Ordovician thrust faults, Silurian-Devonian strike-slip faults, and Permian tension faults. "Bright spots" in seismic records calibrated by Formation Micro-Imager logs were used for indicating paleokarst features and different depth distributions, respectively. Furthermore, the study employed spectral decomposition technique to characterize the morphology of paleocave complexes in detail. The results show the Mid-Late Ordovician thrust faults heavily impacted the distribution of paleokarst mainly distributed along master and secondary thrust faults in shallow areas, as well as along master basement-involved thrust faults in deep strata, and along the most pronounced area of paleokarst, Tazhong No. 10 fault zone bounded by back thrusts. The data provides new forecasting information for deep hydrocarbon exploration in paleokarst-related reservoirs of the Yingshan Formation.

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## 1. Introduction

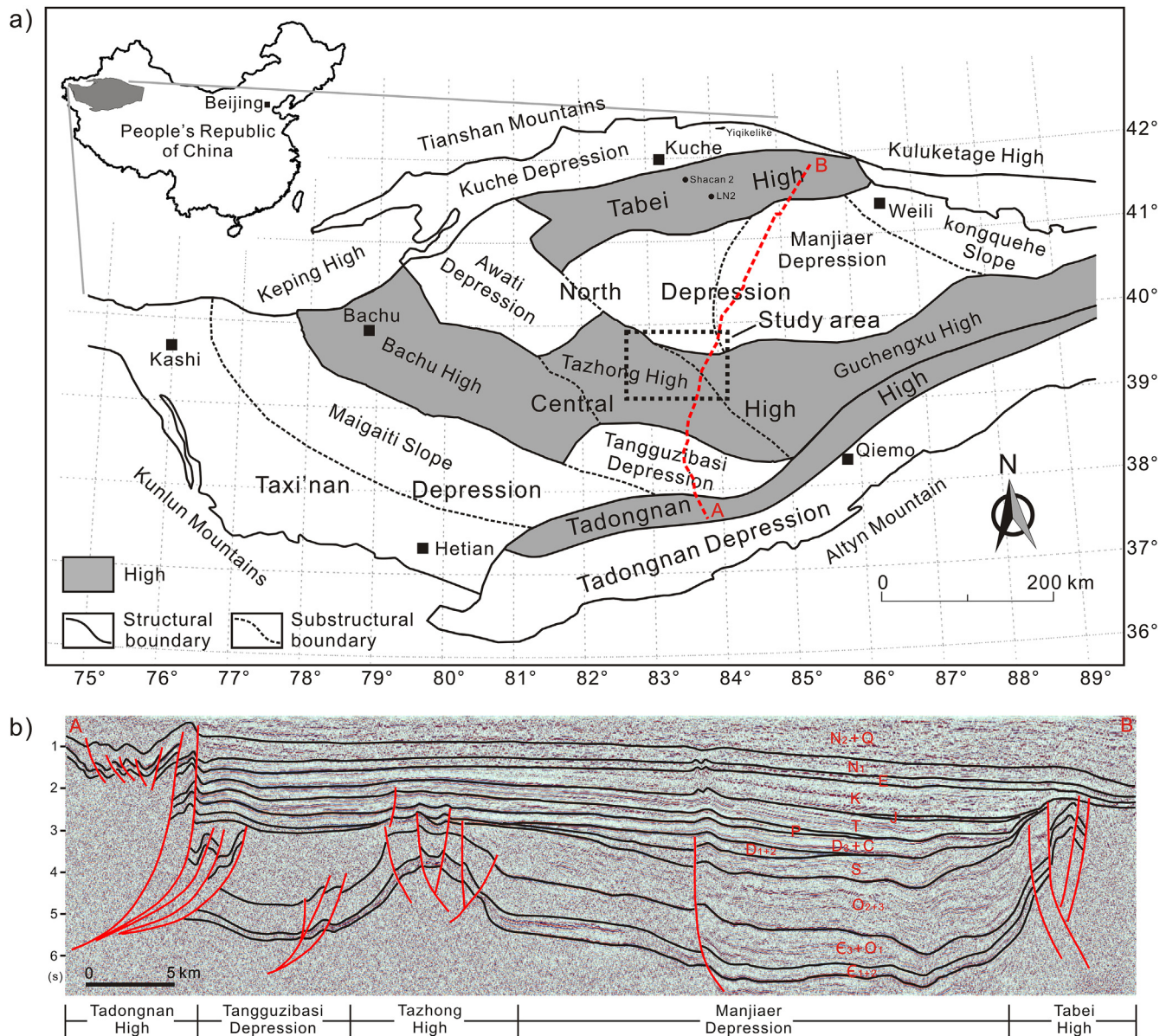
The rhomboidal Tarim basin in the Xinjiang Uygur Autonomous Region, consisting of three paleo-highs and four depressions, is the largest petroliferous basin in China (Fig. 1). The hydrocarbon exploration that has been conducted in this basin since 1951 and the first oil field, Yiqikelike Jurassic, discovered in 1958, were followed by an increase in exploration efforts focusing on the piedmont zone and paleo-highs in this basin (Kang and Kang, 1996; Li et al., 1996). After long-term exploration, the prolific Shacan 2 and LN2 wells were drilled in the Tabei High, which led to extensive hydrocarbon exploration. At the end of 2007, coinciding with the third round of China's national oil and gas resource evaluation resulting in an estimate of proven reserve at  $123.37 \times 10^8$  tons ( $863.59 \times 10^8$  bbl) of oil in the Tarim basin.

Paleo-highs are important exploration targets in the Tarim basin. This study focuses on the Tazhong High (Figs. 1 and 2), because the present Ordovician carbonate rocks contain abundant oil and gas. Recently, the Ordovician Yingshan Formation has been found to be a paleokarst-related hydrocarbon reservoir. The summit of the Yingshan Formation experienced at least 10 Ma of subaerial exposure during the Late Ordovician (Fig. 3) period, which led to strong karstification and provided favorable conditions for the later formation of high quality reservoirs. The reservoirs are overlain by thick Meso-Cenozoic sedimentary rocks and often buried more than 6000 m (19,685 ft) in depth. High risks involved in exploring such deeper targets, so predrilling studies on reservoir prediction are urgently needed.

Previous studies widely reported the paleokarst-related hydrocarbon reservoirs (Kerans, 1988; Loucks, 1999; Wang and Al-Aasm, 2002; Castillo and Mann, 2006; McDonnell et al., 2007; Li et al., 2008; Zeng et al., 2011a, 2011b; Sayago et al., 2012). Loucks et al. (2004) presented a detailed description of a coalesced, collapsed paleocave system considered to be the exploration target. Zeng

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**Fig. 1.** Tarim basin and regional cross section. (a) The Tarim basin and surrounding mountains. (b) Regional cross section AB of the Tarim basin. The Tazhong High is one of the paleo-highs highlighted in the section.

et al. (2011b) indicated paleocave-related reservoirs in the central Tabei High were shown as bright-spot anomalies in seismic sections. These reservoirs were considered to be a constructive tuning effect produced by thick cave sediments. The Tazhong High is situated to the south of the Tabei High (Fig. 1), and also experienced subaerial exposure in the Ordovician period, but for a shorter duration. An important factor impacting the distribution of paleokarst-related reservoirs is the fault system, as it serves as a fluid conduit. Li et al. (2013) recognized four stages of faults in the Tazhong High. The earliest stage formed mainly along the Tazhong No. 1 slope-break zone and the latter three stages were widely distributed on the northern slope of the Tazhong High (Fig. 2). This paper characterizes the fault system and paleokarst features in detail on the northern slope of the Tazhong High. In addition, a comprehensive analysis is completed for establishing the relationship between the fault system and paleokarst distribution.

## 2. Geologic setting

The Tarim basin is situated in northwest of China and bordered to the north, southwest, and southeast by the Tianshan, Kunlun and Altyn Mountains, respectively. It is a composite basin of different basins superimposed on one another (Li et al., 1996; Jia et al., 1998). Three paleo-highs and four depressions (Fig. 1) formed in this basin during long-term tectonic evolution. Several oil and gas fields have been discovered in the paleo-highs that provide favorable conditions for hydrocarbon accumulation. One paleo-high, the Tazhong High, is located in the central Tarim basin. The study area is located in the northern slope of the Tazhong High (Fig. 2).

Three tectonic events at the south margin of the basin heavily impacted the evolution and development of fault systems in the Tazhong High. First, ocean crust formed during the Cambrian period at south margin of Tarim, had begun to subduct northward

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