



Division and resources evaluation of hydrocarbon plays in the Amu Darya basin, central Asia



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Abstract: Based on the newest geological data and exploration achievements and the analysis of hydrocarbon accumulation elements and distribution rules of oil and gas fields, hydrocarbon plays are divided according to the reservoirs in the Amu Darya basin, central Asia. The hydrocarbon plays are evaluated in terms of resources potential and geologic risk, and the favorable hydrocarbon plays are selected using the double factors method of resources-geological risks. Ten hydrocarbon plays have been divided into in the major reservoirs, including the Cenomanian to Turonian sandstones of the Upper Cretaceous, the Hauterivian to Albian sandstones of the Lower Cretaceous, the Callovian to Oxfordian carbonates of the Upper Jurassic, and the Middle-Lower Jurassic sandstones. The undiscovered petroleum resources of the plays, evaluated by the Monte Carlo method, are about 3 308 million tons, in which gas accounts for more than 98%. Considering the geological risks evaluation of the key hydrocarbon elements of reservoirs, traps, migration and preservation, the favorable plays are evaluated and selected using the double factors method of resources-geological risks: two plays of class I, one play of class IIa, two plays of class IIb, three plays of class III, one play of class IVa, and one play of class IVc. The most favorable exploration objectives are the carbonate reservoirs of the Upper Jurassic Callovian-Oxfordian in the Murgab depression.

Key words: Amu Darya basin; hydrocarbon play; resource evaluation; geological risk; exploration direction

Introduction

The Amu Darya basin, mainly located in Turkmenistan and Uzbekistan, is a large-scale petroliferous basin. The basin contains the most abundant hydrocarbon resources in central Asia, due to the discovery of the giant Yolotan-Osman gas field in 2004. Also, the Amu Darya basin is one of the important target basins where the Chinese oil companies carry out their overseas cooperation strategies^[1–4]. To date, more than 340 oil and gas fields with proved and probable reserves of more than 2.7×10^{10} t have been discovered in the Amu Darya basin^[5]. Although the key geological features and patterns of hydrocarbon accumulation in the Amu Darya basin have been investigated by some Chinese researchers, there are few documents reflecting the latest exploration results and geologic findings published, and there are controversies over the resource potential of the basin^[6–12]. Based on analysis of hydrocarbon elements and distribution rules of oil and gas fields, this paper aims to divide hydrocarbon plays and evaluate their

resource potential using the latest geological data and exploration results. Then, the hydrocarbon plays are ranked by the dual-factor method of resources and risks.

1. Main geology and hydrocarbon distribution

The Amu Darya basin, with an area of about 430 000 km², is located in the middle west of the central Asia tectonic domain, and also the largest and most abundant petroleum-bearing basin in central Asia (Fig. 1). Since the Mesozoic, the Amu Darya basin has been situated in the northern edge of the Tethys domain, and has experienced four stages of evolution, the formation of pre-Mesozoic basement, Late Permian-Triassic rifting, Jurassic-Paleogene post-rifting and Neogene-Quaternary foreland basin^[13–15] (Fig. 2). The basement of the Amu Darya basin is composed of metamorphic and volcanic rocks of various ages, on it are the Mesozoic and Cenozoic, in which a gypsum layer deposited in the Gaurdak Formation of Late Jurassic Kimmeridgian-Tithonian age

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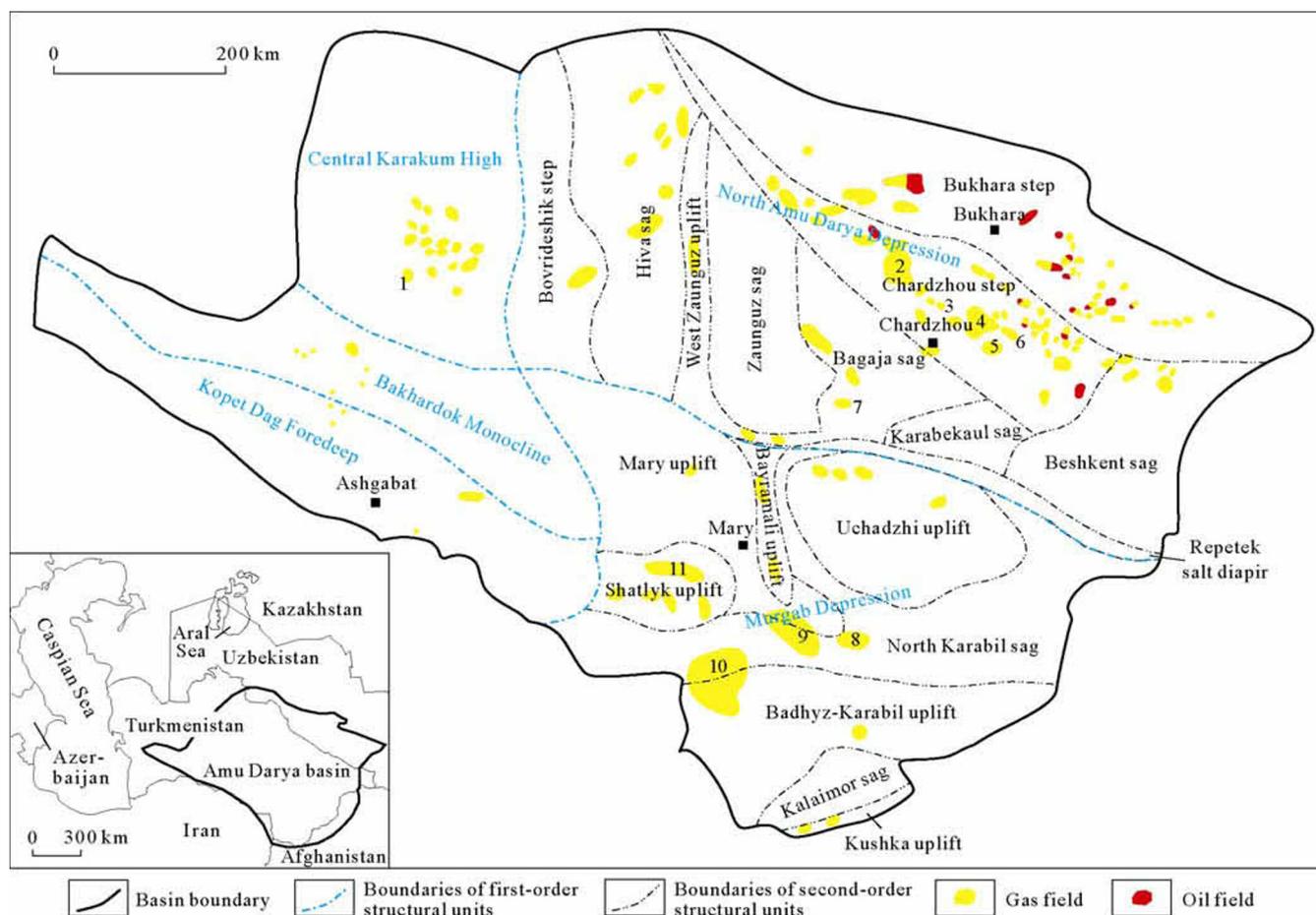


Fig. 1. Structural map of the Amu Darya basin showing oil and gas fields (modified from references 13 and 14). Numbers indicate the gas fields mentioned in the paper: 1—Derzeve-Zeagli; 2—Kandim; 3—Kokdumalak; 4—Dengizkul-Hauzak; 5—Samandep; 6—Urtabulak; 7—Malay; 8—Yashlar; 9—Yolotan-Osman; 10—Dauletabad-Donmez; 11—Shatlyk.

separates the sedimentary strata into the suprasalt and subsalt sequences. The Middle and Lower Jurassic coaly clastics and coals, the main source rocks, are higher in total organic carbon content (TOC), and in gas window in most parts of the basin^[17]. The Upper Jurassic Callovian-Oxfordian carbonate and Lower Cretaceous Shatlyk Formation sandstone are the main reservoirs^[16], constituting good reservoir-seal assemblages with the overlying gypsum and mudstone (Fig. 2).

According to the basement relief and structural features of the sedimentary strata, the Amu Darya basin can be divided into five first-order structural units, including the North Amu Darya Depression, Murgab Depression, Central Karakum High, Bakhardok Monocline and Kopet Dag Foredeep (Fig. 1). In plan view, gas fields discovered so far are widespread across the whole basin, while oil fields are restricted in the Chardzhou and Bukhara steps in the northern basin (Fig. 1). The Upper Jurassic Gaurdak Formation gypsum wide in distribution acts as a good seal for gas accumulations in the Upper Jurassic Callovian-Oxfordian carbonate reservoirs. In some local areas where the gypsum is thin or absent, the Lower Cretaceous Albian mudstone plays the role of seal too.

2. Division of hydrocarbon plays

Based on the reservoirs-cored division rules and processes of hydrocarbon plays^[18], four major reservoirs were firstly identified using the IHS and Tellus data^[5, 19]. They are the Cenomanian to Turonian sandstone of the Upper Cretaceous, Hauterivian to Albian sandstone of the Lower Cretaceous, Callovian to Oxfordian carbonate of the Upper Jurassic, and Middle-Lower Jurassic sandstone. Then, ten hydrocarbon plays were defined in the four reservoirs on the basis of the differences in hydrocarbon accumulation rules of various structural units. The plays are named by their locations, reservoirs and lithology jointly (Table 1).

The discovered oil and gas fields in the Upper Cretaceous Cenomanian-Turonian sandstone are relatively few (Table 1), which are mainly located in the Central Karakum High and the northeastern edges of the North Amu Darya Depression with limited exploration potential, therefore, for simplicity of resources calculation and evaluation, the Upper Cretaceous Cenomanian-Turonian sandstone is regarded as only one hydrocarbon play in the whole basin. This play has oil and gas mainly coming from the Middle-Lower Jurassic source rocks, and Cenomanian-Turonian mudstone as seal, and mainly

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