吐哈盆地
含煤沉积与煤成油

Study on Sedimentology and Oil Source from Jurassic Coal-Bearing Series in Tuha Basin, Northwestern China

吐哈石油勘探开发会战指挥部
中国矿业大学北京研究生部 著

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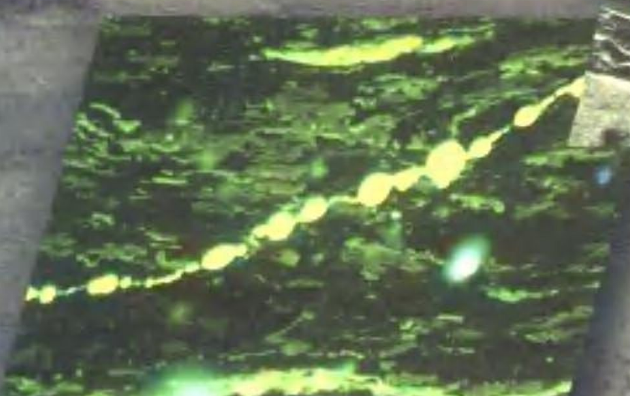

煤炭工业出版社

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吐哈盆地含煤沉积与煤成油

吐哈石油勘探开发会战指挥部　中国矿业大学北京研究生部　著
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煤炭工业出版社

前　　言

吐哈盆地是一个以中生界、新生界为主体的内陆沉积盆地，是新疆三大含油气盆地之一。其大地构造位置为三大古板块的汇合部位。在该盆地发现侏罗纪含煤地层生成和聚积了丰富的油气资源，不仅在国内树立了样板，也给当前国际流行的“中、新生代煤系有利煤成油”观点增加了实例，受到国内外关注。

为揭示该盆地侏罗纪煤系沉积与生油的特色和规律，中国矿业大学北京研究生部与吐哈石油会战指挥部于 1993 年以“吐哈盆地中下侏罗统煤沼沉积环境研究”为题订立合作项目。内容包括构造，古生物与古气候，重点为沉积古地理与煤成油的综合研究。本书是根据此成果，并吸取此前该研究生部 1991～1992 年完成的“吐哈盆地源岩有机岩石学及成烃特征”的材料精心著述而成，作为向第 15 届世界石油大会的献礼。

煤沼课题进行了 5 个月的野外调研，然后经室内测试和研究，历时两年完成，参加人员 20 余人。主要室内研究和成果是：在构造地质方面配合了遥感和物探资料研究，节理与岩组分析，认识到本区历经晚二叠世—三叠纪碰撞造山带前陆残留坳陷，早、中侏罗世伸展盆地发育和中生代末期以来盆地挤压等三期不同构造环境叠加。恢复了中生代以来占主导的南北向，以及次级或局部的北东—南西向、北西—南东向等三期挤压应力场，对阐明圈闭展布规律是重要的。在古生物与古气候方面，进行了大化石与孢粉分析、角质层和植物残体研究，指出吐哈盆地以松柏类和银杏类占支配地位，反映早、中侏罗世属潮湿气候，但有季节性。在沉积学方面，进行了薄片观察、砂岩粒度分析、泥岩 X-射线衍射和微量元素分析，并结合野外地质、测井和地球化学资料，对岩相发育特征和沉积模式进行研究，建立了 5 种沉积体系；编出煤系各层段等厚线、砂岩加砾岩等厚线、砾岩等厚线、棒带岩比和泥岩百分比等值线、煤层等厚线、沉积相断面以及煤系 9 个层段期的古地理图等，从而总结了吐哈盆地古地理面貌和演化、成煤模式和煤层赋存规律。在煤成油方面，根据笔者所提组分是有机相的实体，有机相是组分的集合体，两者都具有岩石学与地球化学双重属性的概念，利用光学方法、岩石热解、热解气相色谱、高压釜和小玻管热模拟（后者配合显微-傅里叶红外检测），再次肯定与补充了笔者 1989 年提出的“低熟期有利煤成油”和“系列单组分成烃模式”；1992 年提出的“吐哈煤成油主要为基质镜质体生成”，而异于国外文献报道。利用压汞法尤其是对镜煤注油和排油证实煤是能排油的。利用共聚焦激光扫描显微镜和透射电镜，根据有机残体实现油源对比属新成果。根据沉积学、地球化学和组分标志，将煤和碳质泥岩划分出 4 种沉积有机相；反过来也可依组分的双重属性特征按统计法来划分沉积有机相，进而编入古地理图和评价。指出流水沼泽有机相有利煤成油，从而解决了地球化学上难以解决煤成油具体来源和量的问题，也从环境和早熟观点对中、新生代煤系有利成油提供了解释。

中国矿业大学北京研究生部张鹏飞教授担任煤沼课题和本书沉积方面的内容设计与研究指导，金奎励教授担任煤沼课题煤成油和前一个课题的内容设计与研究指导，二人皆为本书主编。吐哈石油会战指挥部吴涛副总指挥，王昌桂总工程师对合作项目进行了指导并

担任本书主编。袁明生、燕列灿、王武和等高级工程师担任本书主审。本书执笔人分工如下：

第一篇　第一章　曹代勇
　　　　第二章　梅美棠
第二篇　第一章　第一、二节　罗　忠
　　　　　　　　第三、四节　邵龙义
　　　　　　　　第五节　曲　政
　　　　第二章　邵龙义
　　　　第三章　邵龙义　侯慧敏
　　　　第四章　第一、二、三、五节　邵龙义　侯慧敏
　　　　　　　　第四节　张鹏飞
第三篇　第一章　唐跃刚
　　　　第二章　方家虎
　　　　第三章　金奎励　姚素平
　　　　第四章　金奎励　姚素平　魏　辉　陈中凯
　　　　第五章　金奎励　魏　辉　陈中凯
　　　　第六章　金奎励　唐跃刚　魏　辉

参加研究工作人员，构造组有曹代勇、钱光谟、胡社荣；古生物组有梅美棠、王士俊、郭英廷；沉积组有张鹏飞、邵龙义、罗忠、王延斌、曲政、侯慧敏、袁鼎；煤成油组有金奎励、唐跃刚、方家虎、艾天杰、陈中凯、郝多虎。92 级硕士生张杰林和 94 级硕士生窦建伟、代世峰参加了资料整理与编图。

作　者

1997 年 3 月 5 日

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第三篇　煤成油及其源岩沉积有机相

CONTENTS

Study on Sedimentology and Oil Source from Jurassic Coal-Bearing Series in Tuha Basin, Northwestern China

Abstract

The Early and Middle Jurassic terrestrial coal-bearing strata of Tuha (Turpan-Hami) basin, Xinjiang Autonomous Region, northwestern China, are well known coal and petroleum sources, especially as a first coal measures-related oil model of China from coal and carbonaceous mudstone in situ. This book, based upon authors' research with comprehensive methods including sedimentology, organic petrology and geochemistry for a few years, is dedicated to the 15th World Petroleum Congress.

1. Geological Setting

1. 1 Tectonic framework and tectonic evolution

The Tuha basin lies on the eastern part of the Junggar-Turpan subplate of Kazakhstan paleoplate, which is adjacent to Siberia and Tarim Paleo-plates. The present Tuha basin is an intermontane basin surrounded by orogenic belts of different ages and origins. The basin is characterized by structural zonation both in N-S and E-W directions, controlled dominantly by compressive structures such as thrusts and nappes. Similar to the most sedimentary basins of the northwestern China, the Tuha basin has undergone a long period of complex tectono-sedimentary evolution. We believe that this basin is the superimposition of three basins formed in distinct stages under different geodynamic conditions, i. e., 1) development of the residual foreland trough in front of collided belt during the Late Permian and the Triassic, 2) extensional basin of the Early to Middle Jurassic, 3) compressive basin from the end of Mesozoic.

In the Early Mesozoic, the northwestern China was in the state of stress relaxation after collision of paleo-plates. The late orogenic extension caused many basement faults reactivation as normal faulting, which controlled the deposition and there was a tectono-geomorphic peneplane environment in Xinjiang Autonomous Region. Tuha and Junggar basins belonged to an unified sedimentary basin during the Early to Middle Jurassic, they were separated by uplift of Bogda mountains from the end of Middle Jurassic. Geophysical and lithofacies analyses reveal a framework of rhomb-shaped block basement, six NE-SW trended thickness variation zones and five NW-SE trended ones are identified in the Tuha basin.

Based on field geological investigation and data handling, we have determined three periods of tectonic stress fields since Mesozoic. They are, a dominant stress field of the maximum compressive stress axis in N-S direction, two periods of lower level or local stress field of the maximum compressive stress axis in NE-SW direction and NW-SE direction respectively. This progress is helpful to the study of tectonic evolution of Tuha basin and distribution of traps in the basin.

1. 2 Study on Palaeobotany and Palaeoclimate

13 genus of spore and 12 genus of pollen are distinguished. The genus are *Lycopodiumsporites*, *Deltoidospora*, *Cibotiumspora*, *Granulatisporites*, *Biretisporites*, *Dictyophyllidites*, *Apiculatisporis*, *Stereisporites*, *Calamospora*, *Cerebropollenites*, *Chassopollis*, *Monosulcites*, *Pseudopiceae*, *Araucariacites*, *Podocarpidites*, *Chordasporites*, *Psiloschizosporis*, *Piceaepollenites*, *Quadraeculina*, *Chasmatosporites*.

In the fossil plants, 14 genus and 23 species are determined. Sphenophytes, ferns, ginkgo and conifers are the predominated elements, such as *Equisitites lateralis* Phillips, *Neocalamites hoerensis* (Schimper) Halle, *Coniopteris hymenophylloides* (Brongniart) Seward, *Coniopteris bureyensis* (Zalessky) Seward, *Coniopteris tatungensis* Sze, *Cladophlebis fangtzuensis* Sze, Baiera gracilis (Bean Ms.) Bunbury, *Gingoites sibiricus* (Heer) Seward, *Phoenicopsis speciosa* Heer, *Sphenobaiera late* (Vakhrammev) Dou, *Czekanowskia rigida* Heer, *Podozamites lanceolatus* (L. et H.) Braun, *Pityophyllum solmsi* Seward.

The flora of the Early and Middle Jurassic is represented by the assemblage of *Coniopteris hymenophylloides-Phoenicopsis speciosa*.

The in-situ cuticle of three species in ginkgophytes is examined. The thickness of the cuticleranges from thin to medium thick. Stomata slightly sunk.

Annual rings are seen clearly in the transverse section of the wood. The development of the early wood and the late wood are different. The rings in the early wood are wider than the late wood. The tracheids are larger in the early wood too.

The fusiain is observed with SEM. According to the characters of the tracheids and cross-field pitting, in dicated that the fusiain belongst conifers.

Som segments of wood are discovered from the phyterals of the coal. The wood relates to ginkgophyted or conifers.

Based on the investigation of sporo-pollen, fossil plants, anatomy of wood, fusain (observed with SEM)and the phyterals in the coal, it is shown that the condition of palaeoclimate is temperate and humid. The existence of anuual ring and more developed early wood indicate that there is seasonal change in a year and the warm and humid period is longer than the drier one.

2. Depositional environments and palaeogeography and their controls on coal accumulation

2. 1 Lithofacies, lithofacies association and depositional model

In order to recognize the depositional environments of the Early and Middle Jurassic coal-bearing sequences, various sedimentary characteristics of the coal-bearing sequences have been investigated, including lithology and lithofacies, sedimentary structures, well-logging interpretation, clay mineral assemblages, grain size analysis and geochemical trace element analysis, etc. As a result of synthetic study, twenty-nine lithofacies have been identified and their possible environmental interpretations are summarized. They are further classified into 17 sedimentary facies associations and 5 depositional systems. The five depositional systems are braided fluvial system, meandering fluvial system, braid delta system, (meandering channel) delta system and lacustrine system (Table 1).

2. 2 Palaeogeographical Evolution

2. 2. 1 Methods of Palaeogeographical Analysis

The palaeogeographical maps of different stages during the Early and Middle Jurassic for Tuha basin have been drawn based on five field columnar sections, six basin-wide sedimentary cross sections, and various analytical maps. Five field geological columnar sections are those distributed along Aiwergou, Taoshuyuan, Qiquanhu, Kekeya, and Sandaoling coal mines, respectively. Six basin-wide sedimentary cross sections include one from Tuokesun depression, four from the Taibei depression, and one from the Hami depression, respectively. The maps used for palaeogeographical analyses include isopach of the strata, isopach of sandstone and conglomerate, percentage sandstone and conglomerate map, contour map of the coarse-fine ratio—the ratio of the coarse-grained sediments (sandstone and conglomerate) and fine-grained sediments (siltstone, mudstone, siderite, and coals), isopach of the source rock (coal and carbonaceous mudstone), percentage map of conglomerates and so on. The stages for palaeogeographical analyses have been subdivided into the Early Jurassic Badaowan stage, the Early Jurassic Sangonghe stage, and the Middle Jurassic Xishanyao stage. The Xishanyao stage is further subdivided into four periods, corresponding to four members of Xishanyao Formation. The first two periods belong to the early Xishanyao stage, and the last two periods belong to the late Xishanyao stage. In this abstract we will introduce the palaeogeographical patterns and their evolution of the Badaowan stage (J_1b), Sangonghe stage (J_1s), early Xishanyao stage (J_2x^{1+2}) and late Xishanyao stage (J_2x^{3+4}). Coals and carbonaceous mudstones, which represent the major source rocks, are mainly preserved in Badaowan Formation and the second member of Xishanyao Formation.

2. 2. 2 Lithofacies palaeogeography of the Early Jurassic Badaowan stage

The Badaowan Formation is mainly composed of coarse-grained clastic rocks dominated by conglomerates and coarse grained sandstones, interbedded with fine-grained sandstones and siltstones, and intercalated with some thick coal seams. The palaeogeographical units include alluvial plain (dominated by the braided river system), upper delta plain, lower delta plain, subaqueous delta and shallow lake, which were responses of strong marginal faulting activity and high topographical relieves during the initial stage of the basin re-subsiding. The delta lobes developed during the Badaowan stage include those

Table 1 Depostional System and Depositional Facies Characteristics for the Early and Middle Jurassic Coal-Bearing Sequences in Tuha Oil Basin

Depositional Systems	Facies Association		Subfacies	Lithofacies
Braided fluvial	braided channel		longitudinal and transverse bars	Gm, Gms, Gt, Gp
	flood plain			Sta
Meandering fluvial	meandering channel		basal lags, point bar	Smg, Sh, Sp, St
	channel bank		levee, crevasse splay	Sir, Sim, Sih
	flood basin		flood plain, back-bank lake, swamp	Sir, Sim, My, Mg, Md, Ms, Mc, Msi, C
Braid delta	delta plain		gravelly braided distributary channel	Gt, Gp,
			sandy braided distributary channel	St, Sp
			interdistributary bay	Sir, Mc, C
	delta front		gravelly mouth bar	Gp, Gm
			sandy mouth bar	St, Sp
			distal bar	Sir
	prodelta			Sir, Md
Delta (meandering or low sinuosity channel)	delta plain	upper delta plain	meandering channel	Smg, Sh, Sp
			levee	Sir, Sim
			crevasse splay	Sih, Sir
			flood basin	Sim, Mg
			back swamp	Msi, Mc, C
		lower delta plain	distributary channel	Sp, St, Se
			interdistributary bay	Sih, Sim
			interdistributary swamp	Mg, Mc, C
	subaqueus delta	delta front	subaqueous distributary channel	Sim, St, Sp, Smg
			mouth bar	Sic, Stb, Sta
			distal bar	Sir
		prodelta		Md, Sir, Sih
	interdelta bay			C, Mc, Ms, Md
Lacustrine	deeper lake			Md
	open shallow lake (including storm deposits)			Mg, Sim, Smg, Smp Shu
	lacustrine bay			Md, Mc, C
	longshore bar			Stb

from both north provenance and south provenance. The delta lobes from the north provenance include Aiwergou delta, Kerjan delta, Kekeya delta, and Zhao-1 well delta. The delta lobes from south provenance include Da-1 well-Qiquanhu delta, Qiketai delta, and Gadatai delta. The lake was distributed along the north side of the Taibei depression. The Hami depression was dominated by the deltaic deposits from the east, south and west sides of the depression and with the lake area in the vicinity of Ha-2 and Ha-3 wells in the north of the depression. The Da-1 well-Qiquanhu delta dominating the most area of the western part of Taibei depression controls the facies and source rock distribution.

2. 2. 3 Lithofacies palaeogeography of the Early Jurassic Sangonghe stage

The Sangonghe Formation is composed of brown and dark grey shales and intercalated with sandstones and occasionally marls with cone-in-cone structure. This Formation represents the expanding and water flooding period of the basin. The major palaeogeographical units include retrograded delta, shallow lake, and deeper lake. The shales were formed in shallow and deep lake environments.

2. 2. 4 Lithofacies palaeogeography of the Middle Jurassic Xishanyao stage

The Xishanyao Formation consists of sandstones, siltstones, mudstones and coal seams, which was formed in the deltaic and lacustrine depositional systems when the lake was filled again. During the early period of Xishanyao stage, the water is relatively shallower due to the rapid prograding of the delta. The palaeogeographical units of this period include fluvial-upper delta plain, lower delta plain, subaqueous delta, interdeltaic bay, lacustrine bay and shallow lake. The coal accumulation was favoured in the interdeltaic bay, lacustrine bay and lower delta plain. During the late period of Xishanyao stage, the water became deeper due to relatively rapid subsidence of the basin and consequently, is not beneficial to the coal accumulation. The major paleogeographical units include delta plain, subaquaeous delta, lacustrine bay and shallow lake.

In general, during the Early and Middle Jurassic the basin experienced swamp developing—lake flooding-again swamp developing—again lake flooding processes. Two swamp developing stages are Badaowan stage and early Xishanyao stage, and the large scale coal accumulation occurred in lower deltaic plain and interdelta bay environments.

2. 3 Controls on coal accumulation

The accumulation of source rocks (coal and carbonaceous mudstone) was controlled by both tectonic subsidence and depositional environments. Three dimensional correlation analysis between the percentage of the sandstone and conglomerates (indicating depositional environments), the thickness of the strata (indicating subsidence), and the thickness of the coal and carbonaceous mudstone has been made for the coal members. The analysis shows that the beneficial environments should be the interdelta bay, the lower delta plain and the back swamp of fluvial system, where intermediate subsidence (totally 300-700m for the Badaowan Formation and 400-600m for the first and second members of Xishanyao Formation) was kept and there was little input of coarse—grained sediments (mostly less than 50% of coarse—grained sediments), and water table remains stable which was suitable for the development of swamps.

2. 4 Provenance of the Tuha Basin during the Early and Middle Jurassic

The provenances of the basin during the Early and Middle Jurassic include the Juelotag mountains to the south of the basin and the Bogda and Harik mountains to the north of the basin, but the Juelotag mountains provide major sediments to the basin. The Bogda-Harik mountains do provide detritus to the basin during the Early and Middle Jurassic, which can be proved by the palaeocurrent data, petrographical analysis, and palaeogeographical mapping. This also means that the Bogda Mountains were partly uplifted since the Early Jurassic and possibly isolated by the lake during the Early and Middle Jurassic.

3. Coal and carbonaceous mudstone as oil source rocks

As study objects, we paid attention not only to coal seams but also to carbonaceous mudstones which ought to exceed 10% in maceral content in whole rock estimate, that is to say, they ought to be part of clastic marsh environment, and their organic richness might be 4% roughly. (Based on TOC=POM×0.5× (0.8—0.85), Smyth et al.)

3.1 Oil-generating macerals

The maceral composition of Tuha coal shows that exinite, inertinite and vitrinite may be 6%—8%, 10%—20% and 70%—80%, respectively, of which desmocollinite proportion is very high, generally making up 25%—45% in the total coal, The maceral composition of so-called carbonaceous mudstone in this paper is similar to coal but disseminated and fractured. Based on fluorescence, TEM and micro-FTIR investigations, the desmocollinite can be divided into two types, Type A and Type B. The latter is the dominant and has fluorescence, rich in submicroscopic exinite and good potential of oil generation, with S_1+S_2 up to 200—300 mg/g and change into bituminite, all these characteristics are contrary to the former.

The main oil—generating macerals of coal and carbonaceous mudstone for liquid hydrocarbon are mainly desmocollinite B, bituminite, cutinite and suberinite, which would have generated liquid hydrocarbon in low rank (VR_r=0.4%—0.6%) according to our study on hydrocarbon generated indications (e.g. oil drops, oil films and micrinite). The authors also make the coalification map of the lower part of coal measures.

3.2 Oil-source correlation

We use CLSM and TEM for oil-source correlation, and discover some vitrodetrinites together with a lot of submicromacerals/microfossils respectively, in coal-measures related oil, which can be employed as indicators. From above mentioned methods, results of correlation are successful.

3.3 Hydrocarbon generation models for individual macerals

We made thermal simulation experiments using high pressure vessel and quartz tube under 6(150—330℃) and 7(200—400℃) temperature conditions respectively, and analyzed by using PY-GC for the former, the micro-FTIR as well as fluorescence microscopy for the latter. The results not only confirm that above mentioned macerals can generate oil at the early stage, but also show individual oil generating models for macerals. In the meantime we use factor A and so on proposed by Ganz for study.

3.4 Oil-expulsion experiments

Now, geologists focus attention upon problem of oil-expulsion from coal. Coal manopore volume of extracted and unextracted vitrain samples was compared based on mercury pressure porosimetry together with the TEM and SEM. the results display that the total pore volume increase after extracted and the pore connection may be in series/parallel pattern except the isolated pores. That is to say, oil can be expelled. Moreover, the oil-expulsion experiment which was done for vitrain sample in 72 hr's, below 210°C and 18 atm. was further studied. It confirmed above conclusion by means of PY-GC evidence that the expelled oil is what pressed into the coal.

3.5 Sedimentary organic facies and oil potential evaluation

Organic facies is first proposed by Rogers, and Jones defined it as a mappable subdivision of a designated stratigraphic unit. Based upon this idea and especially that of Huc's, a key organic facies to improve quantitative petroleum evaluation, we emphasize sedimentary parameters including maceral and palynofacies analyses in addition to lithofacies study for the sake of putting them into palaeogeographic map, and call the organic facies proposed by Rogers and Jones as sedimentary organic facies. Therefore, we have revised coal facies that contains coal/mudstone (>10% maceral content) as swamp/marsh facies and further subdivide it in view of sedimentary system, of which the inland plain have lake-swamp (marsh) and river-swamp (marsh) systems. Four sedimentary organic facies of coal and carbonaceous mudstone were suggested, namely high moor, forest swaamp/marsh, running water swamp/marsh and open water facies. the term of running water facies originates from C. H. Наумова. The running water swamp/marsh facies zone may best for coal-generating oil.

Based on above-mentioned result of simulation, we may quickly set up sedimentary organic facies by maceral statistics.

Therefore, either maceral's lithologic and geochemical investigation directly or maceral's statistic method indirectly are true in dividing sedimentary organic facies.

We combine palaeogeographic and sedimentary organic facies maps, It is easy to settle the problems "which" and "where" the coal measures-related oil comes from, the difficult problem for geochemists perhaps.

From oil-generating coal measures' data worldwide, it seems that the running water swamp/marsh is developed on limnic environment frequently, therefore, there is an allochthonous/hypau to chthonous process as well as disintegration, which causes accumulation of macerals rich in hydrogen content. When coal and carbonaceous mudstone have enough high hydrogen contents related to carbon, they can form oil earlier than the birthline of conventional oil generation or so.

第一篇　区域地质背景

作为吐哈盆地主要烃源岩的下、中侏罗统含煤岩系，是适宜的古构造、古地理、古植物和古气候等区域地质因素综合作用的产物。地壳运动形成的构造坳陷为泥炭沼泽沉积提供了场所，盆地构造演化控制了古地理面貌和沉积作用的兴衰，古气候变迁影响到植物群落的繁茂和沉积类型，古植物条件直接决定了沉积有机质的丰度和类型。

第一章　区域构造格局与构造演化

吐哈盆地位于新疆北部东天山地区（图1－1－1），现代地理类型为被山脉所环绕的内陆山间盆地。这一重要的含煤和油气盆地，是地质历史演化过程中不同时代、不同性质的沉积盆地转化叠合的最终结果。本章讨论吐哈盆地的构造演化历程，着重探讨吐哈侏罗纪盆地的古构造格局及其相应的盆地反转过程。

第一节　板块运动背景与区域构造格局

一、大地构造位置

吐哈盆地位于哈萨克斯坦、西伯利亚、塔里木三大古板块的汇合部位。盆地基底属于哈萨克斯坦古板块中准噶尔－吐鲁番次级板块的一部分，北东以克拉美丽－麦钦乌拉缝合带与西伯利亚古板块毗邻，南隔中天山碰撞造山带与塔里木古板块相望（图1－1－2）。

近年来，北疆地区地球物理资料研究取得重要进展，认识到吐哈盆地存在与准噶尔盆地相似的前寒武系结晶基底，表明吐哈盆地基底是古生代时从哈萨克斯坦古板块中分裂出的微大陆碎块，散布于古天山洋中，称之为吐哈地体。该地体经历了漫长的板块演化历程，于晚古生代末期完成与南、北古大陆的拼贴。

二、区域构造背景

吐哈盆地被不同时代和不同性质的构造活动带所环绕（图1－1－3）。南侧中天山山脉是准－吐古板块与塔里木古板块之间的晚古生代碰撞拼贴造山带，中石炭世末期吐哈地体与塔里木古陆北缘拼贴并继之以陆内俯冲形式进一步挤压缩短，使早古生代火山岛弧和晚古生代阿齐山－雅满苏石炭纪钙碱性火山岩岛弧带分别向北逆冲，于晚古生代末期隆起为觉罗塔格山，成为控制吐哈盆地形成和演化的一个重要边界条件。觉罗塔格构造带及其北延南湖隆起是吐哈侏罗纪盆地，尤其是早、中侏罗世的主要物源区。

盆地北侧为博格达－哈尔里克构造带，其大地构造属性有晚古生代坳拉谷——陆间裂谷（程克明等，1994；北京石油勘探开发研究院等，1993①）和晚古生代活动大陆边缘岛弧

① 北京石油勘探开发研究院等，吐哈盆地区域构造研究，1993年5月。

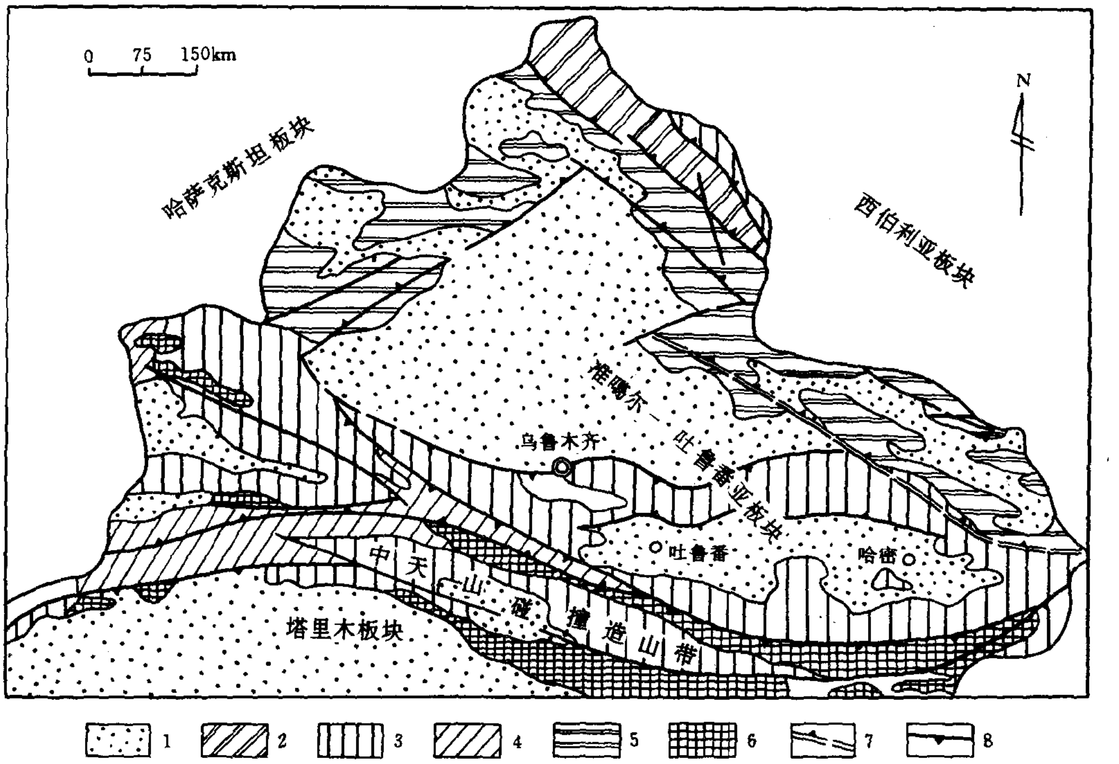

图 1—1—2　北疆板块构造格局图

1—中、新生代盆地；2—寒武、志留纪冒地槽沉积；3—晚古生代冒地槽和岛弧沉积；4—泥盆纪冒地槽沉积；5—志留、泥盆纪大洋沉积；6—前寒武纪结晶基底；7—板块缝合线；8—逆冲推覆构造带

带（马瑞士等，1992；吐哈石油研究大队，1993①）等两种不同认识。实际上，博格达山和哈尔里克山分属不同性质的构造带，博格达山体呈北东东向延展，哈尔里克山体呈北西西向延展，二者在巴里坤山七角井一带相交（图 1—1—3）。在遥感图像上，博格达山区线性构造走向以北东东向—北东向为主，哈尔里克山区线性构造多呈北西西走向，差异明显（图 1—1—4）。哈尔里克山发育石炭纪钙碱性安山质火山岩，具有典型的大陆边缘火山岛弧性质，花岗岩类极为发育，包括早期与 B 型俯冲钙碱性火山岩对应的深成岩体和晚期与 A 型俯冲有关的改造型花岗岩（马瑞士等，1993）。与此相比较，博格达山无花岗岩，变质亦微弱，石炭纪火山岩出现钙碱性和拉斑质并存的双峰特征②，反映拉张体制的裂谷构造环境。马瑞士等人（1993）指出，巴里坤七角井一带存在蛇绿岩套，表明石炭纪时博格达构造带与哈尔里克构造带之间可能被构造圈闭的边缘海隔开，后来的推覆作用才将它们结合在一起，共同组成北天山山脉。综上分析，笔者认为哈尔里克构造带应属于克拉美丽—麦钦乌拉缝合带的南延部分，晚古生代时为塔里木—吐哈古陆北部边缘岛弧带；古天山洋于石炭纪末期消亡，陆—陆碰撞对接导致哈尔里克山隆起，成为中、新生代吐哈盆地东部重

① 吐哈石油研究大队，台北凹陷西部有利区带分布及勘探布置，1993 年 12 月。

② 哈密石油地质综合研究联队，吐哈盆地有利区带油气地质特征及评价，1993 年 11 月。