第46卷第5期 中 国 地 质 Vol.46, No.5
2019年10月 GEOLOGY IN CHINA Oct., 2019

doi: 10.12029/gc20190502

王国灿,张孟,张雄华,廖群安,王玮,田锦明,玄泽悠. 2019. 东天山北部古生代重大构造事件及其对中亚造山带演化的启示:基于1:5万板房沟幅和小柳沟幅地质调查新证据[J]. 中国地质, 46(5): 954−976.

Wang Guocan, Zhang Meng, Zhang Xionghua, Liao Qun'an, Wang Wei, Tian Jinming, Xuan Zeyou. 2019. Significant Paleozoic tectonic events in the northern part of the East Tianshan Mountains, Xinjiang and their implications for the evolution of CAOB: New evidence from 1∶50000 geological survey of Banfanggou and Xiaoliugou sheets[J]. Geology in China, 46(5): 954−976(in Chinese with English abstract).

东天山北部古生代重大构造事件及其对中亚造山带演化的启示:基于1:5万板房沟幅和小柳沟幅地质调查新证据

王国灿[1,2],张孟[2],张雄华[2],廖群安[2],王玮[3],田锦明[2],玄泽悠[1]

(1. 中国地质大学(武汉)地质调查研究院,湖北 武汉,430074;2. 中国地质大学(武汉)地球科学学院全球大地构造研究中心,湖北 武汉,430074;3. 新疆维吾尔自治区地质调查院,新疆 乌鲁木齐,830000)

提要:本文基于新疆哈密地区1:5万板房沟幅和小柳沟幅区域地质调查新成果,对东天山北部古生代的重大构造事件以及演化历史进行了系统的梳理。基于下志留统与奥陶系之间角度不整合、下石炭统与泥盆系之间平行不整合以及上石炭统二道沟组与下伏岩系之间的角度不整合的确定,揭示奥陶纪与志留纪之交、泥盆纪与石炭纪之交以及晚石炭世期间存在几次重大构造事件。结合古生代不同时期沉积大地构造背景转换、岩浆活动构造环境转换以及构造变形格式转换的地质新纪录,提出奥陶纪与志留纪之交的造山事件为北部阿尔曼太洋闭合导致准噶尔—吐哈地块与阿尔泰地块碰撞的响应;泥盆纪与早石炭世之间的造陆构造事件可能是北部卡拉麦里洋盆初始汇拢碰撞的响应,其平行不整合以及下伏的志留纪—泥盆纪较稳定环境的沉积序列预示着介于卡拉麦里洋盆与南部北天山洋盆之间的准噶尔—吐哈地块为古亚洲洋盆体系中相对刚性的稳定陆块区,研究区作为准噶尔—吐哈地块的北部被动陆缘受卡拉麦里洋盆汇聚的影响较小;晚石炭世的造山事件则表现为响应卡拉麦里洋盆闭合后周缘前陆盆地的演化,是早石炭世沿卡拉麦里缝合带发生陆块碰撞以来挤压构造作用峰期的产物,其奠定了东天山北部北西-南东向构造基本格局。本文还重新界定莫钦乌拉断裂为北天山构造带(准噶尔—吐哈地块)与东准噶尔构造带的构造-地层分区界线,推断其为卡拉麦里缝合带向南东的延伸,并讨论了早石炭世受控不同构造体制的沉积和岩浆纪录的空间差异性,认为早石炭世北部莫钦乌拉山区域为与北侧卡拉麦里洋盆闭合后周缘挤压前陆盆地的发育过程,而南部博格达—哈尔里克山则总体呈现为响应南侧北天山洋盆闭合后的碰撞后伸展裂谷发育过程。

关 键 词:东天山;古生代;构造事件;构造演化;1:5万板房沟幅和小柳沟幅;地质调查工程

中图分类号:P54 **文献标志码**:A **文章编号**:1000−3657(2019) 05−0954−23

Significant Paleozoic tectonic events in the northern part of the East Tianshan Mountains, Xinjiang and their implications for the evolution of CAOB: New evidence from 1:50000 geological survey of Banfanggou and Xiaoliugou sheets

WANG Guocan[1,2], ZHANG Meng[2], ZHANG Xionghua[2], LIAO Qun'an[2], WANG Wei[3],

---

收稿日期:2019−07−24;**改回日期**:2019−10−10

基金项目:中国地质调查局基础地质调查项目(DD20160060、DD20179607)资助。

作者简介:王国灿,男,1963年生,教授,博士生导师,长期从事区域地质、构造地质学教学与研究;E−mail: wgcan@ cug. edu. cn。

TIAN Jinming^{2}, XUAN Zeyou^{2}

(1. *Institute of Geological Survey, China University of Geosciences, Wuhan* 430074, *Hubei, China;* 2. *Center for Global Tectonics*, *School of Earth Sciences*, *China University of Geosciences, Wuhan* 430074, *Hubei, China;* 3. *Xinjiang Institute of Geological Survey, Urumqi* 830000, *Xinjiang, China*)

Abstract: Based on the new results of 1:50,000 geological survey of Banfanggou and Xiaoliugou sheets in Hami area, Xinjiang, this paper systematically reviewed the major tectonic events and evolutionary history during Paleozoic in the northern part of the East Tianshan Mountains. There existed three major tectonic events between Ordovician and Early Silurian, between Devonian and Early Carboniferous and in the Late Carboniferous, respectively, as shown by the newly discovered angular unconformity or disconformity. Combined with a series of new records of sedimentation, magmatism and deformation reflecting tectonic transformation, the links between these tectonic events and the evolution of the Central Asian Orogenic Belt (CAOB) are discussed. It is suggested that the orogenic event that occurred at the turning time from Ordovician to Silurian was the response to collision between the Junggar−Tuha terrane and the Altay terrane following the closure of the Armantai oceanic basin. The disconformity between Devonian and Lower Carboniferous shows an epeirogenic event, probably in response to the initial closure of the Kalamaili oceanic basin to the north. This disconformity and underlying Silurian−Devonian deposits in relatively stable tectonic environment also show that the Junggar−Tuha terrane between the Kalamaili oceanic basin and the North Tianshan oceanic basin was a relatively rigid and stable continental block in the Paleo−Asian Ocean system. The study area, as the northern passive continental margin of the Junggar− Tuha block, was less affected by the convergence of the Kalamaili oceanic basin. The orogenic event in the late Carboniferous was the reflection of peak orogenesis in response to the evolution of the peripheral foreland basin after the arc−continental collision that occurred along the Kalamaili suture zone during late Devonian− early Carboniferous period. This event established the basic NW− SE trending structural framework in the East Tianshan Mountains. The authors also redefined the Moqinwula fault as the southeastern extension of the Kalamaili suture zone, the tectonic−stratigraphic boundary between the North Tianshan Mountains (or Junggar−Tuha block) and the East Junggar terranes, and discussed the spatial differences of tectonic regime in the early Carboniferous. Based on the records of sedimentation and magma of the early Carboniferous, the authors hold that a peripheral foreland basin, which was related to the closure of the Kalamaili oceanic basin, was developed in the Moqinwula Mountain, whereas a rift basin was developed in the Bogda− Harrick Mountain, which was in response to the post− collision extension related to the closure of the North Tianshan Ocean.

Keywords: East Tianshan Mountains; Paleozoic; tectonic events; tectonic evolution; 1:50000 geological survey of Banfanggou and Xiaoliugou sheets; geological survey engineering

About the first author: WANG Guocan, male, born in 1963, doctor, professor, major in teaching and research on tectonics and structural geology; E−mail: wgcan@cug.edu.cn.

Fund support: Supported by China Geological Survey Projects (No. DD20160060 and DD20179607).

1 引 言

中亚造山带为古亚洲洋在显生宙时期的俯冲、增生、拼合、碰撞以及陆内造山作用所形成的全球显生宙以来规模最大的增生型造山带之一（图1, Jahn et al., 2000; Buslov et al., 2001; Windley et al., 2007; Xiao et al., 2008, 2014; Şengör et al., 2018）。新疆东准噶尔—北天山造山带是中亚造山带重要组成部分，其沉积、岩浆及构造变形等演化历程的揭示对理解整个中亚造山带构造演化具有重要意义。不同学者对该地区开展了有关基底性质（李锦轶等，2000a; Xu et al., 2013, 2015a）、蛇绿岩及洋盆演化（Xiao et al., 2008, 2014; 秦彪等，2012; 胡朝斌等，2014; Xu et al., 2015b）、古生代岩浆作用（Zhang et al., 2009; Yuan et al., 2010; Xia et al., 2012; Chen et al., 2013）、沉积物源分析（Long et al., 2012; Chen et al., 2014; Huang et al., 2018; 白建科等, 2018a, 2018b）以及中—新生代盆山演化（Zhu et al., 2006; 王宗秀等，2008; Tang et al., 2014; Gillespie et al., 2017）等多方面的研究。但由于不同学者资料掌握的不同，有关东准噶尔—北天山造山带区域构造演化存在多种不同意见。近几年，笔者基于中国地质

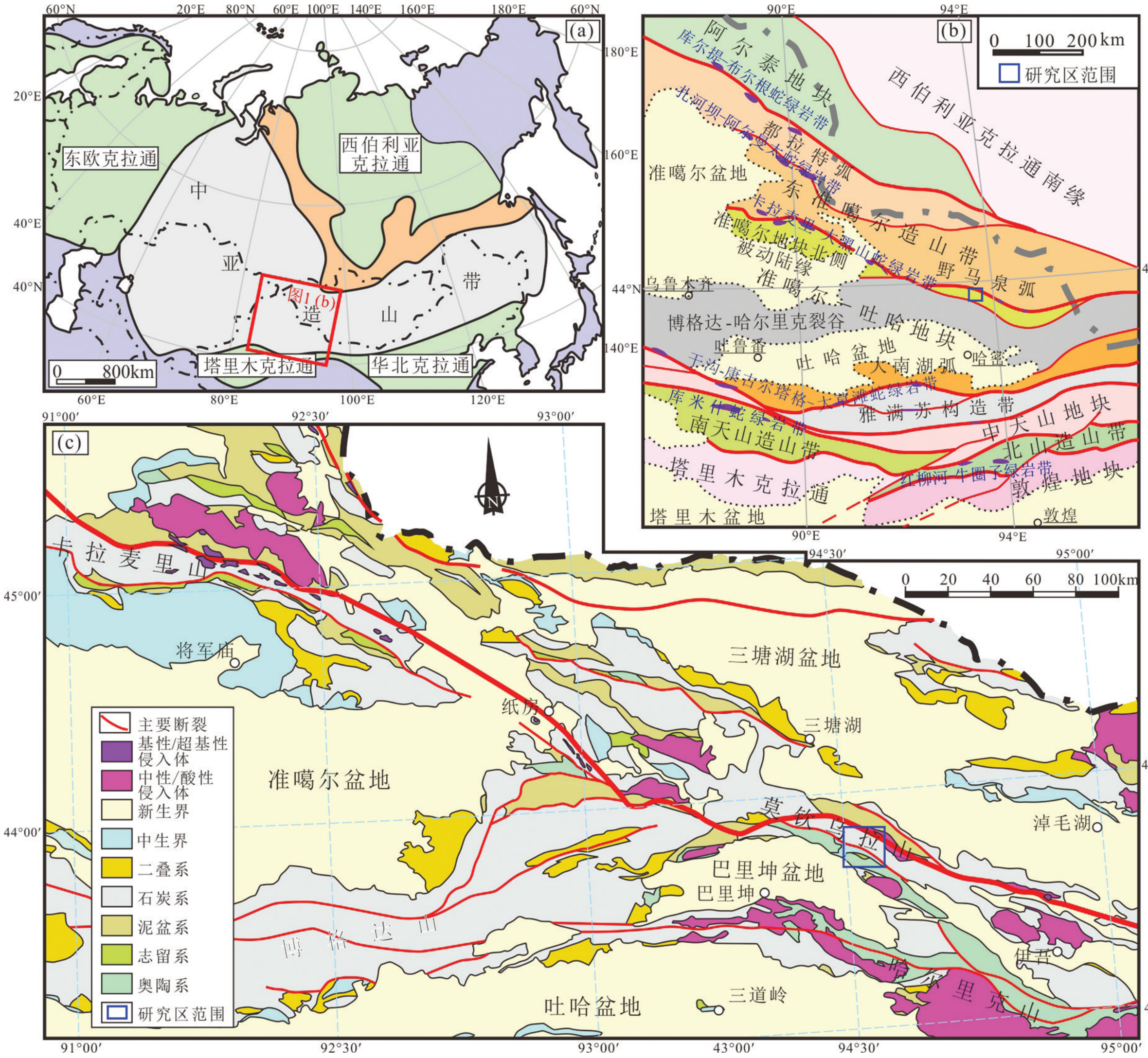


图1 研究区大地构造位置及区域地质简图

a—中亚造山带地质简图(据Jahn et al., 2004修改); b—新疆北部构造单元分区图(据Xiao et al., 2008修改); c—研究区及邻近地区地质简图

Fig.1 Tectonic setting and regional geological sketch map of the study area

a–Geological sketch map of the Central Asian Orogenic Belt (modified from Jahn et al., 2004); b–Tectonic divisions of northern Xinjiang (modified from Xiao et al., 2008); c–Geological map of the study area and adjacent areas

调查局“特殊地质地貌区填图试点”项目工作,在东准噶尔造山带与北天山造山带东段接壤地带的巴里坤地区开展1∶5万地质填图,有机会就关键地区开展地层、岩浆及构造变形等方面的系统性、全方位的研究,获得系列新成果和新进展。研究区横跨东准噶尔和北天山两大构造单元(图2),获取的新素材对理解东准噶尔—北天山造山带乃至整个中亚造山带的结构和演化提供了诸多新信息。本文将就1∶5万板房沟幅和小柳沟幅地质填图取得的有关古生代重大构造事件的新发现做一介绍。结合前人研究成果,从区域构造事件的角度重新审视新疆东准噶尔—北天山东段古生代的构造古地理面貌和演化。

2 地质背景

东准噶尔—北天山造山带东段位于中亚造山带西南部,准噶尔盆地东侧。东准噶尔造山带北以额尔齐斯断裂带与阿尔泰造山带相接,南以卡拉麦里断裂带与北天山造山带毗邻。该造山带以广泛发育泥盆纪岛弧火山岩和石炭纪—二叠纪后碰撞型火山岩和侵入岩为特征(Xiao et al., 2004a; 朱志新等, 2005; Zhang et al., 2009; Li et al., 2014; Liang

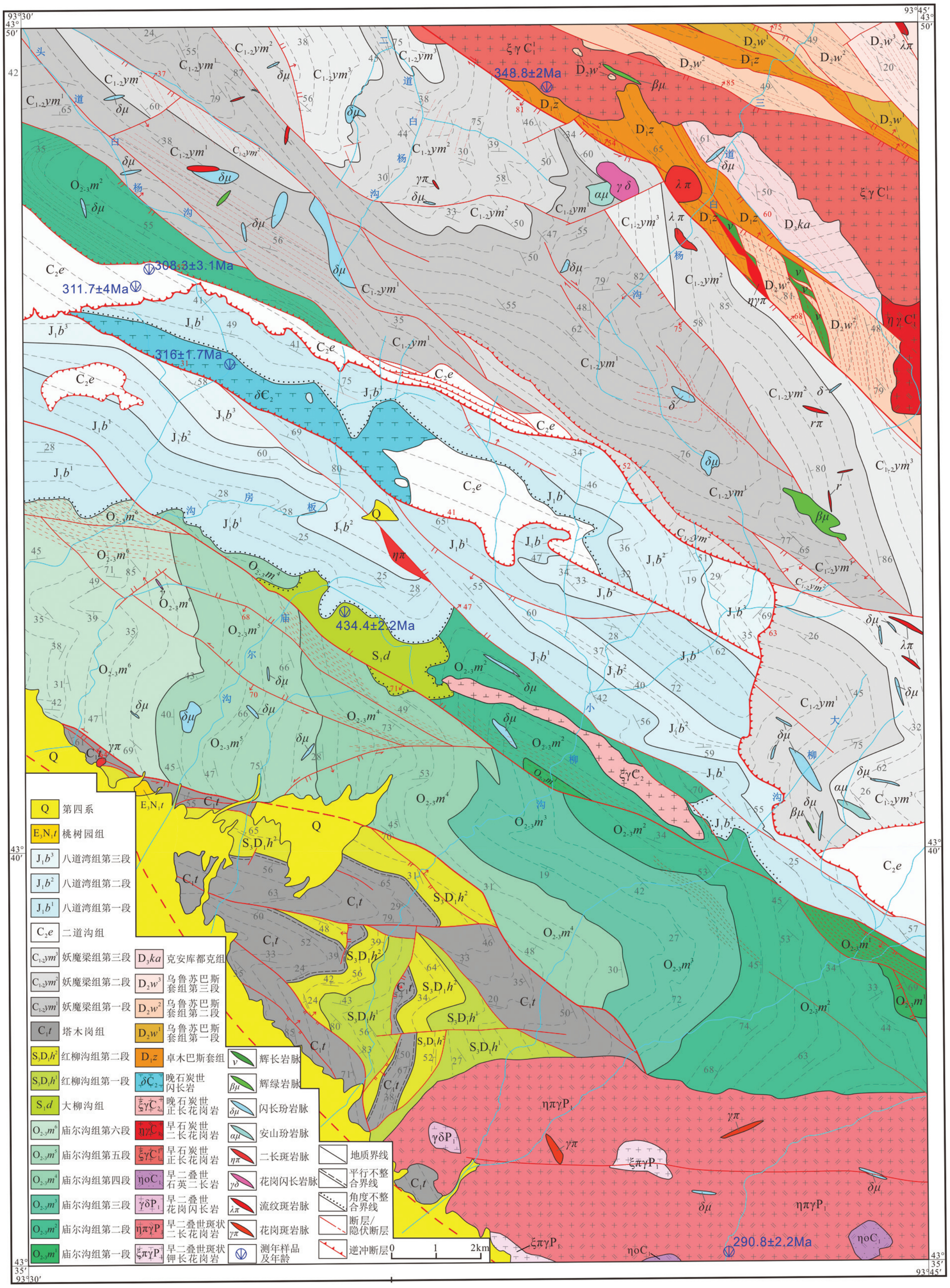


图2 1∶5万板房沟幅和小柳沟幅北半幅地质图

Fig.2 Geological map of 1∶50,000 Banfanggou and North Xiaoliugou sheets et al., 2016; 赵浩等, 2018a; 熊双才等, 2019)，一般认为不具备前寒武纪结晶基底(Zhang et al., 2017; Song et al., 2019)，但最新研究显示野马泉岛弧带中存在捕获前寒武纪基底锆石的侵入岩证据(Xu et al., 2013，2015a)。该造山带自北向南分布有3条蛇绿岩带，其中，北缘的库尔提—布尔根蛇绿岩目前多认为代表了晚古生代形成的弧后盆地(Xu et al., 2003; Wang et al., 2003, 2012; 吴波等, 2006)；中间的扎河坝—阿尔曼太蛇绿岩带则被视为早古生代的洋盆残迹(肖文交等, 2006; 张元元和郭召杰, 2010; 刘亚然等, 2016; 冯晓强等, 2016)；而南侧的卡拉麦里蛇绿岩多被认为是存在于志留纪—泥盆纪的古洋盆(李锦轶等, 1990; 舒良树等, 2003; Han and Zhao, 2018)，其闭合时间应在中泥盆世之后(Wu et al., 2009; Zhang et al., 2013, 2015; Luo et al., 2017; 蔡雄飞等, 2018; 白建科等, 2018a)。

北天山造山带东段夹持于卡拉麦里断裂与阿其克库都克断裂之间。多数学者以康古尔—黄山断裂为界将其进一步划分为北侧的大南湖—哈尔里克构造带和南侧的雅满苏构造带(Xiao et al., 2004b; Han and Zhao, 2018)。大南湖—哈尔里克构造带实际上相当于准噶尔—吐哈地块的一部分(李锦轶, 2004; Xu et al., 2015a; Zhou et al., 2018)。最新的锆石年代学显示准噶尔地块或准噶尔—吐哈地块存在有前寒武纪甚至太古宙的基底(樊婷婷等, 2014; Xu et al., 2015a)。但是，准噶尔—吐哈地块中的古生代岩浆岩的正的$\varepsilon_{\mathrm{Nd}}$值、$\varepsilon_{\mathrm{Hf}}$值以及集中在0.8～0.55 Ga的模式年龄反映其基底主体为形成于0.8~0.55 Ga的新生镁铁质地壳。古生代期间，该地块北缘的将军庙—莫钦乌拉山地区发育奥陶纪被动陆缘浅海—斜坡相碎屑沉积、早志留世伸展背景的陆相火山岩建造、中志留世—泥盆纪陆缘碎屑岩沉积、早石炭世海陆交互相碎屑岩沉积以及晚石炭世的一套裂谷型双峰式火山岩建造(Zhang et al., 2015; Luo et al., 2017)。中志留世—泥盆纪为北部卡拉麦里洋盆的主要发育时期，因此，其南侧的陆缘碎屑沉积对准噶尔—吐哈地块北部陆缘性质的界定具有重要意义。一些学者认为属于东准噶尔岛弧带的弧前增生(Xiao et al., 2004a; Liu et al., 2017)或哈尔里克岛弧的弧前盆地部分(马瑞士等, 1997)，而更多观点认为其属于准噶尔—吐哈地块北缘的被动大陆边缘(李锦轶等, 1988，2009; Han and Zhao, 2018)；中段的博格达—哈尔里克山一带广泛发育石炭纪双峰式火山岩(Chen et al., 2013; Zhang et al., 2017; Wali et al., 2018)和少量与北缘莫钦乌拉山类似的奥陶纪被动陆缘碎屑岩沉积以及早志留世伸展背景的陆相火山岩(王宝瑜，1983; Chen et al., 2014;李江海等2017)。基于石炭纪双峰式火山岩的特点，多数学者认为该地区石炭纪总体处于伸展构造背景(顾连兴等, 2000; Xia et al., 2004, 2012; Chen et al., 2013; 汪晓伟等, 2015;王良玉等, 2016;Zhang et al., 2017; Wali et al., 2018; 颉炜等, 2018)；地块南缘的大南湖地区则广泛发育奥陶—泥盆纪具岛弧背景的火山岩和侵入岩(李玮等, 2016; Du et al., 2018; Mao et al.,2018; Zhang et al., 2018; Sun et al., 2019)以及最近新发现的大草滩蛇绿混杂岩系统(舍建忠等，2017)。康古尔—黄山断裂南侧的雅满苏构造带中广泛发育石炭纪火山岩-碎屑岩-碳酸盐岩沉积和不同时期的蛇绿岩岩片(李文铅等，2006; 李永军等, 2008; 张雄华等, 2012)，其构造环境存在岛弧、弧后盆地、裂谷等不同认识(Hou et al., 2014; Luo et al., 2016; Jiang et al., 2017; 罗婷等, 2019)，应该是石炭纪多种不同构造背景地质体的组合。

随着研究的深入，积累的资料渐趋丰富，但问题和争议也随之产生，突出表现在地层系统建立不完善、岩浆纪录及其产出构造环境的判别意见分歧巨大、构造变形分析及构造年代学限定十分薄弱以及由此而导致的对东准噶尔—北天山不同构造单元的划分、构造属性的界定以及构造演化的认识存在巨大分歧。

3 东天山北部古生代重大构造事件的地质新记录——基于1∶5万板房沟幅和小柳沟幅地质填图的新发现

3.1 重大构造事件的构造界面记录

3.1.1 下志留统与奥陶系之间角度不整合界面的确定

在莫钦乌拉山南坡的庙尔沟上游及大柳沟东地区出露一套火山岩夹少量火山碎屑岩建造，其岩性主要为碱玄岩、玄武粗安岩、粗安岩及对应的火山碎屑岩。前人将其划归中—晚奥陶世大柳沟组

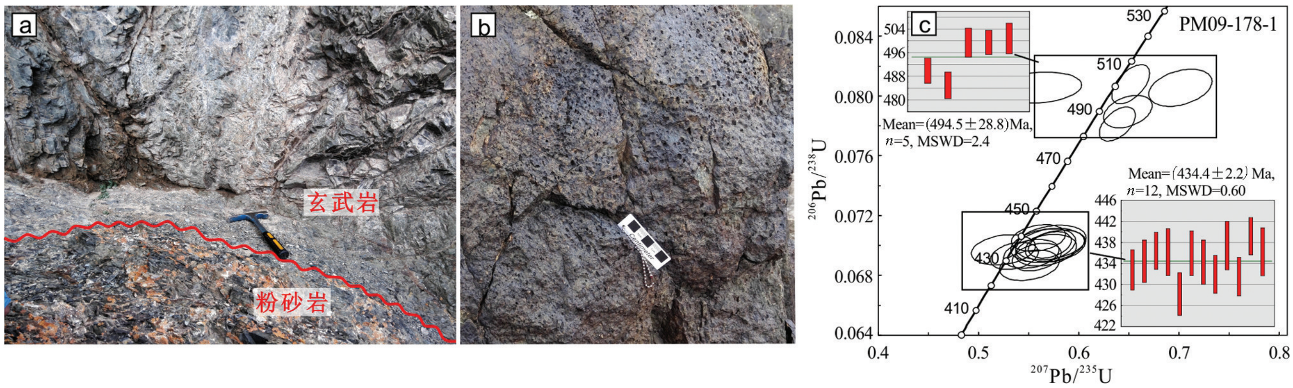


图3 大柳沟组火山岩及其与下伏岩系不整合关系和锆石U−Pb年龄

a—大柳沟组玄武岩与下伏庙尔沟组粉砂岩的角度不整合关系；b—大柳沟组渣状熔岩(气孔玄武岩)；c—大柳沟组粗安质角砾熔岩锆石U−Pb年龄谐和图(据赵浩等, 2018b)

Fig.3 Volcanic rock of Daliugou Formation and its unconformity with underlying strata and zircon U−Pb age

a−Unconformity between basalt of the Daliugou Formation and siltstone of the Miaoergou Formation; b−Stomatal basalt of the Daliugou Formation; c−Zircon U−Pb concordant diagram of the trachyte−andesitic breccia lava of the Daliugou Formation (after Zhao Hao et al., 2018b)

中，与上下地层呈整合关系(蔡土赐等, 1999)。本次研究发现这一火山岩下与奥陶纪庙尔沟组($O_{2-3}m$)一套海相陆缘碎屑岩呈角度不整合接触(图3 a)。其中的粗安质角砾熔岩锆石U−Pb年龄为(434.4±2) Ma(图3 c)，即早志留世晚期(赵浩等，2018b)。火山岩岩石主微量元素显示，该岩石系列具有富碱、强烈富集LILE和亏损Nb、Ta等特征，具有明显伸展背景下火山岩的特征(赵浩等，2018b)。

这样一个角度不整合同样出现于南部的哈尔里克山。该角度不整合的存在说明区域上在奥陶纪与志留纪之交存在强烈的造山事件，并在其后发生后碰撞伸展的岩浆活动。

3.1.2 下石炭统与泥盆系之间平行不整合界面的确定

在莫钦乌拉山南麓黄草坡沟—小柳沟一带的原奥陶系庙尔沟组中解体出一套以灰岩−泥岩−硅质岩为主、水深逐渐增大的海相沉积序列(图4a,4b)以及一套以砂砾岩−泥岩为主的海陆交互相沉积序列(图4d)。其中，前者灰岩层中的牙形石和珊瑚动物化石指示其时代为早泥盆世(另文发表)，而后者中的拟鳞木、芦木等植物化石以及腹足、双壳和较多腕足类动物化石指示其沉积时代为早石炭世(图4)。两者岩性组合分别可与卡拉麦里将军庙一带的红柳沟组和塔木岗组具有较高的相似性，故将两者从原庙尔沟组中解体出来，分别对比为上志留统—下泥盆统红柳沟组(S_3D_1h)和下石炭统塔木岗组(C_1t)。

在南部1∶5万小柳沟幅内，笔者发现塔木岗组与红柳沟组呈平行不整合接触关系(图2，图4c)，西部将军庙地区同样存在下石炭统与志留—泥盆系之间的平行不整合接触关系(李锦轶, 1988, 1990)。该界面上下地层存在时代的缺失和沉积相的突变，但产状一致。界面之上塔木岗组底部发育一套0.5~1 m厚度不等的紫红色、暗紫色砾岩，砾石分选和磨圆皆较好，成分以灰绿色、紫红色硅质岩和硅质泥岩为主，含少量花岗质砾石，具有典型的底砾岩特征，而红柳沟组顶部岩石多不同程度的遭受风化作用，质地松散，局部发育的砖红色铁质砂岩层，指示其曾长期处于近地表氧化暴露的环境中。

3.1.3 晚石炭世角度不整合及其构造环境的转换

早石炭世晚期—晚石炭世在莫钦乌拉山主峰妖魔梁一带相继沉积有妖魔梁组($C_{1-2}ym$)和二道沟组(C_2e)。其中，妖魔梁组以一套深海相−浅海陆棚相−海陆交互相碎屑岩为主(详见3.2.1)，下段和中段丰富的腕足类指示其时代为早石炭世晚期，而上段的孢粉组合*Cyclogranisporites aureus*−*Protohaploxypinus horizontatis*指示其时代为晚石炭世早期(巴什基尔期)。二道沟组角度不整合于下伏地层之上(图5a)，其底部发育巨砾岩、砾质粗砂岩(图5b)，具有陆相磨拉石的特征；砾岩之上为玄武岩、粗面玄武岩、玄武安山岩和流纹岩(图5c)及其对应的火山碎屑岩，其中的基性岩锆石U−Pb年龄在(312±4) Ma，酸性岩年龄在(308±3) Ma，属晚石炭世莫斯科期(罗婷等, 2018)。在火山岩构造判别图解中，二道沟组大多落于WPB(板内火山岩)内(图5d, 5e)，而其源区为受洋壳板片物质混染的上

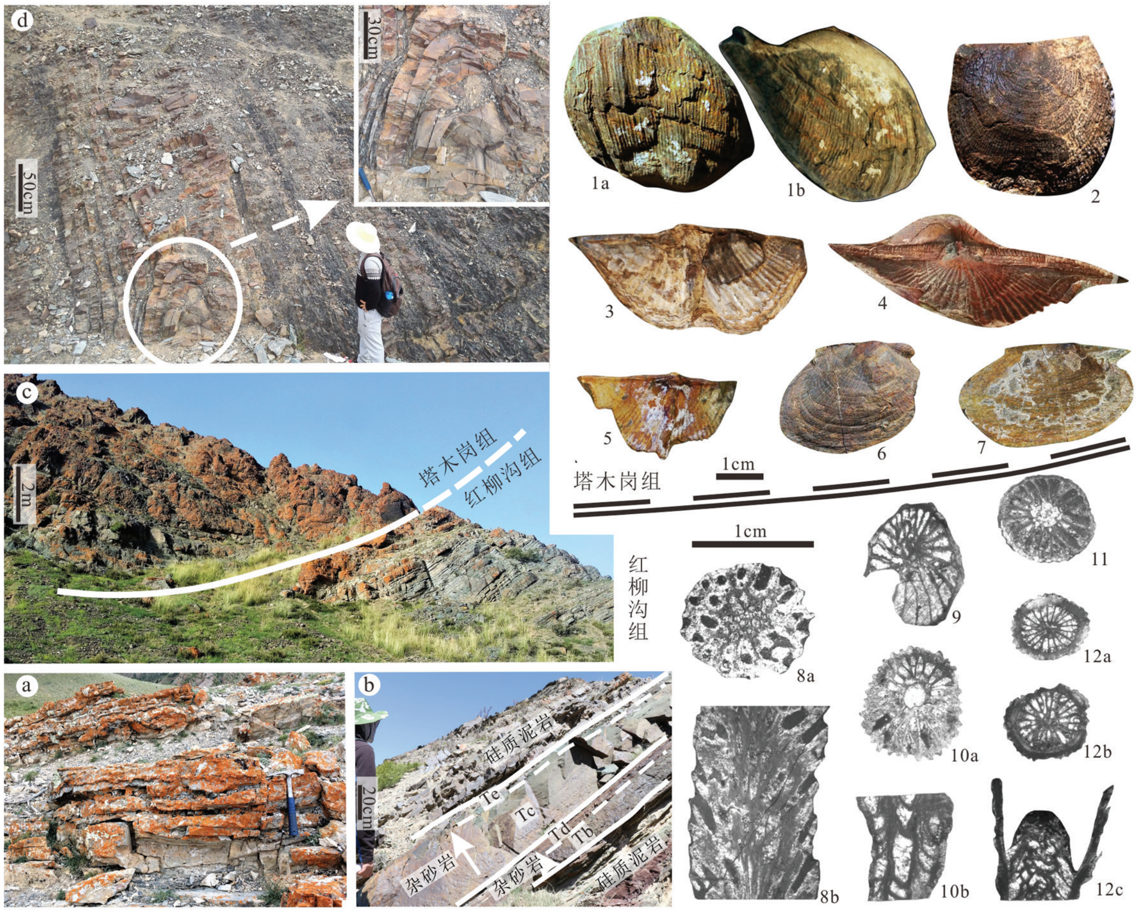


图4 红柳沟组和塔木岗组野外现象及其中化石

a—红柳沟组一段薄层灰岩与钙质泥岩互层; b—红柳沟组第二段的硅质泥岩夹凝灰质杂砂岩; c—红柳沟组和塔木岗组的平行不整合接触关系; d—塔木岗组的中层砂岩-薄层泥岩夹粉砂岩沉积,发育巨大的砂岩结核。化石: 1—*Linoproductus* sp.; 2—*Dictyoclostus deruptus quadratus* F.M. Zhang; 3~4—*Unispirifer* sp.; 5—*Brachthyrina* sp.; 6~7—*Limipectecten* tianshanensis Yang; 8—*Thamnopora* sp.; 9—*Amsdenoides* sp.; 10—*Syringaxon bohemicum* (*Barrande*); 11—Barrandeophyllum sp.; 12—*Palaeocyathus bohemicus* Počta

Fig. 4 Field phenomena and fossils of Hongliugou Formation and Tamugang Formation

a−Interbedded thin−layered limestones and calcareous mudstones in the lower part of the Hongliugou Formation; b−Silty mudstones intercalated with tuffaceous greywacke in the middle part of the Hongliugou Formation; c−Parallel unconformity between the Hongliugou Formation and the Tamugang Formation; d−Interbedded middle−layered sandstones and thin−layered mudstone intercalated with siltstones of the Tamugang Formation, with large sandstone nodules observed

涌软流圈(罗婷等, 2018),故推断二道沟组火山岩形成于碰撞后的陆内伸展环境,其火山岩成因可能与俯冲大洋岩石圈板片的拆沉有关。

妖魔梁组与二道沟组沉积构造环境的巨大变革以及二道沟组与下伏岩系的角度不整合关系,反映了晚石炭世区域上一次强烈的构造事件(详见后讨论),此后的后造山伸展则导致二道沟组陆相裂谷型双峰式火山岩喷发。

3.2 志留纪—泥盆纪重大构造-地层分区界线的确定——莫钦乌拉断裂

前人将准噶尔地层区与北天山地层区的界线界定为巴里坤盆缘断裂。新的地层资料揭示,该断裂南北两侧古生代地层系统并没有巨大差异,而显示巨大构造-地层差异的界线为北部的莫钦乌拉断裂。该断裂南北两侧在志留—泥盆纪呈现出截然不同的地层序列和构造背景,代表东准噶尔与北天山构造-地层区的分隔界线,是卡拉麦里缝合带向南东方向的延伸。

3.2.1 莫钦乌拉断裂以南区域

莫钦乌拉断裂以南至哈尔里克山北坡的奥陶系为一套厚度巨大的碎屑岩沉积(Long et al., 2014; Chen et al., 2014),至哈尔里克山南坡—大南湖一带

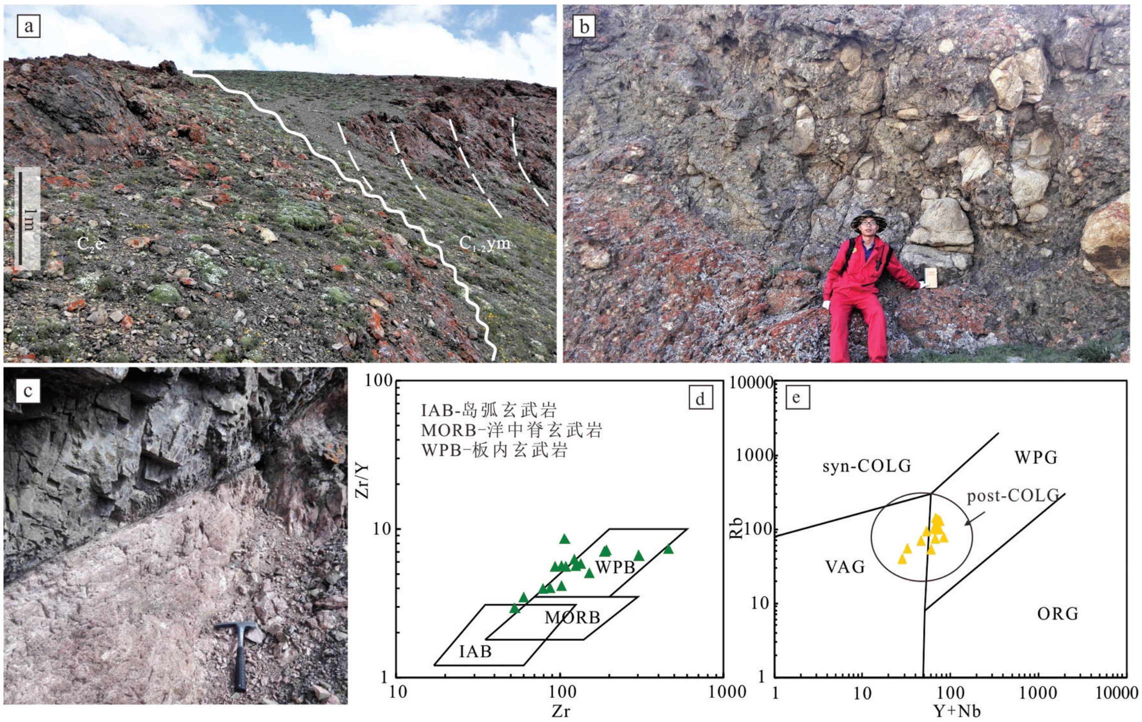


图5 二道沟组火山岩及其与妖魔梁组角度不整合关系和构造环境判别

a—二道沟组地层与下伏地层呈角度不整合接触; b—二道沟组底部的巨砾岩; c—基性火山岩(上)与酸性火山岩(下)互层; d—基性岩Zr/Y-Zr图解 (底图据Pearce and Norry, 1979); e—酸性岩Rb-Y+Nb图解(底图据Pearce, 1984), 其中: ORG—大洋脊花岗岩, WPG—板内花岗岩, VAG—火山弧花岗岩, Syn-COLG—同碰撞花岗岩, post—COLG-后碰撞花岗岩

Fig. 5 Volcanic rock of Erdaogou Formation and its angular unconformity with underlying Yaomoliang Formation and tectonic setting discrimination

a-Angular unconformity between the Erdaogou Formation and underlying strata; b-Giant conglomerates at the bottom of the Erdaogou Formation; c-Basic volcanic rocks (upper) interbedded with acidic volcanic rocks (lower) in the Erdaogou Formation; d-Zr/Y-Zr diagram of basic rocks of the Erdaogou Formation (after Pearce and Norry, 1979); e-Rb-Y+Nb diagram of acid rocks of the Erdaogou Formation (after Pearce, 1984). ORG-Oceanic ridge granite, WPG-Intraplate granite, VAG-Volcanic arc granite, syn-COLG-Syn-collision granite, post-COLG-post-collision granite

逐渐过渡到一套火山岩-火山碎屑岩沉积。前人将这一沉积划至奥陶系荒草坡群或庙尔沟组中。这一沉积同样分布在该断裂以北区域(李锦轶等, 2000b),说明在奥陶纪时期,莫钦乌拉断裂尚未成为区域上构造-地层分区界线。

莫钦乌拉断裂以南的志留—泥盆纪地层自下而上依次发育下志留统大柳沟组(S_1d)、中-上志留统白山包组($S_{2-3}b$)、上志留—下泥盆统红柳沟组(S_3D_1h)和下—中泥盆统卡拉麦里组($D_{1-2}kl$)。大柳沟组为一套碱玄岩、玄武粗安岩、粗安岩及对应的火山碎屑岩建造,发育红顶绿底结构和气孔、杏仁构造(图3b),具陆相特征(赵浩等, 2018b),其不整合于奥陶系庙尔沟组之上;白山包组主要出露于红柳峡一带,以灰-灰绿色浅海相碎屑岩为主,夹少量含砾粗砂岩、砂质灰岩和生屑灰岩,产较多腕足类Tuvaella(图瓦贝)化石(张梓歆等, 1983);红柳沟组广泛分布在巴里坤盆地北缘的青石海—小柳沟一带,下部以凝灰岩和凝灰质砂岩为主,中部以薄层泥晶灰岩和钙质泥岩为主(图4a),为一套深水陆棚环境的沉积,产四射珊瑚、床板珊瑚化石(图4)和早泥盆世最早的牙形石分子*Caudicriodus hesperius Klapper and Murphy*,上部以硅质泥岩、硅质岩为主,夹少量凝灰质杂砂岩,为一套远洋深水环境的沉积(另文发表)。卡拉麦里组主要发育于填图区西部的将军庙地区,其下段为一套深水相的硅质泥岩、粉砂质泥岩和杂砂岩,上段为浅水相碎屑岩沉积(蔡雄飞等, 2015a)。红柳沟组或卡拉麦里组之上被下石炭统塔木岗组(C_1t)平行不整合覆盖。

综上所述,莫钦乌拉断裂以南地区的志留系—泥盆系为一完整的海进-海退序列,并于中泥盆世

之后发生地壳的强烈隆升，缺失晚泥盆世沉积。

3.2.2 莫钦乌拉断裂以北区域

莫钦乌拉断裂以北区域主要发育一套的火山岩-碎屑岩沉积，前人笼统的将其划至泥盆系。笔者对这一地层序列进行了重新梳理，确定该地区泥盆系自下而上分别为下泥盆统卓木巴斯套组（D_1z）、中泥盆统乌鲁苏巴斯套组（D_2w）和上泥盆统克安库都克组（D_3ka）。该序列中，卓木巴斯套组（D_1z）为一套凝灰质砂岩夹钙质砂岩、砂质灰岩和生屑灰岩，其中的珊瑚动物化石指示其时代为早泥盆世晚期（张孟等，2018）。乌鲁苏巴斯套组（D_2w）岩性以安山质火山碎屑岩、凝灰质杂砂岩和泥岩为主，夹少量安山岩，常见鲍马序列、同沉积变形发育，上部常见砂泥岩互层，整体反映了水深较大且向上变浅的沉积序列，底部产中泥盆世早期的床板珊瑚*Xinjiangolites rarus* Wang。克安库都克组（D_3ka）岩性单一，以发育平行层理、砂纹层理的砂岩与泥岩互层，局部可见透镜状砂岩，代表三角洲前缘-平原环境沉积。

这一序列具有典型岛弧背景下的沉积特征，与位于巴里坤考克赛尔盖山经典的泥盆纪地层序列（蔡土赐，1991）存在一定差异，但碎屑成分、火山岩夹层位置及生物化石特征都具有可对比性（闫臻等，2018），均反映莫钦乌拉断裂以北泥盆纪时期的岛弧环境。其中，中泥盆统乌鲁苏巴斯套组的火山岩具有成熟岛弧的特征（赵浩等，2018a），与广泛分布于东准噶尔地区的中—晚泥盆世火山岩也基本一致。

对比莫钦乌拉断裂南北两侧志留—泥盆纪地层序列（图6），反映出显著的构造古地理面貌的差异，其中南部主体呈现为相对稳定的被动陆缘，早期（早志留世）还表现出陆内伸展裂解环境，而北部则呈现为显著的与俯冲相关的活动陆缘岛弧。推测沿莫钦乌拉断裂为洋盆缝合带，并很可能是卡拉麦里洋盆向南东方向的延伸，具有显著的构造单元分割意义。

3.3 早石炭世构造体制——空间分异的沉积岩与花岗岩

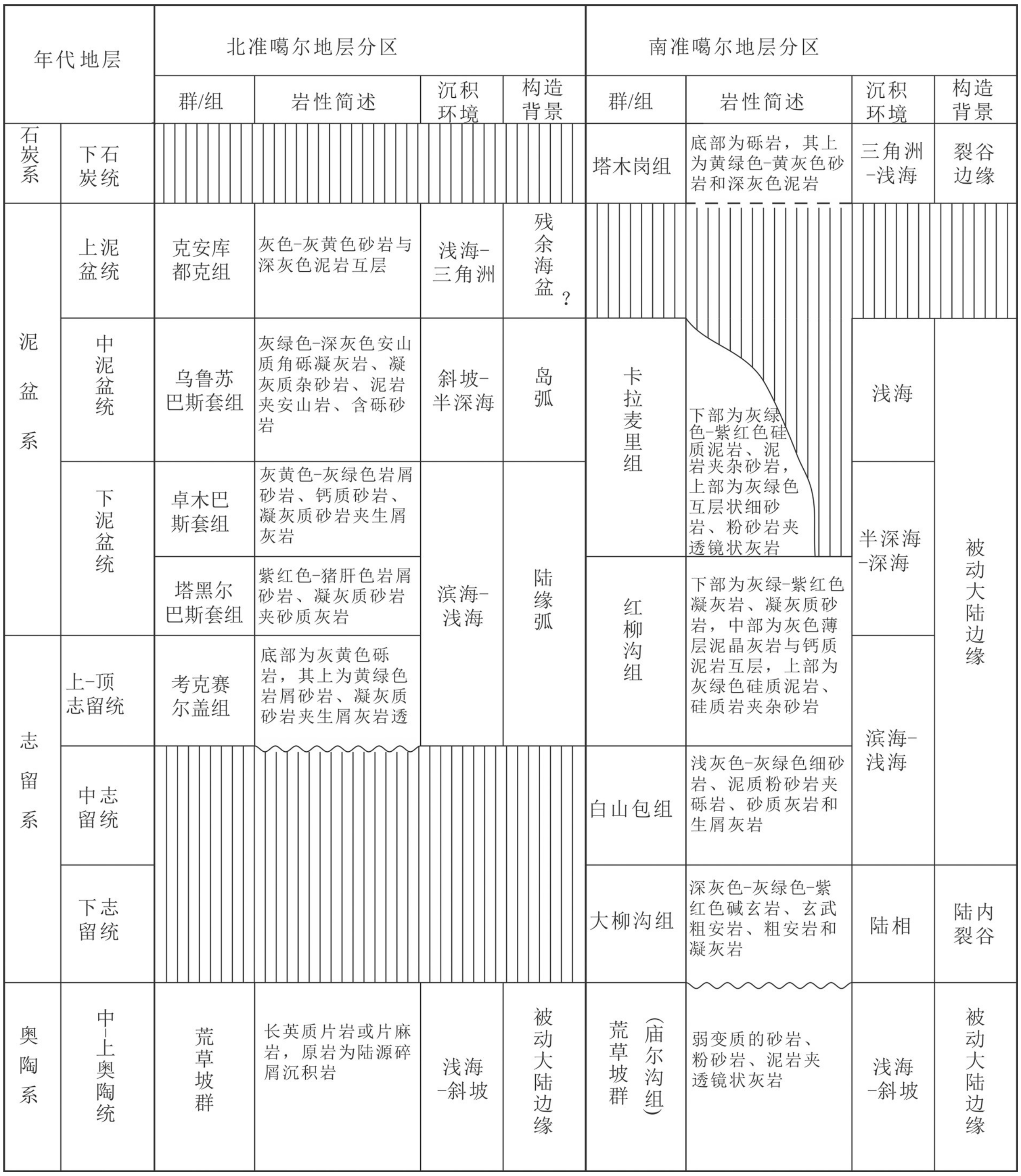
莫钦乌拉断裂以南博格达—哈尔里克山—莫钦乌拉山石炭纪特别是早石炭世构造环境主要存在岛弧和裂谷两种不同意见。笔者基于沉积和岩浆纪录认为不同部位构造环境存在不同的面貌，受控不同的构造体制，北部的莫钦乌拉山更多体现为造山挤压构造环境，而南部博格达—哈尔里克山则总体呈现为伸展裂解环境。

3.3.1 沉积岩

研究区北侧邻近莫钦乌拉断裂区域早石炭世—晚石炭世早期发育妖魔梁组（$C_{1-2}ym$），可划分为三段，下段以砂岩与粉砂岩、泥岩互层为主要特征，发育包卷层理、软沉积变形和不完整鲍马序列（图7a, 7b），代表深水盆地环境的沉积；中段底部发育一套复成分砾岩，其上以砂岩、粉砂岩和泥岩为主（图7d），砂岩比例较一段明显增多，发育多层介壳层（图7c），顶部见植物化石碎片（图7e），指示浅海-三角洲环境沉积；上段下部为砾岩夹含砾砂岩、泥岩（图7f），上部以泥岩与粉砂岩互层为主（图7g），代表三角洲水道-三角洲平原环境沉积。角度不整合其上发育晚石炭世晚期的二道沟组（C_2e）一套陆相磨拉石-双峰式火山岩建造。

研究区南部巴里坤盆地北缘—哈尔里克山一带早石炭世则主要发育一套海陆交互相-陆相沉积的塔木岗组和七角井组（Huang et al., 2018）。该套沉积平行不整合在下伏地层之上，底部发育一套底砾岩或砾质粗砂岩，向上迅速变细为细-中砂岩，产腹足类和植物化石碎片。这一序列下段为一套粉砂岩、泥岩夹砂岩沉积，具有浅海—前三角洲的沉积特征，产早石炭世维宪期的腕足类化石；中段以砂泥岩为主，砾岩夹层增多，反映三角洲前缘-三角洲平原环境的沉积；上段以砾岩和砂岩为主，夹少量粉砂岩、泥岩，具有河流沉积的特征。

北侧的妖魔梁组整体上为一套海退地层序列，早期最大海侵面指示的水深较大，而到晚石炭世中晚期造山隆起并进一步转为角度不整合其上的二道沟组陆相磨拉石-双峰式火山岩建造。这一序列可与典型周缘前陆盆地沉积序列进行对比（Pfiffner, 1986; 闫臻等，2018），反映与挤压相关的造山带前陆地区的沉积构造环境。而南侧的塔木岗组—七角井组为一快速海侵-缓速海退的特征，符合板内伸展裂谷环境下的沉积填充序列（Martins-Neto and Catuneanu, 2010），且其最大海侵仅有浅海规模。此外，博格达山一带下石炭统七角井组出现有大量的双峰式火山岩，反映为伸展裂谷环境，研究区范围可能表现为裂谷边缘。综上所述，莫钦乌拉断裂南侧的哈尔里克山—巴



年代地层		北准噶尔地层分区				南准噶尔地层分区			
		群/组	岩性简述	沉积环境	构造背景	群/组	岩性简述	沉积环境	构造背景
石炭系	下石炭统					塔木岗组	底部为砾岩，其上为黄绿色-黄灰色砂岩和深灰色泥岩	三角洲-浅海	裂谷边缘
泥盆系	上泥盆统	克安库都克组	灰色-灰黄色砂岩与深灰色泥岩互层	浅海-三角洲	残余海盆？				
	中泥盆统	乌鲁苏巴斯套组	灰绿色-深灰色安山质角砾凝灰岩、凝灰质杂砂岩、泥岩夹安山岩、含砾砂岩	斜坡-半深海	岛弧	卡拉麦里组	下部为灰绿色-紫红色硅质泥岩、泥岩夹杂砂岩，上部为灰绿色互层状细砂岩、粉砂岩夹透镜状灰岩	浅海	被动大陆边缘
	下泥盆统	卓木巴斯套组	灰黄色-灰绿色岩屑砂岩、钙质砂岩、凝灰质砂岩夹生屑灰岩	滨海-浅海	陆缘弧			半深海-深海	
		塔黑尔巴斯套组	紫红色-猪肝色岩屑砂岩、凝灰质砂岩夹砂质灰岩			红柳沟组	下部为灰绿-紫红色凝灰岩、凝灰质砂岩，中部为灰色薄层泥晶灰岩与钙质泥岩互层，上部为灰绿色硅质泥岩、硅质岩夹杂砂岩		
志留系	上-顶志留统	考克赛尔盖组	底部为灰黄色砾岩，其上为黄绿色岩屑砂岩、凝灰质砂岩夹生屑灰岩透					滨海-浅海	
	中志留统					白山包组	浅灰色-灰绿色细砂岩、泥质粉砂岩夹砾岩、砂质灰岩和生屑灰岩		
	下志留统					大柳沟组	深灰色-灰绿色-紫红色碱玄岩、玄武粗安岩、粗安岩和凝灰岩	陆相	陆内裂谷
奥陶系	中-上奥陶统	荒草坡群	长英质片岩或片麻岩，原岩为陆源碎屑沉积岩	浅海-斜坡	被动大陆边缘	荒草坡群（庙尔沟组）	弱变质的砂岩、粉砂岩、泥岩夹透镜状灰岩	浅海-斜坡	被动大陆边缘

图6 莫钦乌拉断裂南北志留—泥盆系地层对比图

Fig.6 Correlation of Silurian−Devonian strata on the north and south sides of the Moqinwula fault

里坤盆地北缘与莫钦乌拉山主峰一带的石炭纪沉积记录存在明显差异，分别受控于挤压和伸展两种不同构造体制。

3.3.2 侵入岩

沿莫钦乌拉断裂一带出露沿断裂走向分布的带状花岗质岩体。其岩性可分为正长花岗岩和二长花岗岩两个岩石单元。正长花岗岩锆石U−Pb年龄为(348.8±2.0) Ma，即早石炭世早期。岩石总体为过铝质高钾钙碱性系列，在*R*1−*R*2图解中，除一个样品位于6区之内（同碰撞花岗岩），其余点都落点

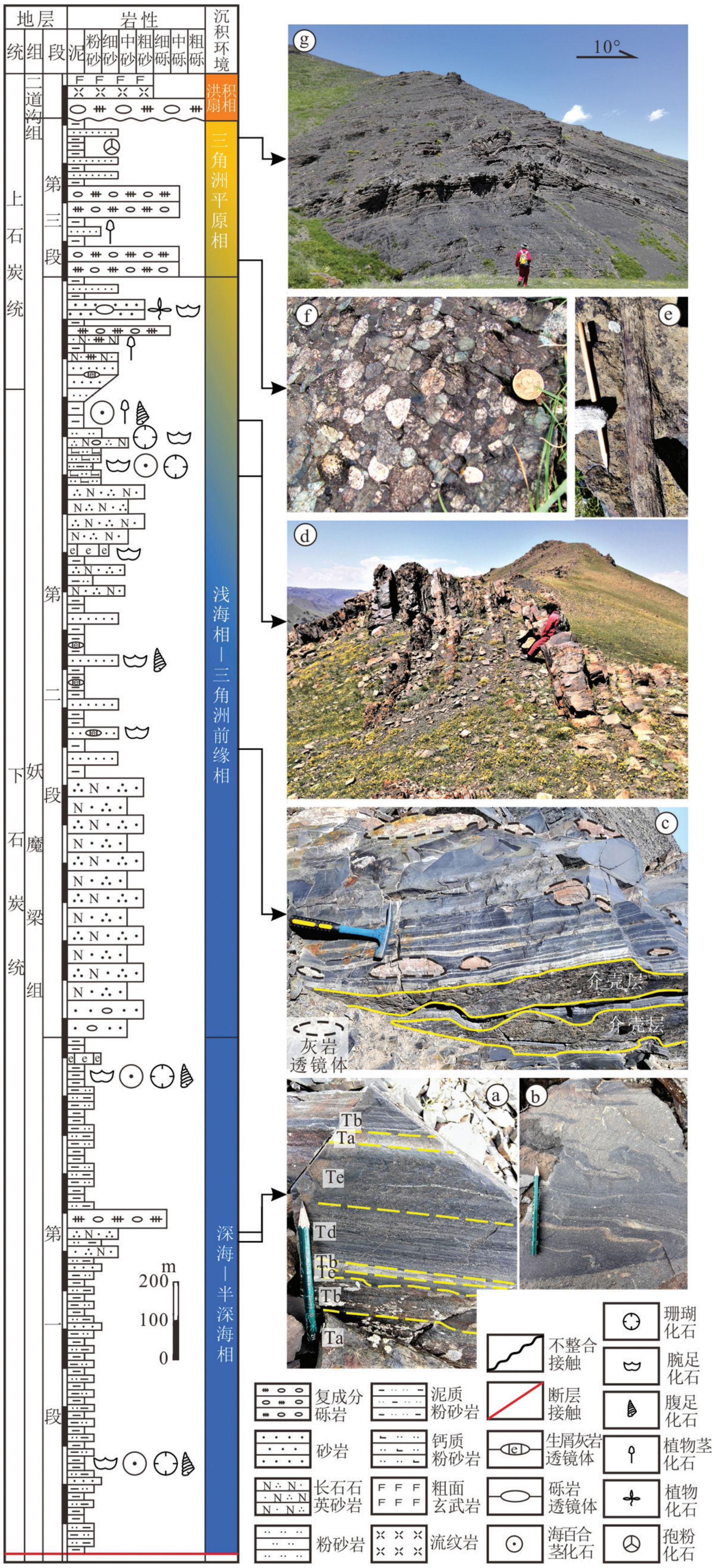

地层
统
组
段
岩性
泥
粉砂
细砂
中砂
粗砂
细砾
中砾
粗砾
沉积环境
二道沟组
上石炭统
第三段
洪积扇相
三角洲平原相
下石炭统
妖魔梁组
第二段
浅海相—三角洲前缘相
第一段
深海—半深海相
m
200
100
0
g
10°
f
e
d
c
介壳层
介壳层
灰岩透镜体
a
b
Tb
Ta
Te
Td
Tb
Tc
Tb
Ta
复成分砾岩
泥质粉砂岩
不整合接触
珊瑚化石
砂岩
钙质粉砂岩
断层接触
腕足化石
长石石英砂岩
粗面玄武岩
生屑灰岩透镜体
腹足化石
粉砂岩
流纹岩
砾岩透镜体
植物茎化石
海百合茎化石
植物化石
孢粉化石

图7 莫钦乌拉山妖魔梁一带妖魔梁组地层序列

a—第一段的鲍马序列; b—第一段中火焰状软沉积变形构造; c—第二段中部薄层泥岩与粉砂岩互层,夹介壳层和形态规则的灰岩透镜体; d—第二段上部的中–厚层砂岩与泥岩互层; e—第二段上部的植物茎化石; f—第三段的砾岩; g—第三段上部的泥岩夹粉–细砂岩或两者互层,发育宽缓褶皱,局部可见箱状褶皱

Fig.7 Stratigraphic sequence of the Yaomoliang Formation in the Yaomoliang area, Moqinwula Mountain

a–Bouma sequence in the first section; b–Flame–shaped soft deformation in the first section; c–Thin–layered mudstones interbedded with siltstones, intercalated with shell layers and regular limestone lens in the middle part of the second section; d–Thick–layered sandstones interbedded with mudstones in the upper part of the second section; e–Fossilized plant stems at the top of the second section; f–Conglomerates in the third section; g–Mudstones interbedded with silt–fine sandstones in the upper part of the third section, gentle folds and partially flat topped folds well developed

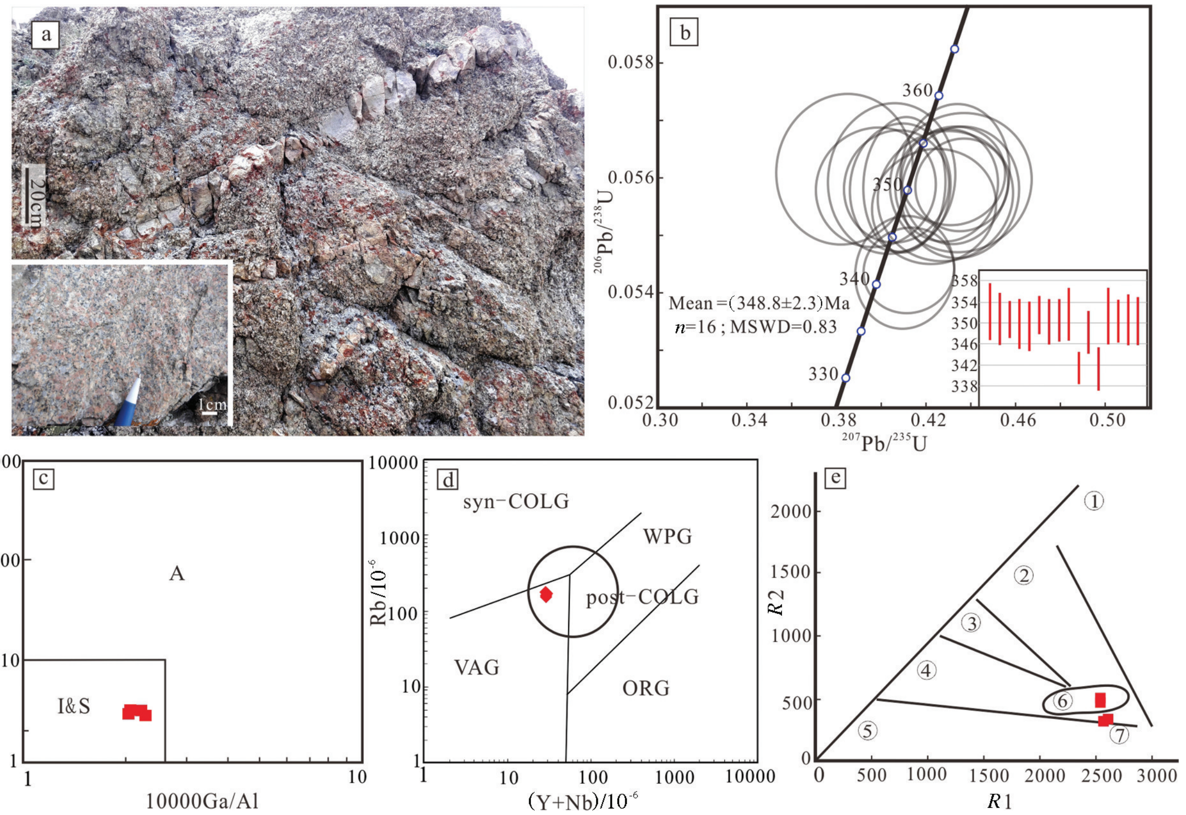


图8莫钦乌拉山早石炭世花岗岩及其锆石U–Pb年龄协和图及构造背景判别图解

a—花岗岩野外露头; b—锆石U–Pb谐和年龄; c—花岗岩类型判别图解; d—花岗岩Rb–(Y+Nb)成因判别图 (底图据Pearce, 1984), 其中: ORG—大洋脊花岗岩, WPG–板内花岗岩, VAG—火山弧花岗岩, syn–COLG—同碰撞花岗岩, post—COLG–后碰撞花岗岩; e–花岗岩*R*1–*R*2判别图 (底图据Batchelor and Bowden, 1985), 其中: ①—幔源花岗岩, ②—板块碰撞前消减地区花岗岩, ③—板块碰撞后隆起花岗岩,④—晚造山期花岗岩,⑤—非造山花岗岩, ⑥—地壳熔融的花岗岩(同碰撞), ⑦—造山后期花岗岩 . *R*1=4Si–11(Na+K)–2(Fe+Ti), *R*2=6Ca+2Mg+Al

Fig. 8 Early Carboniferous granite, zircon U–Pb age and tectonic setting discrimination in the Moqinwula Mountain

a–Granite outcrop; b–Zircon U–Pb concordant age; c–Discrimination diagram of granite types; d–Rb–(Y+Nb) discrimination diagram of tectonic setting (after Pearce, 1984); e–R1–R2 discrimination diagram of tectonic setting. ORG–Oceanic ridge granite, WPG–Intraplate granite, VAG–Volcanic arc granite, syn–COLG–Syn–collision granite, post–COLG–Post–collision granite. ①–Mantle–derived granite; ②–Subduction related granite before plate collision; ③–Uplifted granite after plate collision; ④–Serorogenic granite; ⑤–Anorogenic granite; ⑥–Crust melting granite (syn–collision), ⑦–Post–orogenic granite. *R*1=4Si–11(Na+K)–2(Fe+Ti), *R*2=6Ca+2Mg+Al

在6区与7区(后碰撞花岗岩)的边界上(图8e),但是主、微量元素特征上其与I型花岗岩相似,在花岗岩类型判别图上落入I & S型花岗岩范围内(图8c),在Pearce花岗岩构造判别图中,所有样品皆落点于VAG(火山弧花岗岩)的一侧(图8d)。这些岩石地球化学特征说明,早石炭世其构造环境可能处于同碰撞向后碰撞过渡的构造背景,但深部可能仍有残留大洋岩石圈板片俯冲,从而保留有与俯冲相

关的岛弧岩浆信息。

与莫钦乌拉山花岗质侵入岩不同的是，研究区南部的哈尔里克山的早石炭世花岗质侵入岩主要呈现为碱长花岗岩和正长花岗岩，具富碱、贫钙镁和低铝铁的特征，微量元素明显富集Rb、Th、K等大离子亲石元素和Zr、Hf等高场强元素，而强烈亏损Ba、Sr、Eu等元素，10000 Ga/Al值变化于2.93~3.80，属于典型的A型板内花岗岩。在Pearce花岗岩构造判别图解中，大多数样品落于WPG(板内花岗岩)的一侧，推断其形成于造山后的陆内裂谷环境(王良玉等，2016)，为博格达石炭纪裂谷带向东的延伸。

上述沉积和岩浆纪录均说明，巴里坤盆地南北构造环境存在显著分异，北部总体处于与碰撞相关的挤压背景，而南部为陆内伸展环境。

3.4 早古生代与晚古生代以来构造体制变革的变形记录

3.4.1 奥陶纪地层的南北向构造变形

莫钦乌拉山南坡庙尔沟和小柳沟一带奥陶系庙尔沟组($O_{2-3}m$)虽然受到了后期北西-南东向褶皱的叠加，但岩层的主体产状倾向北西西，地层序列由东往西逐渐变新，反映早期总体近南北向的构造线方向(图9a,9c)。平行层理走向方向尚发育有早期近南北走向的劈理(图9b)。早期近南北向构造绝大部分被后期北西-南东向构造发生近横跨叠加，导致早期近南北向的层理或劈理沿走向发生波状弯曲或直立倾伏褶皱，并伴生透入性近直立的区域性北西-南东向轴面劈理(图9d)。

卷入南北向褶皱构造的地层仅限于奥陶系庙

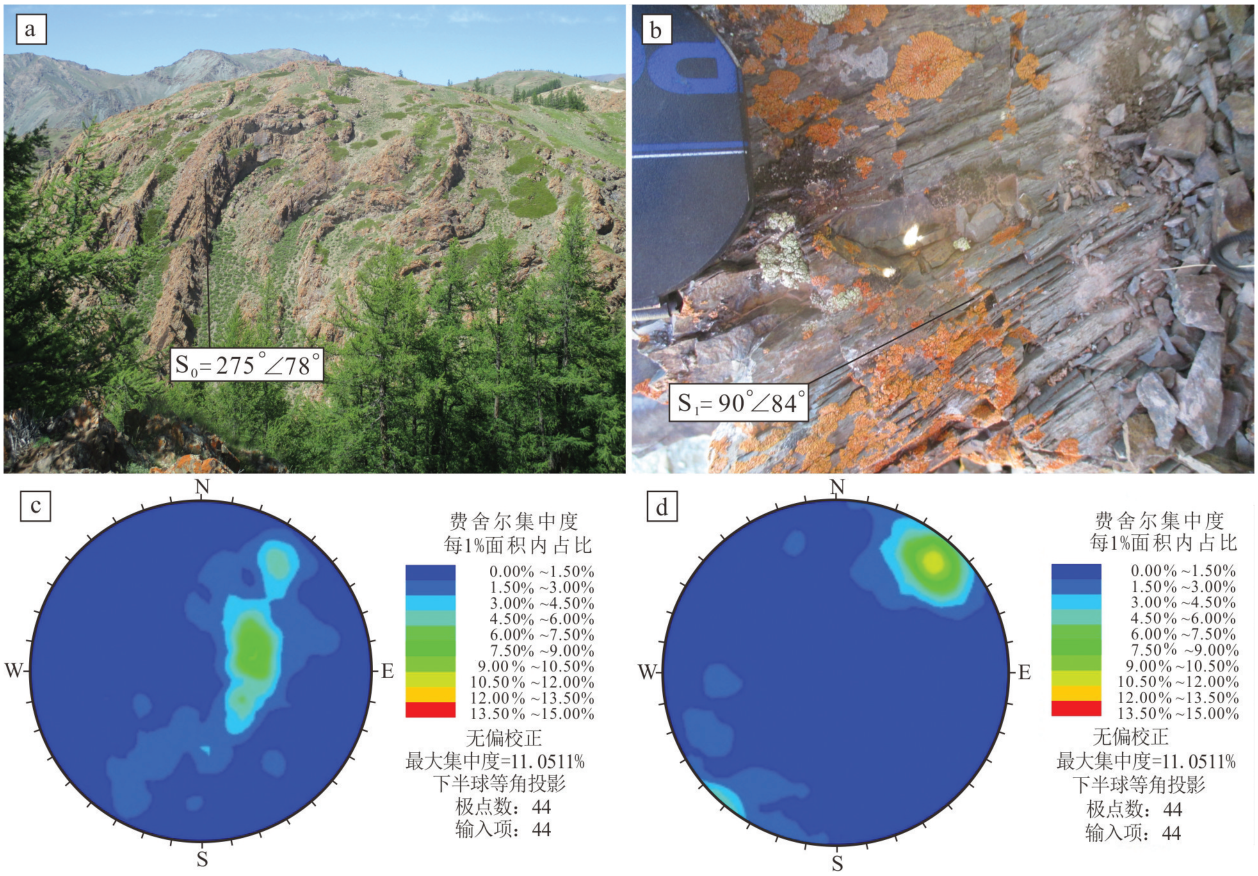


图9 奥陶系庙尔沟组地层南北向构造变形特征

a—南北向层理沿走向的弯曲，反映后期北西-南东向褶皱对早期近南北向构造的叠加；b—平行层理方向的近南北向劈理；c—层理极点的下半球极射赤平投影极密图；d—后期叠加的NW-SE走向的区域性劈理极点的下半球极射赤平投影极密图

Fig.9 NS-trending deformation in the Ordovician Miaoergou Formation

a-Bending along the NS-striking bedding, showing the superimposed fold of late NW-SE trending folds on early NS-trending structures; b-Approximately NS-trending cleavage parallel to the bedding; c-Lower hemisphere stereographic projection of bedding poles; d-Lower hemisphere stereographic projection of late superimposed NW-SE trending cleavage poles

尔沟组，其上覆地层的构造线方向则主要为北西−南东向，不具备南北向的构造线方向。结合前文提到的下志留统与奥陶系之间的角度不整合关系，笔者认为，早期近南北向构造的发育时间应为奥陶纪与志留纪之交，反映一次近东西向的挤压变形。

3.4.2 晚古生代以来的北西−南东向褶皱−冲断构造

东天山地区现今的基本构造线方向以及盆山地貌格局均呈现为北西−南东走向，在研究区内突出表现在莫钦乌拉断裂两侧的晚志留世—晚石炭世早期的地层中。

莫钦乌拉断裂北侧泥盆纪地层中广泛发育北西−南东向褶皱−冲断构造。在靠近莫钦乌拉断裂的地区褶皱多表现为较紧闭褶皱（图10a,10b），向远离断裂方向逐渐转换为宽缓褶皱。露头尺度褶皱规模不大，受一系列北西−南东向逆冲断层的破坏，多不完整。褶皱枢纽走向北西西−南东东向，轴面产状近直立，略向北东倾斜。与褶皱相伴发育大量透入性劈理构造（图10 c），走向稳定，较之南部的石炭系中的劈理构造更为强烈和连续。相伴逆冲断层倾向多为北北东或北东向，地表断面倾角多为在50~80°（图10c）。发育由逆冲断层活动造成的轴面倾向北东的牵引褶皱叠加在先期形成的近直立褶皱之上（图10 b）。

莫钦乌拉断裂南侧古生代地层中的北西−南东向褶皱−冲断构造表现相对完整连续，但变形程度整体较断裂北侧弱。其褶皱总体相对北侧开阔，轴面多近直立或略向北东倾斜（图10d,10e），相对软弱的泥岩夹层中发育层间劈理。与褶皱伴生发育有一系列倾向北东的中等角度逆冲断层（图10f）。奥陶系庙尔沟组中同样发育北西−南东向褶皱，对早期近南北向构造发生横跨叠加，导致早期近南北向的层理或劈理沿走向发生波状弯曲或形成直立倾伏褶皱，并相伴北西−南东走向的透入性高角度或近直立的区域性轴面劈理（图9d）。

古生界北西−南东向主期褶皱冲断构造的发育时间可以从晚石炭世二道沟组与下伏岩系的角度

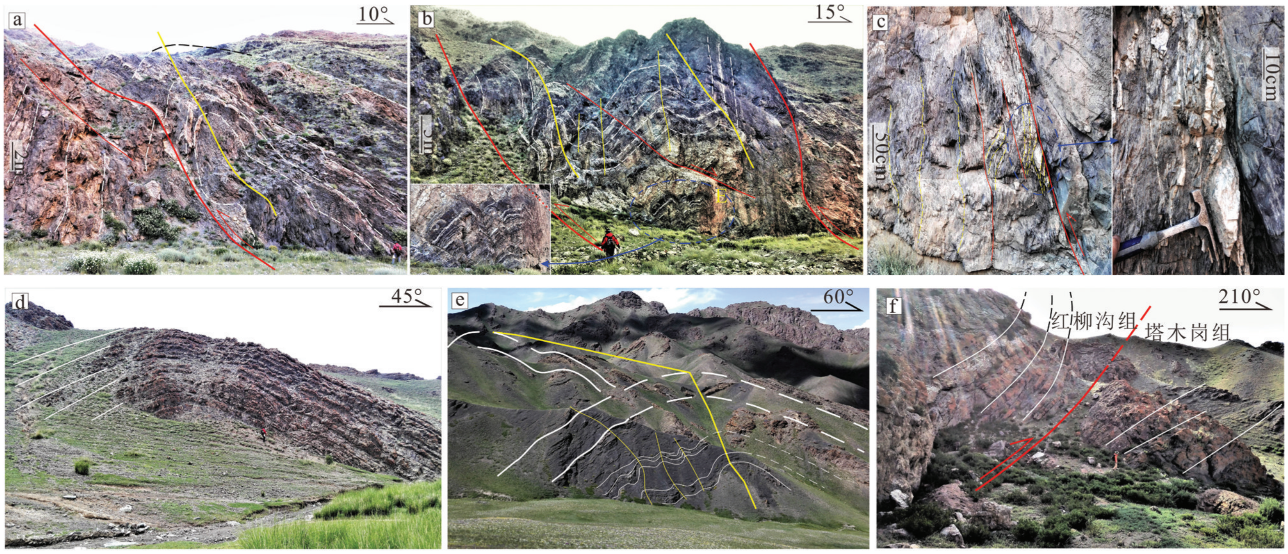


图10 莫钦乌拉断裂南北两侧志留—石炭纪地层中的北西−南东向构造变形对比

a~c—莫钦乌拉断裂北侧泥盆纪地层中的变形：a—逆冲推覆构造相关的轴面倾向东北的牵引褶皱；b—逆冲推覆相关的牵引褶皱叠加在先期的尖棱褶皱之上；c—高角度逆冲断裂带中发育的S−C面理和构造透镜体；d~e—莫钦乌拉断裂南侧志留—石炭纪地层中的变形：d—红柳沟组中的宽缓褶皱；e—妖魔梁组中的宽缓褶皱，轴面均高角度倾向北东；f—上志留统—下泥盆统红柳沟组逆冲至下石炭统塔木岗组之上，红柳沟组地层发生倒转。图中红色线条代表断层，白色虚线代表地层层理，黄色实线代表褶皱轴面，黄色虚线代表劈理

Fig.10 Deformation comparison in the Silurian−Carboniferous strata between the north side and south side of the Moqinwula fault

a−c−Deformations in the Devonian strata on the north side of the Moqinwula fault: a−Thrust related drag folds with axial plane dipping to the NE; b−Thrust related drag folds superimposed on the earlier angular folds; c−S−C fabric and tectonic lens along the reverse fault; d−e−Deformations in the Silurian−Carboniferous strata on the south side of the Moqinwula fault: d−Gentle folds in the Hongliugou Formation; e−Gentle folds in the Yaomoliang Formation with axial plane dipping to the NE; f− Hongliugou Formation thrusting on the Tamugang Formation with reversed Hongliugou Formation. On the photos, red line=fault, white line=bedding, yellow full line=axial plane and yellow dash line=cleavage

不整合关系得到限定。相比较下伏岩系,二道沟组的变形十分微弱,褶皱极为宽缓,反映该期区域性的造山事件发生在晚石炭世早期及之前,它奠定了研究区乃至整个东准噶尔—北天山东段北西-南东向构造的基本格架。中新生代的构造变形以及盆山地貌格局基本承袭这一构造格局,使北西-南东向构造趋于复杂化。

4 讨 论

4.1 下志留统与奥陶系之间角度不整合的区域构造意义

蔡土赐(1989)曾报道在巴里坤考克赛尔盖山一带晚志留世含珊瑚化石地层与下伏奥陶系之间存在角度不整合。新疆地调院1∶25万纸房幅(1996—2000年)进一步印证了这一不整合的存在,并推测东准噶尔地区存在加里东期的造山运动。但由于其他证据的匮乏,对这一构造事件的时代约束并不精确,对这一事件的具体原因及其构造意义也不明确。

本次工作进一步揭示北天山东段的北部地区志留系与奥陶系之间存在角度不整合关系。不整合面上下地层沉积古地理环境迥异,下伏奥陶系庙尔沟组以一套碎屑岩为主,在其中段发现腕足、三叶虫化石指示其时代为中—晚奥陶世,砂岩组分特征和地球化学特征皆反映其沉积背景主要为被动大陆边缘或弧后被动陆缘(另文发表),不整合在其上的下志留统大柳沟组则为典型的伸展环境的陆相火山岩系(赵浩等,2018b),同期的在研究区南部的哈尔里克山一带则为后碰撞背景的高分异I型和A型花岗岩(肖典等,2016),侵入活动和火山活动都指向后碰撞的伸展环境。另外,不整合面下伏奥陶系地层的近南北向构造变形格架与志留系—上古生界的北西-南东向构造格架迥异。奥陶纪庙尔沟组地层中存在的早期南北向构造被晚期北西-南东向叠加。这些都说明在奥陶纪—志留纪之交曾发生过明显的近东西向挤压造山事件,而早志留世则处于后造山伸展的背景。

那么,这次区域性的挤压事件是由何引起的呢?有关研究表明,研究区北部相邻的东准噶尔地区存在3条著名的蛇绿岩带,但只有扎河坝—阿尔曼太蛇绿岩残存有早古生代洋壳的记录(肖文交等, 2006; 张元元和郭召杰, 2010; 刘亚然等, 2016; 冯晓强等, 2016)。目前对阿尔曼太洋的演化则有两种不同的解释:一些学者认为该洋盆在奥陶纪发生持续向北的洋内俯冲,形成都拉特岛弧,随后阿尔曼太蛇绿岩增生就位至都拉特弧南缘,而南侧的主洋盆在早古生代并未发生闭合(Xiao et al., 2004a; Luo et al., 2017);另一些学者根据角度不整合于奥陶系或蛇绿岩之上的碎屑岩的时代及物源特征认为该洋盆在晚志留世以前已经闭合(李锦轶等1988;黄岗等,2013),生物古地理证据(Tuvaella动物群的分布)也说明准噶尔地块与西伯利亚南缘在志留纪已经相连(苏养正, 1981; 张梓歆等, 1983; 王宝瑜, 1990; 蔡雄飞等, 2015)。研究区内下志留统与奥陶系之间的角度不整合、构造背景转换以及近东西向构造挤压事件可视为准噶尔地块与阿尔泰地块发生碰撞以及阿尔曼太洋盆闭合的响应,指示阿尔曼太洋盆闭合于奥陶纪与志留纪之交。

4.2 泥盆纪—石炭纪的构造体制转换

卡拉麦里—莫钦乌拉断裂以南区域在奥陶纪与志留纪之交的造山事件后,早志留世发育有大柳沟组(S_1d)后造山伸展背景的火山岩,随后发育较完整的包括白包山组($S_{2-3}b$)、红柳沟组(S_3D_1h)和卡拉麦里组($D_{1-2}k$)的中志留世—中泥盆世地层序列,整体上存在由陆相→滨浅海→深海→半深海或浅海的沉积环境变化。除了底部早志留世的后造山陆相火山岩外,上部主体地层中基本不含火山岩,沉积厚度不大且横向相对稳定。这一沉积中含有一定的源自火山弧的火山碎屑物质,其中红柳沟组的碎屑锆石存在与吐哈地块南部的大南湖岛弧火山岩一致的(460~400 Ma)年龄峰值(Huang et al., 2017),体现了两者之间的物源联系。因此,莫钦乌拉断裂以南的吐哈地块北部呈现为以研究区为代表的弧后被动大陆边缘的沉积序列,而吐哈地块南部(大南湖一带)呈现为岛弧性质的活动陆缘,北部被动陆缘沉积物源来自南部的活动岛弧。

卡拉麦里—莫钦乌拉断裂以北区域尽管地层出露不全,但是结合区域上泥盆纪地层来看,其呈现为一套完整的具有火山弧特点的火山-碎屑岩沉积,与断裂南侧的沉积特征截然不同。这就意味着在志留纪—泥盆纪期间,莫钦乌拉断裂具有明显的古洋盆构造古地理分割意义。作为重大构造边界分

隔着南部的被动大陆边缘和北部的岛弧，反映其代表的卡拉麦里洋盆在志留纪—泥盆纪期间呈现为北向俯冲。尽管研究区内沿莫钦乌拉断裂没有古洋盆残余的蛇绿岩产出，但是其往北西方向可与卡拉麦里蛇绿岩带相连，往南东方向的大黑山和阿勒吞昆多地区也有蛇绿岩的报道(李嵩龄等, 1999; 秦彪等, 2012)。因此，研究区内的莫钦乌拉断裂应该是卡拉麦里洋向南东的延伸。海相沉积序列指示该洋盆于中志留世拉开，并于早泥盆世晚期开始向北单向俯冲，形成研究区北侧的具有岛弧特点的火山-碎屑沉积建造(赵浩等, 2018a)。

进入石炭纪，由于洋盆两侧地块的碰撞闭合，上述北向俯冲的卡拉麦里—莫钦乌拉洋盆分割的南部被动陆缘和北部岛弧的构造古地理格局发生了根本性的变化。莫钦乌拉断裂以北多转换为剥蚀区，为南侧的前陆盆地或准噶尔地块内部提供物源(Zhang et al., 2013; 白建科等, 2018a)，而南部的吐哈地块北部构造环境发生了显著空间分异。靠南部的博格达—哈尔里克山呈现为后造山伸展裂谷环境；向北至莫钦乌拉山的南缘则表现为下石炭统海陆交互相碎屑平行不整合于遭受隆起剥蚀的泥盆系之上，而更北侧邻近莫钦乌拉断裂的妖魔梁一带则发育一套具有周缘前陆盆地沉积序列特征的妖魔梁组。早石炭世花岗岩的特征也反映了北侧莫钦乌拉山与南侧哈尔里克山构造环境的差异，北部形成于同碰撞向后碰撞过渡的构造背景下，而南侧形成于造山后的陆内裂谷伸展环境(王良玉等, 2016)。

上述沉积与岩浆记录所体现的早石炭世与泥盆纪构造环境的变化，实际反映了卡拉麦里—莫钦乌拉山洋盆于泥盆纪—石炭纪之交的闭合及其后石炭纪的持续挤压造山。洋盆闭合过程中可能由于准噶尔—吐哈地块北向运动受阻而导致缝合带南部被动陆缘弯曲隆起，导致其内部的志留—泥盆系垂向抬升接受剥蚀，而邻近缝合带处则由于北侧造山隆起形成周缘前陆盆地，沉积妖魔梁组水体总体向上变浅的地层序列。早石炭世的构造古地理格局如图11a所示，莫钦乌拉缝合带北侧原泥盆纪岛弧区转化为山系剥蚀区，并发育强烈的褶皱冲断变形，南侧则发育周缘前陆盆地，而塔木岗组(C_1t)沉积区相当于周缘前陆盆地的前缘隆起，发育下石

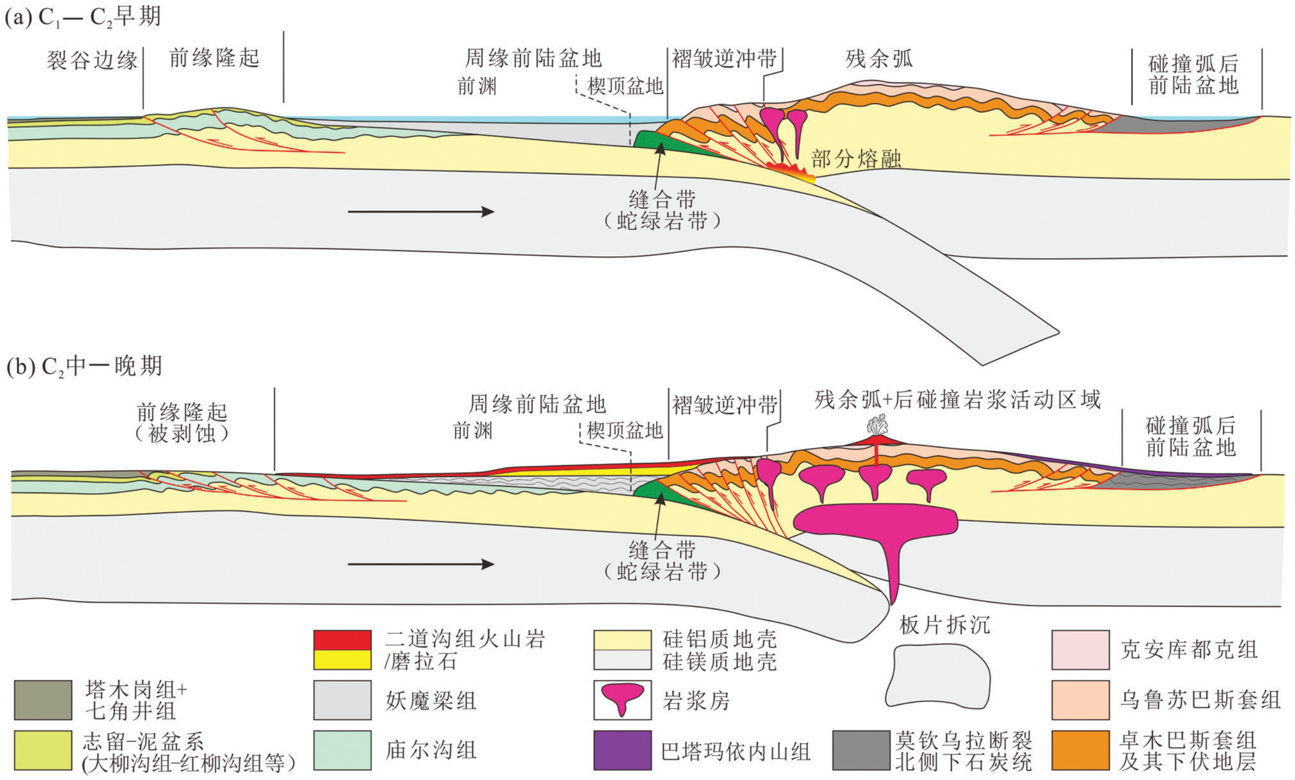


图11 莫钦乌拉山石炭纪周缘前陆盆地演化模型

Fig.11 Model showing the evolution of Carboniferous peripheral foreland basin of the Moqinwula Mountain

炭统与泥盆系之间的平行不整合。晚石炭世的进一步的汇集挤压则引起早石炭—晚石炭世早期地层的广泛褶皱-冲断变形，晚石炭世晚期二道沟组与早石炭—晚石炭世早期妖魔梁组之间的角度不整合代表该期挤压造山事件的时间上限。这一构造变形事件是奠定研究区乃至整个东准噶尔—北天山东段北西-南东向基本构造格架的重大构造事件，也导致了对研究区奥陶系近南北向构造的横跨叠加。

至于早石炭世巴里坤盆地南北构造环境的不同说明，尽管两者同处于莫钦乌拉断裂南部的吐哈地块北侧，但受控的构造体制存在差异。北部总体处于与卡拉麦里洋盆碰撞闭合相关的挤压背景，而南部的陆内伸展背景则可能受到其南侧洋陆相互作用的影响。在最近开展的区域地质调查工作中，笔者在哈密南部的大草滩一带甄别出一套早古生代—早中泥盆世的蛇绿混杂岩带，其上被一套晚泥盆世陆相火山岩角度不整合覆盖，揭示中—晚泥盆世之交大草滩洋盆的闭合(另文发表)。哈尔里克山早石炭世裂谷型的沉积-火山岩组合及伸展背景的花岗岩可能反映此次碰撞造山事件后的板内伸展。

晚石炭世晚期构造环境进一步发生变化，所沉积的二道沟组(C_2e)陆相粗碎屑-双峰式火山岩建造反映整个构造环境转化为后造山伸展(图11b)。

综上所述，研究区及邻近区域构造体制在石炭纪发生了多次转换，并在空间上呈现受不同构造体制控制下的分异。

5 结 论

(1)在研究区内首次发现下志留统大柳沟组(S_1d)与奥陶系庙尔沟组($O_{2-3}m$)呈角度不整合接触关系。庙尔沟组中广泛发育近南北向构造，而上覆的大柳沟组中发育后碰撞伸展背景的火山岩。这一角度不整合的确定说明奥陶纪与志留纪之交存在近东西向挤压应力以及构造背景的转换，结合区域不整合面的位置以及生物古地理，笔者推断该事件很可能与阿尔曼太洋的闭合有关。

(2)志留—泥盆系地层资料的重新界定揭示东准噶尔与北天山东段(吐哈地块)之间的构造-地层界线为莫钦乌拉山断裂，而非前人所定的巴里坤盆缘断裂，莫钦乌拉山断裂为卡拉麦里缝合带向南东的延伸，具有明显的区域性构造单元分割意义。这一阶段总体构造古地理格局呈现为南侧属吐哈地块北部被动陆缘，北侧发育活动陆缘岛弧带，卡拉麦里洋盆为向北的单向俯冲。

(3)泥盆—石炭纪的沉积地层系列及岩浆记录揭示石炭纪区域构造体制发生多次转换。其中泥盆纪与石炭纪之交，响应卡拉麦里—莫钦乌拉山洋盆的闭合，吐哈地块北侧被动陆缘与北部活动陆缘碰撞，莫钦乌拉缝合带南部靠南侧的被动陆缘受阻弯曲隆起，形成泥盆系与石炭系之间平行不整合接触关系，而向北邻近莫钦乌拉缝合带则由于缝合带北部造山隆起而形成周缘前陆盆地。晚石炭世进一步的汇集挤压则引起早石炭—晚石炭世早期地层的广泛褶皱-冲断变形。这一构造变形事件奠定了研究区乃至整个东准噶尔—北天山东段的北西-南东向基本构造格架，也导致对研究区奥陶系近南北向构造的横跨叠加。晚石炭世中晚期构造环境再次发生转化，响应后碰撞伸展发育陆相磨拉石-伸展裂谷型双峰式火山岩建造，并形成其与下伏地层之间的角度不整合关系。

致谢:感谢中国地质调查局授予本文涉及的1∶5万板房沟幅“特优图幅”荣誉称号！感谢项目组全体师生在填图工作中的辛勤付出！

References

Bai Jianke, Chen Juanlu, Tang Zhuo, Zhang Yue. 2018a. The closure time of Junggar Paleozoic oceanic basin: Evidence from Carboniferous detrital zircon U- Pb geochronology in Kalamaili area[J]. Geological Bulletin of China, 37(1): 26- 38 (in Chinese with English abstract).

Bai Jianke, Chen Juanlu, Zhu Xiaohui, Feng Bo.2018b. Provenance characteristics of Kalamaili Formation in northeastern margin of Junggar Basin: Constraints of geochemistry and detrital zircon U-Pb geochronology[J]. Earth Science, 43(12): 4411- 4426(in Chinese with English abstract).

Batchelor R A, Bowden P. 1985. Petrogenetic interpretation of granitoid rock series using multicationic parameters[J]. Chemical Geology, 48(1/4): 43−55.

Buslov M M, Saphonova I Y, Watanabe T, Obut O T, Fujiwara Y, Iwata K, Semakov N N, Sugai Y, Smirnova L V, Kazansky A Y. 2001. Evolution of the Paleo−Asian Ocean (Altai−Sayan Region, Central Asia) and collision of possible Gondwana- derived terranes with the southern marginal part of the Siberian continent[J]. Geosciences Journal, 5(3): 203−224.

Cai Tuci. 1989. Late Silurian Strata and Tetracoralla in the Barkol region of Xinjiang[J]. Xinjiang Geology, 7(1): 67−80 (in Chinese with English abstract)..

Cai Tuci. 1991. Tetracoralla of Early−Middle Devonian epoch in the Barkol region of Xinjiang[J]. Xinjiang Geology, 9(2): 138−150 (in Chinese with English abstract).

Cai Tuci, Zhu Qingliang, Sun Qiaoli, He Weidong, Han Xiaoming, Zhang Jiandong, Du Tianxing, Li Jie, Mei Shaowu, Zhang Yuqian, Miao Chanquan, Zhang Yuting, Wang Futang, Du Qing, Qiao Xindong. 1999. Stratigraphy (Lithostratic) of Xinjiang Uygur Autonomous Region[M]. China University of Geosciences Press, Wuhan, 1−430 (in Chinese).

Cai Xiongfei, Fan Guangming, Liao Qun'an, Wang Fuming, Wu Liyun. 2015. Evolution of the Tuvaella fauna in the Silurian Baishanbao Formation of Dongzhun, Xinjiang and its relationship with environment and construction[J]. Acta Palaeontologica Sinica, 54 (3): 369−380 (in Chinese with English abstract).

Cai Xiongfei, Huang Xing, Liao Qun'An, Luo Zhongjie, Fan Guangming. 2018. Discussions on the Final Closure of Karamaili Suture Zone: Constraints from Strata Records of Silurian, Devonian and Early Carboniferous in Karamaili Stratigraphic Minor Region[J]. Geological Review, 64(3): 521−542 (in Chinese with English abstract)

Carey S, Sigurdsson H. 1984. A model of volcanogenic sedimentation in marginal basins[J]. Geological Society London Special Publications, 16: 37−58.

Chen Xijie, Shu Liangshu, Santosh M, Zhao Xixi. 2013. Island arc−type bimodal magmatism in the eastern Tianshan Belt, Northwest China:Geochemistry, zircon U−Pb geochronology and implications for the Paleozoic crustal evolution in Central Asia[J]. Lithos, 168: 48−66.

Chen Xijie, Shu Liangshu, Santosh M, Xu Zhiqin. 2014. The provenance and tectonic affinity of the Paleozoic meta−sedimentary rocks in the Chinese Tianshan belt: New insights from detrital zircon U−Pb geochronology and Hf−isotope analysis[J]. Journal of Asian Earth Sciences, 94: 12−27.

Du Long, Long Xiaoping, Yuan Chao, Zhang Yunying, Huang Zongying, Sun Min, Zhao Guochun, Xiao Wenjiao. 2018. Early Paleozoic dioritic and granitic plutons in the Eastern Tianshan Orogenic Belt, NW China: Constraints on the initiation of a magmatic arc in the southern Central Asian Orogenic Belt[J]. Journal of Asian Earth Sciences, 153: 139−153.

Fan Tingting, Zhou Xiaohu, Gao Jie, Zhao Weibo. 2014. U−Pb Zircon ages of the gabbro in Hongliuxia area of the eastern Junggar and its geological implications[J]. Journal of Xi'an University of Science and Technology, 34(6): 707−712 (in Chinese with English abstract).

Feng Xiaoqiang, Cui Yubao, Cheng Long, Liu Yumei, Yu Jing. 2016. LA−ICP−MS zircon U−Pb age of gabbro from Aermantai ophiolite in east Junggar, Xinjiang, and its geological significance[J]. Geological Bulletin of China, 35(9): 1411−1419 (in Chinese with English abstract).

Galewsky J, Silver E A. 1997. Tectonic controls on facies transitions in an oblique collision: The Western Solomon Sea, Papua New Guinea[J]. Geological Society of America Bulletin, 109: 1266−1278.

Gillespie J, Glorie S, Jepson G, Zhang Z Y, Xiao W J, Danišík M, Collins A S. 2017. Differential exhumation and crustal tilting in the easternmost Tianshan (Xinjiang, China), revealed by low−temperature thermochronology[J]. Tectonics, 36(10): 2142−2158.

Han Yigui, Zhao Guochun. 2018. Final amalgamation of the Tianshan and Junggar orogenic collage in the southwestern Central Asian Orogenic Belt: Constraints on the closure of the Paleo− Asian Ocean[J]. Earth−Science Reviews, 186: 129−152.

Hou Tong, Zhang Zhaochong, Santosh M, Encarnacion John, Zhu Jiang, Luo Wenjuan. 2014. Geochronology and geochemistry of submarine volcanic rocks in the Yamansu iron deposit, Eastern Tianshan Mountains, NW China: Constraints on the metallogenesis[J]. Ore Geology Reviews, 56: 487−502.

Hu Chaobin, Liao Qun'an, Fan Guangming, Chen Shuai, Wu Weiwei, Tian Jian, Wang Fuming. 2014. Discovery of MOR− type ophiolites from the Dishuiquan region, eastern Junggar[J]. China Science Bulletin, 59(22): 2213− 2224 (in Chinese with English abstract).

Huang Bo, Fu Dong, Kusky T M, Ruan Kunpeng, Zhou Wenxiao, Zhang Xionghua. 2018. Sedimentary provenance in response to Carboniferous arc− basin evolution of East Junggar and North Tianshan belts in the southwestern Central Asian Orogenic Belt[J]. Tectonophysics, 722: 324−341.

Huang Gang, Niu Guangzhi, Wang Xinlu, Guo Jun, Yu Feng. 2013. Formation and emplacement age of Karamaili ophiolite: LA−ICP−MS zircon U−Pb age evidence from the diabase and tuff in eastern Junggar, Xinjiang[J]. Geological Bulletin of China, 31(8): 1267−1278 (in Chinese with English abstract).

Jahn B M, Wu Fuyuan, Hong Dawei. 2000. Important crustal growth in the Phanerozoic: Isotopic evidence of granitoids from east−central Asia[J]. Journal of Earth System Science, 109(1): 5−20.

Jahn B M, Windley B F, Natal'In B, Dobretsov N. 2004. Phanerozoic continental growth in central Asia − Preface[J]. Journal of Asian Earth Sciences. 23(5): 599−603.

Jiang Hongjun, Han Jinsheng, Chen Huayong, Zheng Yi, Lu Wanjian, Deng Gang, Tan Zhixiong. 2017. Intra−continental back−arc basin inversion and Late Carboniferous magmatism in Eastern Tianshan, NW China: Constraints from the Shaquanzi magmatic suite[J]. Geoscience Frontiers, 8(6): 1447−1467.

Jiang Yuxiang, Li Wenliang, Wang Zhe, Feng Jun. 2019. Geochemical characteristic and age characteristics and geological significance of ophiolite in the Kushui ophiolite mélange belt, Hami area[J]. Mineral Exploration, 10(3): 445− 452 (in Chinese with English abstract).

Li Di, He Dengfa, Santosh M, Tang Jieyun. 2014. Petrogenesis of Late

Paleozoic volcanics from the Zhaheba depression, East Junggar: insights into collisional event in an accretionary orogen of Central Asia[J]. Lithos, 184: 167−193.

Li Jinyi. 2004. Late Neoproterozoic and Paleozoic Tectonic Framework and Evolution of Eastern Xinjiang, NW China[J]. Geological Review, 50(3): 304− 322 (in Chinese with English abstract).

Li Jinyi, Xiao Xuchang, Tang Yaoqing, Zhao Min, Feng Yimin, Zhu Baoqing. 1988. Research progress of Paleozoic plate tectonics in Karamaili belt, eastern Junggar of Xinjiang[J]. China Science Bulletin, 3: 762−764 (in Chinese).

Li Jinyi, Xiao Xuchang, Tang Yaoqing, Zhao Min, Zhu Baoqing, Feng Yimin, 1990. Main characteristics of Late Paleozoic plate tectonics in the southern part of East Junggar, Xinjiang[J]. Geological Review, 36(4): 305−316 (in Chinese with English abstract).

Li Jinyi, Xiao Xuchang, Chen Wen. 2000a. Late Ordovician continental basement of the eastern Junggar Basin in Xinjiang, NW China: Evidence from the Laojunmiao metamorphic complex on the northeast basin margin[J]. Regional Geology of China, 19(3): 297−302 (in Chinese with English abstract).

Li Jinyi, Xiao Xuchang, Chen Wen, Zhang Sihong, Li Weidong. 2000b. Late Carboniferous to Late Triassic thermal evolution of the crust of northern Xinjiang, NW China——^{40}Ar− ^{39}Ar dating to Huangcaopo Group in the Kaokesai'ergai Mountain of East Junggar[J]. Acta Geologica Sinica, 74(4): 303− 312 (in Chinese with English abstract).

Li Jinyi, Yang Tiannan, Li Yaping, Zhu Zhixin. 2009. Geological features of the Karamaili faulting belt, eastern Junggar region, Xinjiang, China and its constraints on the reconstruction of Late Paleozoic ocean− continental framework of the Central Asian region[J]. Geological Bulletin of China, 28(12): 1817− 1826 (in Chinese with English abstract).

Li Songling, Dong Furong, Feng Xinchang, Li Wenqian. 1999. REE features of ophiolitic suite of Kelameili−Takezhale−Daheishan[J]. Xinjiang Geology, 17(4): 356−364 (in Chinese with English abstract).

Li Wei, Chen Juanlu, Dong Yunpeng, Xu Xueyi, Li Zhipei, Liu Xiaoming, He Dengfeng. 2016. Early Paleozoic subduction of the Paleo− Asian Ocean: Zircon U− Pb geochronological and geochemical evidence from the Kalatag high−Mg andesites, East Tianshan [J]. Acta Petrologica Sinica, 32(2): 505−521 (in Chinese with English abstract).

Li Wenqian, Ma Huadong, Wang Ran, Wang He, Xia Bin. 2008. SHRIMP dating and Nd− Sr isotopic tracing of Kangguertage ophiolite in eastern Tianshan, Xinjiang[J]. Acta Petrologica Sinica, 24(4): 773−780 (in Chinese with English abstract).

Li Yongjun, Du Zhigang, Hu Keliang, Li Xinguang, Liu Jing, Zhang Hongrui. 2008. On Disintegration of Qi' eshan Group and Its Definition of Lithostratigraphic Units from Kumutag Sand−Ridge Area in the Eastern Tianshan[J]. Earth Science, 33(4): 458−464 (in Chinese with English abstract).

Liang Pei, Chen Huayong, Hollings Pete, Wu Chao, Xiao Bing, Bao Zhiwei, Xu Deru. 2016. Geochronology and geochemistry of igneous rocks from the Laoshankou district, north Xinjiang: Implications for the late Paleozoic tectonic evolution and metallogenesis of east Junggar[J]. Lithos, 266: 115−132.

Liu Xijun, Xiao Wenjiao, Xu Jifeng, Castillo P, Shi Yu. 2017. Geochemical signature and rock associations of ocean ridge−subduction: Evidence from the Karamaili Paleo−Asian ophiolite in East Junggar, NW China[J]. Gondwana Research, 48: 34−49.

Liu Yaran, Jian Ping, Zhang Wei, Shi Yuruo, Wang Yizhao, Zhang Luqiao, Liu Dunyi. 2016. Zircon SHRIMP U− Pb dating and O isotope of the Beitashan ophiolitic mélange in the East Junggar, Xinjiang, and its geological significance[J]. Acta Petrologica Sinica, 32(2): 537−554 (in Chinese with English abstract).

Long Xiaoping, Yuan Chao, Sun Min, Safonova I, Xiao Wenjiao, Wang Yujing. 2012. Geochemistry and U−Pb detrital zircon dating of Paleozoic graywackes in East Junggar, NW China: insights into subduction− accretion processes in the southern Central Asian Orogenic Belt[J]. Gondwana Research, 21(2/3): 637−653.

Luo Jun, Xiao Wenjiao, Wakabayashi J, Han Chunming, Zhang Ji'en, Wan Bo, Ao Songjian, Zhang Zhiyong, Tian Zhonghua, Song Dongfang, Chen Yichao. 2017. The Zhaheba ophiolite complex in Eastern Junggar (NW China): long lived supra− subduction zone ocean crust formation and its implications for the tectonic evolution in southern Altaids[J]. Gondwana Research, 43: 17−40.

Luo Ting, Liao Qun'an, Zhang Xionghua, Chen Jiping, Wang Guocan, Huang Xing. 2015. Geochronology and geochemistry of Carboniferous metabasalts in eastern Tianshan, Central Asia: Evidence of a back−arc basin[J]. International Geology Review, 58 (6): 756−772.

Luo Ting, Liao Qun'an, Chen Jiping, Hu Chaobin, Wang Fuming, Chen Shuai, Wu Weiwei, Tian Jian, Fan Guangming. 2017. A record of post− collisional transition: evidence from geochronology and geochemistry of Palaeozoic volcanic rocks in the eastern Junggar, Central Asia[J]. International Geology Review, 59(10): 1256−1275.

Luo Ting, Chen Jiping, Liao Qun'an, Wang Guocan, Hu Chaobin, Wang Liangyu. 2018. Geochronology, geochemistry and geological significance of the Late Carboniferous bimodal volcanic rocks in the Balikun area, eastern Tianshan[J]. Earth Science, 43(9): 3018−3035 (in Chinese with English abstract).

Luo Ting, Chen Jiping, Liao Qun'an, Wang Guocan, Zhang Xionghua, Liu Shehu, Zhang Sui'an, Kang Qinqin. 2019. A back−arc basin in eastern Tianshan, central Asia: evidence from geochronology and geochemistry of Carboniferous basalts[J], Earth Science, in press (in Chinese with English abstract). https://doi: 10.3799/dqkx.2018.325

Ma Jiachang. 1999. Study on the Huangcaopo Group in the eastern Junggar[J]. Journal of Mineralogy and Petrology, 19(4): 52−55 (in Chinese with English abstract).

Ma Ruishi, Shu Liangshu, Sun Jiaqi. 1997. Tectonic Evolution and

Metallogeny of Eastern Tianshan Mountains[M]. Beijing, Geological Publishing House, 1−202 (in Chinese).

Martins−Neto M A, Catuneanu O. 2010. Rift sequence stratigraphy[J]. Marine and Petroleum Geology, 27(1): 247−253.

Mao Qigui, Yu Mingjie, Xiao Wenjiao, Windley B F, Li Yuechen, Wei Xiaofeng, Zhu Jiangjian, Lü Xiaoqiang. 2018. Skarn−mineralized porphyry adakites in the Harlik arc at Kalatage, E. Tianshan (NW China): Slab melting in the Devonian−Early Carboniferous in the southern Central Asian Orogenic Belt[J]. Journal of Asian Earth Sciences, 153: 365−378.

Pearce J A, Norry M J. 1979. Petrogenetic implication of Ti, Zr, Y and Nb variations in volcanic rocks[J]. Contributions to Mineralogy and Petrology, 69(1): 33−47.

Pearce J A, Harris N B W, Tindle A G. 1984. Trace element discrimination diagrams for the tectonic interpretation of granitic rocks[J]. Journal of petrology, 25(4): 956−983.

Peng Dong, Xu Shenglan, Lin Li, Peng Bo, Wang Xianfeng, Xie Yunxi. 2008. Redefinition of Caledonian and Hercynian regional metamorphism in the Baihaba− Chonghu'er district, northwestern Altay, Xinjiang[J]. Geology in China, 35(4): 628−638 (in Chinese with English abstract).

Pfiffner O A. 1986. Evolution of the north Alpine foreland basin in the Central Alps[J]. Foreland basins, 8: 219−228.

Qin Biao, Zhang Xiaolin, Fan Wenjun. 2012. Characteristics of Aletunkunduo ophiolitic melanges in Yiwu county, Xinjiang[J]. Xinjiang Geology, 30(2): 152− 156 (in Chinese with English abstract).

Şengör A M C, Natal'in B A, Sunal G, van der Voo R. 2018. The tectonics of the Altaids: crustal growth during the construction of the continental lithosphere of Central Asia between− 750 and− 130 Ma ago[J]. Annual Review of Earth and Planetary Sciences, 46: 439−494.

She Jianzhong, Yang Wanzhi, Qu Xun, Jia Jian, Di Xiaochen. 2017. Geochemistry and zircon U−Pb dating of the Dacaotanbei mafic−ultramafic complex, eastern Tianshan, and its geological significance[J]. Bulletin of Mineralogy, Petrology and Geochemistry, 36(1): 82−91 (in Chinese with English abstract).

Sinclair H D. 1997. Flysch to molasse transition in peripheral foreland basins: The role of the passive margin versus[J]. Geology, 25(12): 1123−1126.

Shu Liangshu, Wang Yujing. 2003. Late Devonian− Early Carboniferous radiolarian fossils from siliceous rocks of the Kelameili ophiolite, Xinjiang[J]. Geological Review, 49(4): 408−412 (in Chinese with English abstract).

Song Peng, Wang Tao, Tong Ying, Zhang Jianjun, Huang He, Qin Qie. 2019. Contrasting deep crustal compositions between the Altai and East Junggar orogens, SW Central Asian Orogenic Belt: Evidence from zircon Hf isotopic mapping[J]. Lithos, 328−329: 297−311.

Su Yangzheng. 1981. On the geological and geographical distribution of Tuvaella with reference to its habitat[J]. Acta Palaeontologica Sinica, 20(6): 567−576 (in Chinese with English abstract).

Su Yuping, Zheng Jianping, Griffin W, Zhao Junhong, Tang Huayun, Ma Qiang, Lin Xiangyang. 2012. Geochemistry and Geochronology of Carboniferous Volcanic Rocks in the Eastern Junggar Terrane, NW China: Implication for a Tectonic Transition[J]. Gondwana Research, 22: 1009−1029.

Sun Guihua, Li Jinyi, Yang Tiannan, Wang Yu, Gao Liming, Hao Sufeng. 2006. Permian post− collisional NS− compression deformation in Thanshan orogen: example from Komenzi ductile shear zone of thrusting−type in northern slope of Harlik mountains [J]. Acta Petrologica Sinica, 22(5): 1359− 1368 (in Chinese with English abstract).

Sun Yan, Wang Jingbin, Wang Yuwang, Long Lingli, Mao Qigui, Yu Mingjie. 2019. Ages and origins of granitoids from the Kalatag Cu cluster in Eastern Tianshan, NW China: Constraints on Ordovician−Devonian arc evolution and porphyry Cu fertility in the Southern Central Asian orogenic belt[J]. Lithos, 330−331: 55−73.

Tang Wenhao, Zhang Zhicheng, Li Jianfeng, Li Ke, Chen Yan, Guo Zhaojie. 2014. Late Paleozoic to Jurassic tectonic evolution of the Bogda area (northwest China): evidence from detrital zircon U−Pb geochronology[J]. Tectonophysics, 626: 144−156.

Tian Jian, Liao Qun'an, Fan Guangming, Nie Xiaomei, Wang Fuming. 2015. The discovery and tectonic implication of Early Carboniferous post−collisional I−type granites from the south of Karamaili in eastern Junngar[J]. Acta Petrologica Sinica, 31(5): 1471−1484 (in Chinese with English abstract).

Wali G, Wang Bo, Cluzel D, Zhong Linglin. 2018. Carboniferous−Early Permian magmatic evolution of the Bogda Range (Xinjiang, NW China): Implications for the Late Paleozoic accretionary tectonics of the SW Central Asian Orogenic Belt[J]. Journal of Asian Earth Sciences, 153: 238−251.

Wang Baoyu. 1983. Lower Devonian Pseudofavosites in northern Xinjiang[J]. Acta Palaeontologica Sinica, 11(6): 701− 705 (in Chinese with English abstract).

Wang Liangyu, Liao Qun'an, Xiao Dian, Luo Ting, Zhao Hao, Liu Hongfei, Wang Guocan. 2016. Petrogenesis and tectonic significance of Early Carboniferous A− type granite in Harlik, Xinjiang[J]. Journal of Geomechanics, 22(4): 1032−1048 (in Chinese with English abstract).

Wang Yuwang, Wang Jingbin, Wang Lijuan, Long Lingli, Tang Pingzhi, Liao Zhen, Zhang Huiqiong, Shi Yu. 2012. The Tuerkubantao ophiolite mélange in Xinjiang, NW China: New evidence for the Erqis suture zone[J]. Geoscience Frontiers, 3(5): 587−602.

Wang Zhihong, Sun Shu, Li Jiliang, Hou Quanlin, Qin Kezhang, Xiao Wenjiao. 2003. Paleozoic tectonic evolution of the northern Xinjiang, China: Geochemical and geochronological constraints from the ophiolites[J]. Tectonics, 22(2): 1014.

Wang Zongxiu, Li Tao, Zhang Jin, Liu Yongqing, Ma Zongjin. 2008. The uplift progresses of the Bogda Mountain and its signifcance [J]. Science China (Series D), 38(3): 312− 326 (in Chinese with English abstract).

Windley B F, Alexeiev D, Xiao Wenjiao, Kröner A, Badarch G. 2007. Tectonic models for accretion of the Central Asian Orogenic Belt[J]. Journal of the Geological Society, 164(1): 31−47.

Wu Bo, He Guoqi, Wu Tairan, Li Huijun, Luo Hongling. 2006. Discovery of the Buergen ophiolitic mélange belt in Xinjiang and its tectonic significance[J]. Geology in China, 33(3): 476−486 (in Chinese with English abstract).

Wu Xiaoqi, Liu Deliang, Li Zhensheng. 2009. Post− collisional volcanism of Kalamaili suture zone[J]. Earth Science Frontiers, 16 (3): 220−230.

Xia Linqi, Xu Xueyi, Xia Zuchun, Li Xiangmin, Ma Zhongpin, Wang Lishe. 2004. Petrogenesis of Carboniferous rift− related volcanic rocks in the Tianshan, northwestern China[J]. Geological Society of America Bulletin, 116(3/4): 419−433.

Xia Linqi, Xu Xueyi, Li Xiangmin, Ma Zhongping, Xia Zuchun. 2012. Reassessment of petrogenesis of Carboniferous− Early Permian rift− related volcanic rocks in the Chinese Tianshan and its neighboring areas[J]. Geoscience Frontiers, 3(4): 445−471.

Xiao Dian, Liao Qun'an, Wang Liangyu, Zhao Hao, Cha Yanhong, Zhao Hongwei, Yin Tingwang, Tian Jinming, Liu Hongfei. 2016. Petrogenesis and tectonic implications of two types Early Silurian granites in east Junggar[J]. Journal of Geomechanics, 22(4): 1049−1061 (in Chinese with English abstract).

Xiao Wenjiao, Windley B F, Badarch G, Sun Shu, Li Jiliang, Qin Kezhang, Wang Zhihong. 2004a. Palaeozoic accretionary and convergent tectonics of the southern Altaids: Implications for the growth of Central Asia[J]. Journal of the Geological Society, 161 (3): 339−342.

Xiao Wenjiao, Zhang Lianchang, Qin Kezhang, Sun Shu, Li Jiliang. 2004b. Paleozoic accretionary and collisional tectonics of the Eastern Tianshan (China): implications for the continental growth of central Asia[J]. American Journal of Science, 304(4): 370−395.

Xiao Wenjiao, BF Windley, Yan Quanren, Qin Kezhang, Chen Hanlin, Yuan Chao, Sun Min, Li Jiliang, Sun Shu. 2006. SHRIMP zircon age of the Aermantai ophiolite in the North Xinjiang area, China and its tectonic implications[J]. Acta Geologica Sinica, 80(1): 32−37 (in Chinese with English abstract).

Xiao Wenjiao, Han Chunming, Yuan Chao, Sun Min, Lin Shoufa, Chen Hanlin, Li Zilong, Li Jiliang, Sun Shu. 2008. Middle Cambrian to Permian subduction− related accretionary orogenesis of Northern Xinjiang, NW China: implications for the tectonic evolution of central Asia[J]. Journal of Asian Earth Sciences, 32(2/4): 102−117.

Xiao Wenjiao, Han Chunming, Liu Wei, Wan Bo, Zhang Ji'en, Ao Songjian, Zhang Zhiyong, Song Dongfang, Tian Zhonghua, Luo Jun. 2014. How many sutures in the southern Central Asian orogenic belt: Insights from east Xinjiang− west Gansu (NW China)?[J]. Geoscience Frontiers, 5(4): 525−536.

Xiong Shuangcai, Zhang Zhengfeng, Li Guang, Liu Runze, Hua Xudeng, Zhao Fuzhuang, Zhou Pengfei, Li Guanlu. 2019. Zircon U− Pb Dating, Geochemical characteristics of alkali− granites in Laoyemiao area, eastern Junggar, and geological significance[J]. Geological Review, 65(1): 221− 231 (in Chinese with English abstract).

Xu Jifeng, Castillo P, Chen Fanrong, Niu Hecai, Yu Xueyuan, Zhen Zuoping. 2003. Geochemistry of late Paleozoic mafic igneous rocks from the Kuerti area, Xinjiang, northwest China: implications for backarc mantle evolution[J]. Chemical Geology, 193(1/2): 137−154.

Xu Xingwang, Jiang Neng, Li Xianhua, Qu Xun, Yang Yueheng, Mao Qian, Wu Qi, Zhang Yong, Dong Lianhui. 2013. Tectonic evolution of the East Junggar terrane: Evidence from the Taheir tectonic window, Xinjiang, China[J]. Gondwana Research, 24(2): 578−600.

Xu Xingwang, Li Xianhua, Jiang Neng, Li Qiuli, Qu Xun, Yang Yueheng, Zhou Gang, Dong Lianhui. 2015a. Basement nature and origin of the Junggar terrane: New zircon U− Pb− Hf isotope evidence from Paleozoic rocks and their enclaves[J]. Gondwana Research, 28(1): 288−310.

Xu Xingwang, Jiang Neng, Li Xianhua, Wu Chu, Qu Xun, Zhou Gang, Dong Lianhui. 2015b. Spatial−temporal framework for the closure of the Junggar Ocean in central Asia: New SIMS zircon U−Pb ages of the ophiolitic mélange and collisional igneous rocks in the Zhifang area, East Junggar[J]. Journal of Asian Earth Sciences, 111: 470−491.

Yan Zhen, Wang Zongqi, Yan Quanren, Fang Aimin, Chen Juanlu. 2018. Identification and reconstruction of tectonic archetype of the sedimentary basin within the orogenic belt developed along convergent margin[J]. Acta Petrologica Sinica, 34(7): 1943− 1958 (in Chinese with English abstract).

Yang Gaoxue, Li Yongjun, Wu Hong'en, Si Guohui, Jin Chao, Zhang Yongzhi. 2009. LA− ICP− MS zircon U− Pb dating of the Huangyangshan pluton and its enclaves from Kalamaili area eastern Junggar, Xinjiang, and geological implications[J]. Acta Petrologica Sinica, 25(12): 3197− 3207 (in Chinese with English abstract).

Yuan Chao, Sun Min, Wilde S, Xiao Wenjiao, Xu Yigang, Long Xiaoping, Zhao Guochun. 2010. Post− collisional plutons in the Balikun area, East Chinese Tianshan: evolving magmatism in response to extension and slab break−off[J]. Lithos, 119(3/4): 269−288.

Zhang Jianjun, Wang Tao, Tong Ying, Zhang Zhaochong, Song Peng, Zhang Lei, Huang He, Guo Lei, Hou Zengqian. 2017. Tracking deep ancient crustal components by xenocrystic/inherited zircons of Palaeozoic felsic igneous rocks from the Altai− East Junggar terrane and adjacent regions, western Central Asian Orogenic Belt and its tectonic significance[J]. International Geology Review, 59 (16): 2021−2040.

Zhang Meng, Zheng Fei, Nan Lingling, Zhang Xionghua, Huang Xing, Jin Suosuo. 2018. Early Devonian coral fauna from Hami area of

Xinjiang and their geological significance[J]. Geological Bulletin of China, 37(10): 1789−1797 (in Chinese with English abstract).

Zhang Xionghua, Huang Xing, Chen Jiping, Liao Qun'an, Duan Xianfeng. 2012. Stratigraphical sequence of Carboniferous marine volcanic− deposit rock and its geological age in Jueluotage area, eastern Tianshan[J]. Earth Science, 37(6): 1305−1314 (in Chinese with English abstract).

Zhang Yuanyuan, Guo Zhaojie. 2010. New constraints on formation ages of ophiolites in northern Junggar and comparative study on their connection[J]. Acta Petrologica Sinica, 26(2): 421−430 (in Chinese with English abstract).

Zhang Yuanyuan, Pe−Piper G, Piper D J W, Guo Zhaojie. 2013. Early Carboniferous collision of the Kalamaili orogenic belt, North Xinjiang, and its implications: Evidence from molasse deposits[J]. Geological Society of America Bulletin, 125(5/6): 932−944.

Zhang Yuanyuan, Guo Zhaojie, Pe− Piper G, Piper D J W. 2015. Geochemistry and petrogenesis of Early Carboniferous volcanic rocks in East Junggar, North Xinjiang: Implications for post−collisional magmatism and geodynamic process[J]. Gondwana Research, 28(4): 1466−1481.

Zhang Yunying, Yuan Chao, Long Xiaoping, Sun Min, Huang Zongying, Du Long, Wang Xinyu. 2017. Carboniferous bimodal volcanic rocks in the Eastern Tianshan, NW China: Evidence for arc rifting[J]. Gondwana Research, 43: 92−106.

Zhang Yunying, Sun Min, Yuan Chao, Long Xiaoping, Jiang Yingde, Li Pengfei, Huang Zongying, Du Long. 2018. Alternating trench advance and retreat: Insights from Paleozoic magmatism in the eastern Tianshan, Central Asian Orogenic Belt[J]. Tectonics, 37(7): 2142−2164.

Zhang Zhaochong, Zhou Gang, Kusky T M, Yan Shenghao, Chen Bailin, Zhao Li. 2009. Late Paleozoic volcanic record of the Eastern Junggar terrane, Xinjiang, Northwestern China: major and trace element characteristics, Sr− Nd isotopic systematics and implications for tectonic evolution[J]. Gondwana Research, 16(2): 201−215.

Zhang Zixin, Rong Jiayu, Di Qiaoling. 1983. Silurian Tuvaella gigantea faunule (Brachiopoda) of the Barkol area, northeastern Xinjiang[J]. Acta Palaeontologica Sinica, 22(3): 278−294 (in Chinese with English abstract).

Zhou Jianbo, Wilde S, Zhao Guochun, Han Jie. 2018. Nature and assembly of microcontinental blocks within the Paleo− Asian Ocean[J]. Earth−science Reviews, 186: 76−93.

Zhao Hao, Liao Qun'an, Luo Ting, Tian Jinming, Zhang Meng, Wang Liangyu, Liu Hongfei. 2018a. Geochemistry and geological implications of two sets of Devonian volcanic rocks in south margin of East Junggar[J]. Earth Science, 43(2): 371− 388 (in Chinese with English abstract).

Zhao Hao, Liao Qun'an, Xiao Dian, Luo Ting, Wang Liangyu, Yin Tingwang, Liu Hongfei. 2018b. Discovery of the Early Silurian alkali basalt and its geological implications in northeastern Junggar, NW China [J]. Acta Petrologica Sinica, 34(3): 586− 600 (in Chinese with English abstract).

Zhu Yanfei, Mu Hetaer · zhari, Zhao Tongyang, Han Qiong, Zheng Jiaxing. 2018. Zircon U−Pb age and geochemical characteristics of Ordovician volcanic rocks from Kanasi area in Western Altay Mountains, Xinjiang[J]. Geology in China, 45(3): 469− 482 (in Chinese with English abstract).

Zhu Wenbin, Shu Liangshu, Sun Yan, Wang Feng, Zhao Zhongyan, Pushparani D, Verma S. 2006. Mesozoic−Cenozoic deformation of the central structure belt in the Turpan− Hami Basin, northwest China: tectonic evolution of an intracontinental basin, central Asia[J]. International Geology Review, 48(3): 271−285.

Zhu Zhixin, Li Shaozhen, Li Songling. 2005. The characteristics of sedimentary system− continental facies volcano in Later Carboniferous Batamayi Group, Zhifang region, East Junggar[J]. Xinjiang Geology, 23(1): 14−18 (in Chinese with English abstract).

附中文参考文献

白建科, 陈隽璐, 唐卓, 张越. 2018a. 新疆准噶尔古生代洋盆闭合时限——来自卡拉麦里地区石炭纪碎屑锆石U−Pb年代学的约束[J]. 地质通报, 37(1): 26−38.

白建科, 陈隽璐, 朱小辉, 冯博. 2018b. 准噶尔盆地东北缘卡拉麦里组物源区特征:碎屑岩地球化学及锆石U−Pb年代学的制约[J]. 地球科学(中国地质大学学报), 43(12):147−162.

蔡土赐. 1989. 新疆巴里坤地区晚志留世地层及四射珊瑚[J]. 新疆地质, 7(1): 67−80.

蔡土赐. 1991. 新疆巴里坤地区早—中泥盆世四射珊瑚[J]. 新疆地质, 9(2): 138−150.

蔡土赐, 朱庆亮, 孙巧缡, 贺卫东, 韩小明, 张建东, 杜天星, 李洁, 梅绍武, 张玉谦, 缪长泉, 张玉亭, 王福堂, 杜青, 乔新东. 1999. 全国地层多重划分对比研究——新疆维吾尔自治区岩石地层[M]. 武汉: 中国地质大学出版社,1−430.

蔡雄飞, 樊光明, 廖群安, 王富明, 吴丽云. 2015. 新疆东准志留系白山包组图瓦贝动物群演化特征及与环境, 构造的关系[J]. 古生物学报, 54(3): 369−380.

蔡雄飞, 黄兴, 廖群安, 罗中杰, 樊光明. 2018. 新疆卡拉麦里碰撞带闭合时间的讨论——来自卡拉麦里小区志留、泥盆系、下石炭统地层约束的报告[J]. 地质论评, 64(3): 521−542.

樊婷婷, 周小虎, 高洁, 赵伟波. 2014. 东准噶尔红柳峡辉长岩锆石U−Pb年龄及地质意义[J]. 西安科技大学学报, 34(6): 707−712.

冯晓强, 崔玉宝, 程龙, 刘玉梅, 鱼静. 2016. 新疆东准噶尔阿尔曼泰蛇绿构造混杂岩带中辉长岩LA−ICP−MS锆石U−Pb年龄及其地质意义[J]. 地质通报, 35(9):1411−1419.

胡朝斌, 廖群安, 樊光明, 陈帅, 吴魏伟, 田健, 王富明. 2014. 东准噶尔滴水泉地区发现洋中脊型蛇绿岩[J]. 科学通报, 59(22): 2213−2222.

黄岗, 牛广智, 王新录, 郭俊, 宇峰. 2013. 东准噶尔阿尔曼泰蛇绿混杂带中发现~4.0Ga碎屑锆石[J]. 科学通报, 58(28/29): 2966−2979.

李锦轶. 2004. 新疆东部新元古代晚期和古生代构造格局及其演变[J]. 地质论评, 50(3):304−322.

李锦轶, 肖序常, 汤耀庆, 赵民, 冯益民, 朱宝清. 1988. 新疆东准噶尔卡拉麦里地区古板块构造研究的新进展[J]. 科学通报, 3: 762−764.

李锦轶, 肖序常, 汤耀庆, 赵民, 朱宝清, 冯益民. 1990. 新疆东准噶尔卡拉麦里地区晚古生代板块构造的基本特征[J]. 地质论评, 36(4): 305−316.

李锦轶, 肖序常, 陈文. 2000a. 准噶尔盆地东部的前晚奥陶世陆壳基底——来自盆地东北缘老君庙变质岩的证据[J]. 中国区域地质, 19(3): 297−302.

李锦轶, 肖序常, 陈文, 张思红, 李卫东. 2000b. 新疆北部晚石炭世至晚三叠世地壳热演化——东准噶尔考克塞尔盖山荒草坡群的^{40}Ar−^{39}Ar定年[J]. 地质学报, 74(4): 303−312.

李锦轶, 杨天南, 李亚萍, 朱志新. 2009. 东准噶尔卡拉麦里断裂带的地质特征及其对中亚地区晚古生代洋陆格局重建的约束[J]. 地质通报, 28(12): 1817−1826.

李嵩龄, 冯新昌, 董富荣, 李文铅. 克拉麦里—塔克札勒—大黑山蛇绿岩建造稀土元素特征[J]. 新疆地质, 1999, 17(4): 356−364.

李玮, 陈隽璐, 董云鹏, 徐学义, 李智佩, 柳小明, 何登峰. 2016. 早古生代古亚洲洋俯冲记录:来自东天山卡拉塔格高镁安山岩的年代学、地球化学证据[J]. 岩石学报, 32(2): 505−521.

李文铅, 马华东, 王冉, 王核, 夏斌. 2008. 东天山康古尔塔格蛇绿岩SHRIMP 年龄, Nd−Sr 同位素特征及构造意义[J]. 岩石学报, 24(4): 773−780.

李永军, 杜志刚, 胡克亮, 李新光, 刘静, 张洪瑞. 2008. 东天山库姆塔格沙垄地区企鹅山群的解体及岩石地层单位厘定[J]. 地球科学——中国地质大学学报, 33(4): 32−38.

刘亚然, 简平, 张维, 石玉若, 王义召, 张履桥, 刘敦一. 2016. 新疆东准噶尔北塔山蛇绿混杂岩锆石SHRIMP U−Pb定年、氧同位素及其地质构造意义[J]. 岩石学报, 32(2): 537−554.

蒋宇翔, 李文亮, 王哲, 凤俊. 2019. 哈密苦水蛇绿混杂岩带岩石化学、年代学特征及地质意义[J]. 矿产勘查, 10(3): 445−452.

罗婷, 陈继平, 廖群安, 王国灿, 胡朝斌, 王良玉. 2018. 东天山巴里坤地区晚石炭世双峰式火山岩年代学、地球化学及其构造意义[J]. 地球科学, 43(9): 3018−3035.

罗婷, 陈继平, 廖群安, 王国灿, 张雄华, 刘社虎, 张随安, 康琴琴. 2019. 东天山觉罗塔格构造带石炭纪弧后盆地——来自基性火山岩的证据[J]. 地球科学, 待刊. https:// doi: 10.3799/dqkx.2018.325

马家常. 1999. 东准噶尔地区荒草坡群研究新进展[J]. 矿物岩石, 19(4): 52−55.

马瑞士, 舒良树, 孙家齐. 1997. 东天山构造演化与成矿[M]. 北京: 科学出版社. 152−170.

秦彪, 张小林, 樊文军. 2012. 新疆伊吾阿勒吞昆多蛇绿混杂岩特征[J]. 新疆地质, 30(2): 152−156.

舍建忠, 杨万志, 曲迅, 贾健, 邸晓辰. 2017. 东天山大草滩北镁铁超镁铁岩锆石U−Pb年龄、地球化学特征及其地质意义[J]. 矿物岩石地球化学通报, 36(1): 82−91.

舒良树, 王玉净. 2003. 新疆卡拉麦里蛇绿岩带中硅质岩的放射虫化石[J]. 地质论评, 49(4): 408−412.

苏养正. 1981. 论图瓦贝Tuvaella的时空分布和生态环境[J]. 古生物学报, 20(6): 567−576.

孙桂华, 李锦轶, 杨天南, 王瑜, 高立明, 郝素凤. 2006. 天山造山带二叠纪后碰撞南北向挤压变形:以哈尔里克山北坡口门子逆冲型韧性剪切带为例[J]. 岩石学报, 22(5): 1359−1368.

田健, 廖群安, 樊光明, 聂小妹, 王富明. 2015. 东准噶尔卡拉麦里断裂以南早石炭世后碰撞花岗岩的发现及其地质意义[J]. 岩石学报, 2014, 31(5): 1471−1484.

王宝瑜. 1990. 关于图瓦贝动物群的时代及古地理意义[J]. 科学通报, 35(18): 1413−1415.

王良玉, 廖群安, 肖典, 罗婷, 赵浩, 刘鸿飞, 王国灿. 2016. 新疆哈尔里克早石炭世A型花岗岩的岩石成因及构造意义[J]. 地质力学学报, 22(4): 235−251.

王宗秀, 李涛, 张进, 柳永清, 马宗晋. 2008. 博格达山链新生代抬升过程及意义[J]. 中国科学D辑: 地球科学, 38(3): 312−326.

吴波, 何国琦, 吴泰然, 李会军, 罗红玲. 2006. 新疆布尔根蛇绿混杂岩的发现及其大地构造意义[J]. 中国地质, 33(3): 476−486.

肖典, 廖群安, 王良玉, 赵浩, 查雁鸿, 赵红伟, 尹庭旺, 田锦明, 刘鸿飞. 2016. 准噶尔东部早志留世两类花岗岩的岩石成因及构造意义[J]. 地质力学学报, 22(4): 1049−1061.

肖文交, Windley B F, 阎全人, 秦克章, 陈汉林, 袁超, 孙敏, 李继亮, 孙枢. 2006. 北疆地区阿尔曼太蛇绿岩锆石SHRIMP年龄及其大地构造意义[J]. 地质学报, 80(1): 32−37.

熊双才, 张征峰, 李广, 刘润泽, 华叙登, 赵富庄, 周鹏飞, 李关禄. 2019. 东准噶尔老爷庙地区碱性花岗岩锆石U− Pb定年、地球化学及其地质意义[J]. 地质论评, 65(1): 221−231.

闫臻, 王宗起, 闫全人, 方爱民, 陈隽璐. 2018. 造山带汇聚板块边缘沉积盆地的鉴别与恢复[J]. 岩石学报, 34(7): 87−102.

张孟, 郑飞, 南玲玲, 张雄华, 黄兴, 靳锁锁. 2018. 新疆哈密地区早泥盆世珊瑚动物群及其地质意义[J]. 地质通报, 37(10): 23−31.

张雄华, 黄兴, 陈继平, 廖群安, 段先锋. 2012. 东天山觉罗塔格地区石炭纪火山−沉积岩地层序列及地质时代[J]. 地球科学——中国地质大学学报, 37(6): 1306−1314.

张元元, 郭召杰. 2010. 准噶尔北部蛇绿岩形成时限新证据及其东, 西准噶尔蛇绿岩的对比研究[J]. 岩石学报, 26(2): 421−430.

张梓歆, 戎嘉余, 邸巧玲. 1983. 新疆巴里坤地区志留纪的大型图瓦贝组合[J]. 古生物学报, 22(3): 50−152.

赵浩, 廖群安, 罗婷, 田锦明, 张孟, 王良玉, 刘鸿飞. 2018a. 东准噶尔南缘两套泥盆纪火山岩地球化学特征对比及其地质意义[J]. 地球科学, 43(2): 371−388.

赵浩, 廖群安, 肖典, 罗婷, 王良玉, 尹庭旺, 刘鸿飞. 2018b. 准噶尔地块东北缘志留纪碱性玄武岩的发现及其地质意义[J]. 岩石学报, 34(3): 586−600.

朱志新, 李少贞, 李嵩龄. 2005. 东准噶尔纸房地区晚石炭世巴塔玛依内山组陆相火山−沉积体系特征[J]. 新疆地质, 23(1): 14−18.