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华北克拉通及相邻造山带古生代—侏罗纪早期大地构造演化

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提要：华北克拉通古生代的大地构造演化始于大约520 Ma，此时冈瓦纳古陆的聚合正处于峰期。中寒武世华北克拉通古生代最早的沉积记录始于其边缘的更老地层或者变质基底之上。随后，海相环境扩展，广泛的海侵导致中寒武世晚期馒头组及其上的地层广泛分布于华北克拉通。华北克拉通北部以北的白乃庙岛弧带新的研究结果显示这一岛弧始于520 Ma，并延续到420 Ma，其可以向东延伸到我国东北的四平以东。沿着华北克拉通南部边缘，商丹洋在514~420 Ma期间发生向北的俯冲。华北克拉通的大部分地区在中奥陶世马家沟期发生海退。近10年来在华北克拉通北缘识别出一个又一个泥盆纪深成岩体和火山岩。石炭纪晚期开始的新的沉积层序以"G层"铝土矿为底，其平行不整合，或假整合在中奥陶世马家沟组灰岩之上。铝土矿很可能是从内蒙古古隆起，一个深位剥蚀的岩浆弧，曾经发育的火山喷发活动形成的广布的火山灰转变而来。这进一步说明晚古生代华北克拉通北缘曾经是一个安第斯型活动大陆边缘。这一沉积序列以碎屑岩为主，下部夹海相灰岩和火山灰层，表明其形成于海陆过渡的火山弧环境。二叠纪早期之后华北克拉通的沉积环境转变为陆相。华南地块与南秦岭地块和华北克拉通之间的勉略洋在晚古生代持续向北俯冲增生，三叠纪晚期发生碰撞，导致大别—苏鲁超高压变质带的形成。与此同时，在华北克拉通北部显著的构造变形和岩浆作用发生在三叠纪晚期。燕山地区盘山等地三叠纪晚期的强烈褶皱、冲断发生在约210 Ma，与华北克拉通周缘的强烈构造变形同期。这也暗示华北克拉通此时已经开始失去克拉通的稳定构造性质。

关　键　词：大地构造演化；古生代—侏罗世早期；华北克拉通；中亚造山带；秦岭造山带

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Paleozoic−early Jurassic tectonic evolution of North China Craton and its adjacent orogenic belts

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Abstract: The Early Paleozoic tectonic stage of the North China Craton (NCC) began around 520 Ma, when Gondwana assembled in its peak tectonism. The Middle Cambrian deposition occurred on older strata or basement rocks along margins of the NCC. Then the marine environment expansion and its extensive invasion led to the late Middle Cambrian marine deposition, with the Mantou Formation and afterward strata distributed throughout the NCC. New research results of the Bainaimiao arc belt to the north of northern NCC indicate that the arc was active from 520 Ma and lasted until 420 Ma, which could extend to east Siping in Northeast China. Along the southern edge of the NCC the northward subduction of the Shangdan Ocean took place during ca. 514−420 Ma. Marine regression occurred later than the Majiagou phase in Middle Ordovician in most parts of the NCC. Recently some Devonian plutons and volcanic rocks were recognized in northern NCC. The Late Carboniferous sedimentary sequence with the 'G' layer of bauxites at its bottom overlies the Middle Ordovician limestone in unconformity. The bauxites were derived mainly from ashes produced by volcanism mainly in the Inner Mongolia Paleo− uplift during Paleozoic period, particularly in latest Early Carboniferous to Early Permian when the northern margin of the NCC evolved as an Andean−style active continental margin. The sequence is mainly clastic formations composed of coal−bearing sandstones and siltstones interlayered with marine limestone and volcanic ash, which demonstrates that they formed in a terrestrial−marine transitional or terrestrial environment with volcanic arc settings. After late Early Permian a terrestrial environment was dominant in the NCC. In southern NCC and the Qinling Orogenic Belt spreading of the Mianlue Ocean between the South China Craton and the South Qinling Block was sustained in Late Paleozoic, and the northward subduction−accretion of the Mianlue Ocean was active in Late Paleozoic. In Triassic the collision between the South China Craton and the South Qinling Block along the Mianlue suture resulted in intense shortening and uplift of Qinling Orogenic Belt and HP/UHP metamorphism documented in Hong’an−Dabie−Sulu terranes. Meanwhile in northern NCC significant changes in tectonic deformation and magmatism occurred in Late Triassic. In the Panshan region, Xiabancheng region and Niuyingzhi region of northern NCC, intense regional folding and thrusting took place around 210 Ma or slightly later, suggesting that the NCC entered into its initial decratonization stage.

Key words: tectonics; Paleozoic−Early Jurassic; North China Craton; Central Asian Orogenic Belt; Qinling Orogenic Belt

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1 引 言

华北克拉通是世界上最古老的克拉通之一,其特点是经历了从早前寒武纪以来复杂的演化历史(如:Zhai and Santosh, 2011; Zhao and Zhai, 2013; Zhai, 2014)。进入显生宙,华北克拉通展现了早古生代典型的克拉通演化阶段。中寒武世开始,华北克拉通在长约8亿年的沉积间断后发生了广泛的海侵,记录了其典型的克拉通沉积层序。华北克拉通在早古生代记录的事件似乎众所周知,但其与全球重大构造事件和与相邻造山带的构造事件的关系仍不甚了了。近10年来针对华北克拉通及其邻区的研究进展为认识这些事件的联系奠定了基础。它们是早古生代广泛的海侵和海退,钾盐矿产和金伯利岩的形成,石炭纪的“G层”铝土矿,晚古生代华北克拉通北缘安第斯型活动大陆边缘,华北克拉通,特别是燕山地区和华北北缘三叠纪的构造变形事件等。燕山期的构造发展最晚从中侏罗世初南大岭期火山喷发开始,这是中国东部乃至东亚燕山期构造变形的开始。本文将重点阐述这些进展并讨论这些事件与全球重大构造事件和与相邻造山带的构造事件的关系。

2 早古生代

2.1 华北克拉通内部

在早古生代之前,华北克拉通在约1320 Ma至约515 Ma经历了长达约800 Ma的沉积间断期。在中寒武世冈瓦纳超大陆聚合的峰期后,华北克拉通可能受控于这一事件的地球深部过程,其边缘于中—新元古代地层或变质基底岩系之上开始出现海相沉积地层,包括辽西的建昌组、北京的昌平组、天津的府君山组、河南的李官组/辛集组/朱砂洞组及

陕西的辛集组/朱砂洞组(图1,图2)。之后,馒头期至中奥陶世马家沟期,海相沉积地层的分布范围明显扩大到几乎整个华北克拉通。在马家沟组沉积之后,华北克拉通发生了大规模海退及区域性抬升,古地理面貌发生重大变化,在鄂尔多斯盆地东部还形成了蒸发盐沉积矿产,如钾盐等(张永生等,2015)。这一转变与华北克拉通东部及东北部463~470 Ma含金刚石金伯利岩的时代接近(张宏福和杨岳衡, 2007; Yang et al., 2009)。北京西山南大岭组玄武岩中继承锆石的分析结果显示,在华北克拉通深部可能存在520 Ma及430 Ma至少两期岩浆活动(赵越等, 2006),前已述及520 Ma与冈瓦纳超大陆的聚合峰期一致。而其中430 Ma岩浆活动与古大西洋最终封闭导致波罗的古陆与劳伦古陆碰撞形成劳亚大陆和加里东期造山带的时代一致(Lawver et al., 2011)。因此,华北克拉通早古生代演化的关键节点很可能与其深部过程受控的全球性构造事件有关。然而对这种过程的认识,我们目前还知之甚少。而奥陶纪马家沟期后区域性抬升及沉积地层缺失一直持续到早石炭世末期。

2.2 北缘及中亚造山带南部

作为华北克拉通北缘边界的白云鄂博—多伦—赤峰—开原断裂也是华北克拉通与白乃庙岛弧带的分界线(图3a)。尽管前人认为奥陶纪—志留纪期间华北北缘为活动大陆边缘(如:张允平等, 1986; Wang and Liu, 1986; 胡骁等, 1990; 王荃等, 1991; 唐克东, 1992; Chao et al., 1997; Xiao et al., 2003),但沉积及岩浆记录却显示华北克拉通在早

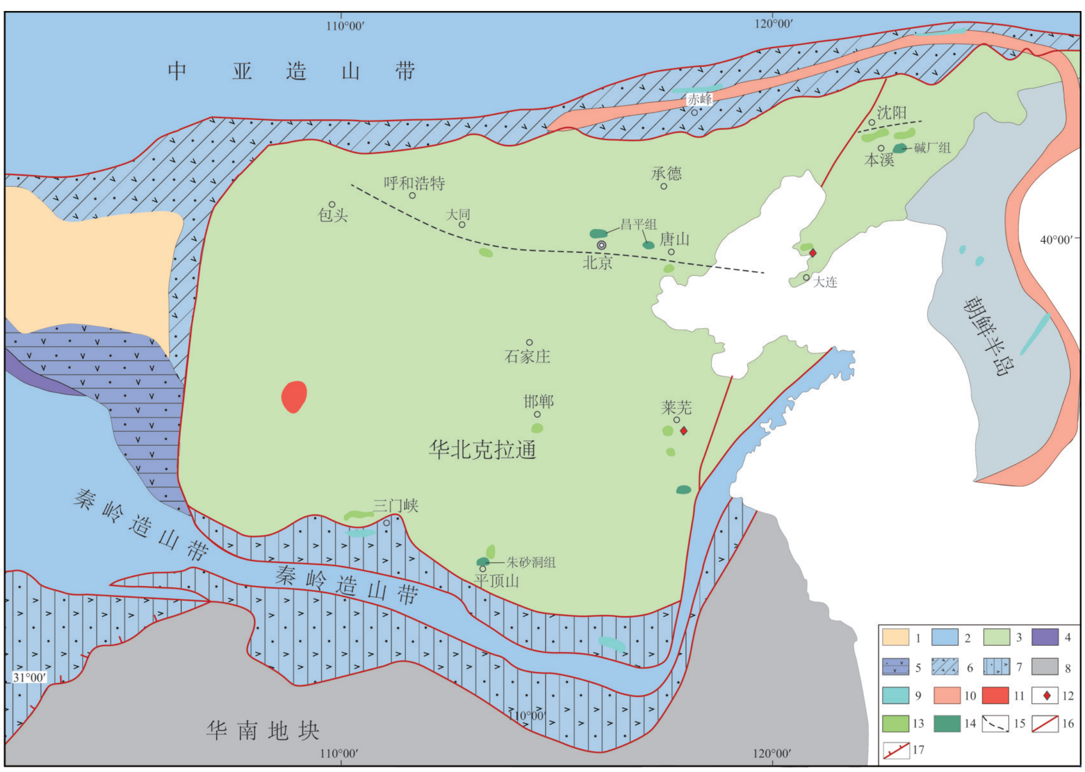

图1 早古生代华北克拉通古地理图(据潘桂棠等,2014年修改)

1—克拉通隆起;2—洋盆;3—碳酸盐台地;4—陆缘岩浆弧;5—弧后盆地;6—被动陆缘盆地;7—陆缘坳陷盆地;8—华南地块;9—志留系;10—推测志留系沉积物;11—钾盐;12—~470 Ma金伯利岩;13—峰峰组(上奥陶统);14—下寒武统;15—峰峰组北部边界(上奥陶统);16—断裂;17—坳陷盆地边缘断裂

Fig.1 Early Paleozoic paleogeographical map of the North China Craton (modified from Pan et al.,2014)

1−Craton uplift; 2− Ocean basin; 3−Carbonate platform; 4−Continental margin magmatic arc; 5−Back-arc basin; 6− Passive continental margin basin; 7−Continental margin depressed basin; 8−South China block; 9−Outcrops of Silurian (S); 10−Silurian sediments distribution inferred; 11− Potash saline; 12−Kimberlites at ~ 470 Ma; 13−Fengfeng Formation (O_3); 14−Outcrops of Early Cambrian ($Є_1$); 15−Northern margin of Fengfeng Formation (O_3); 16−Fault; 17−Boundary fault on depressed basin margin

系	统	年龄/Ma	北京	辽宁	河南	陕西
石炭系	上石炭统	323	本溪组	本溪组	本溪组	本溪组
	下石炭统	359				
泥盆系	上泥盆统	383				
	中泥盆统	393				
	下泥盆统	419				
志留系	普里多利统	423				
	拉德洛统	427				
	文洛克统	433				
	兰多弗里统	444				
奥陶系	上奥陶统	458			峰峰组	背锅山组 平凉组
	中奥陶统	470	上马家沟组 下马家沟组	马家沟组 北庵庄组	马家沟组 北安庄组	三道沟组 ?
	下奥陶统	485	亮甲山组 冶里组	亮甲山组 冶里组	亮甲山组 冶里组 凤山组	
寒武系	芙蓉统	497	凤山组 长山组 崮山组	炒米店组 崮山组	三山子组	三山子组
	第三统	509	张夏组 徐庄组	张夏组	张夏组	张夏组
	第二统	521	毛庄组 昌平组	馒头组 碱厂组	馒头组 朱砂洞组 辛集组	馒头组 朱砂洞组 辛集组
	纽芬兰统	541				

图2 华北克拉通古生代地层时代及划分

Fig.2 Lower Paleozoic strata of the North China Craton

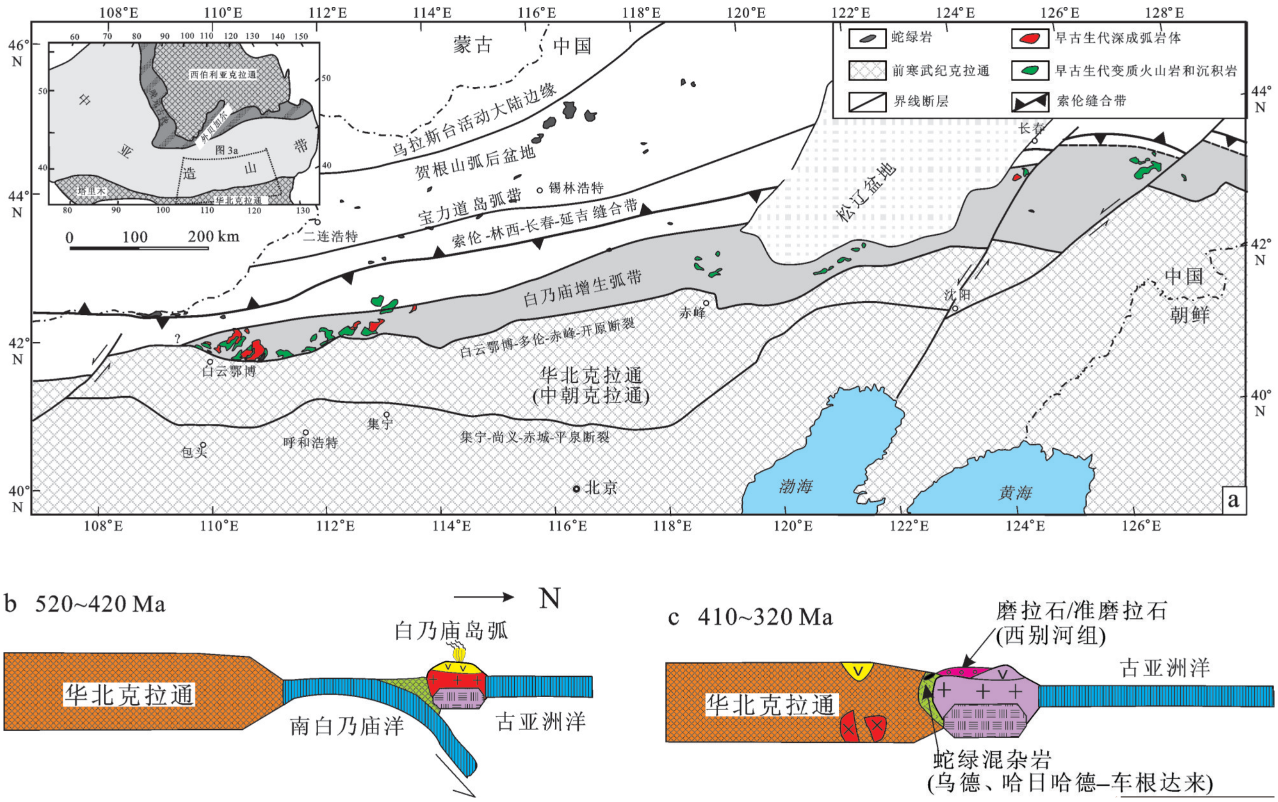

图3 (a)中亚造山带南部及华北克拉通北缘构造简图（据Zhang et al., 2014修改; 插图据Jahn et al., 2000修改）; (b,c) 早古生代–泥盆纪华北克拉通北缘演化示意图(据Zhang et al., 2014修改)

Fig.3 (a) Sketch tectonic map of southern CAOB and the northern margin of the North China Craton (modified from Zhang et al., 2014, insert map modified after Jahn et al., 2000); (b,c) schematic maps showing evolution of the northern NCC during Early Paleozoic–Devonian period (modified from Zhang et al., 2014). See the text for discussion

古生代期间是保持稳定的,北缘为被动大陆边缘性质(李锦轶等, 2009; Zhang et al., 2014)。华北北缘的早古生代520～420 Ma岩浆岩主要分布在白乃庙岛弧带上,但在华北克拉通北部和北缘却没有发现早古生代岩浆活动的记录(Zhang et al., 2014)。白乃庙岛弧带上岩浆岩及变质沉积岩的锆石U–Pb及Sr–Nd–Hf同位素分析结果表明白乃庙岛弧带不是华北克拉通的大陆边缘弧,其演化历史与华北克拉通明显不同(图3b, Zhang et al., 2014)。与中亚造山带(兴蒙造山带)中大多数古陆块性质相似(王涛等, 2001; Zhao et al., 2006; Demoux et al., 2009; Levashova et al., 2010, 2011; Kozakov et al., 2012; Kröner et al., 2011, 2014),早古生代期间白乃庙岛弧岩带发育在类似塔里木型(或扬子型)基底性质的微陆块之上(Zhang et al., 2014)。晚志留世—泥盆纪初期,华北克拉通与白乃庙岛弧带发生弧–陆碰撞,导致了白乃庙岛弧带增生在华北克拉通北缘。中亚造山带南部志留纪末—泥盆纪初西别河组磨拉石或类磨拉石的形成(Zhang and Tang, 1989; Tang, 1990; 内蒙古自治区地质矿产局, 1991; 苏养正, 1996; 许立权等, 2003; 王平, 2005; Chen and Boucot, 2007; 张允平等, 2010)及华北北缘与中亚造山带南部早—中泥盆世碱性岩的形成可能与此次弧–陆碰撞及其后的伸展有关(Zhang et al., 2009a)。与世界其他一些地区相似(McKenzie, 1969; Johnson and Jaques, 1980; Konstantinovskaia, 2001; Clift et al., 2003),这一弧–陆碰撞后,华北北缘陆缘性质由被动陆缘向活动陆缘转变(图3c)。但是这一重要转变的细节和一些关键问题仍不甚明了。

2.3 南缘及秦岭造山带

早古生代期间在华北克拉通南缘及秦岭造山带发生了几期重要的构造事件。在这一时期位于华北克拉通与北秦岭之间的二郎坪弧后盆地扩张

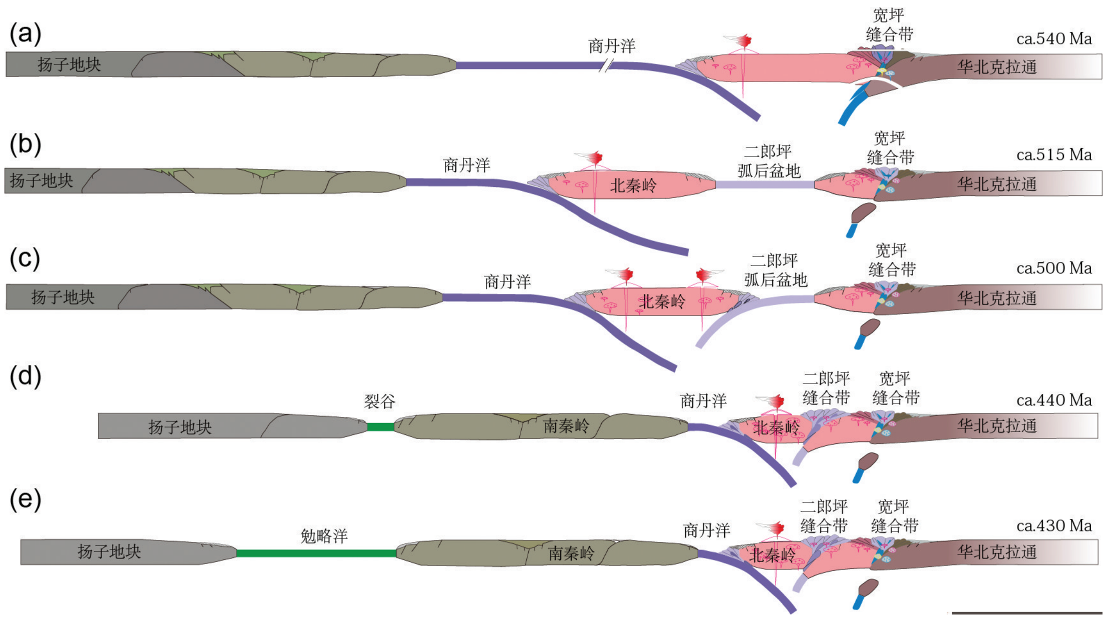

图4 早古生代期间商丹及勉略缝合带构造演化示意图(据Dong and Santosh, 2016修改)
Fig.4 Schematic maps showing evolution along the Shangdan suture and the Mianlue suture between North Qinling Belt, South Qinling Belt and South China Craton, respectively, during Early Paleozoic period (modified from Dong and Santosh, 2016)

并最终关闭;商丹洋向北俯冲在北秦岭陆块之下。根据北秦岭构造带变质岩(510~400 Ma)及岩浆岩(ca. 514~420 Ma)年代学及地壳深熔和混合岩化的时代(517~445 Ma)推断(Dong et al., 2011),位于北秦岭及南秦岭之间商丹洋的俯冲起始于~514 Ma或稍晚,一直持续到大约420 Ma结束(图4)(Liu et al., 2012; Wu and Zheng, 2013; Dong and Santosh, 2016)。而位于北秦岭与华北克拉通南缘之间的二郎坪弧后盆地在508 Ma左右逐渐打开并开始扩张,在450 Ma或稍晚闭合,导致了北秦岭与华北克拉通南缘及北秦岭北部S型花岗岩的形成(Liu X C et al., 2012; Wu and Zheng et al., 2013; Dong and Santosh, 2016)。但目前对发育在华北克拉通南缘之上的二郎坪群时代及构造背景还有很大争议(王宗起等, 2009; Liu et al., 2012; Wu and Zheng et al., 2013; Dong and Santosh, 2016)。

3 晚古生代构造演化

3.1 华北克拉通

晚古生代华北克拉通大地构造最显著的变化是其北缘活动大陆边缘的出现。至少从早石炭世晚期开始,古亚洲洋向南俯冲在华北地块之下,华北地块北缘演变为安第斯型活动大陆边缘(图5),并导致了华北克拉通上石炭统底部“G”铝土矿的沉积。“G”铝土矿在华北克拉通北部及中部非常广泛,普遍平行不整合覆盖在中奥陶统马家沟组碳酸盐之上(图6),并且是华北克拉通最为主要的铝土矿层位之一(孟祥化等, 1987)。

传统观点认为,位于华北克拉通北部中奥陶统马家沟组灰岩与石炭系碎屑岩之间平行不整合面上的“G”铝土矿是由于下伏灰岩长期风化的产物。但马家沟组灰岩纯度较高,铝的含量极低。因此马家沟碳酸盐的风化不可能形成大规模的铝土矿。近年来研究结果显示,在这些铝土矿中存在有大量岩浆成因的锆石(赵越等, 2010[1]; Wang et al., 2010; Liu et al., 2014; Wang et al., 2016。锆石U-Pb测年结果显示,这些岩浆锆石主要形成于晚石炭世。作为岩浆源区示踪的锆石微区Hf同位素组成(如:Bodet and Schärer, 2000; Kosler et al., 2002; Königer et al., 2002; Lizuka et al., 2005; Veevers et al., 2005; Boni et al., 2012),为“G”铝土矿中这些锆石的来源提供了新的制约。这些岩浆锆石的$\varepsilon_{Hf}(t)$值变化于2.2~−24.5,且主要为负值,与华北北缘内蒙古隆起上同岩浆期岩浆岩中锆石Hf同位素组成相似,而与中亚造山带同期岩浆岩以锆石$\varepsilon_{Hf}(t)$正值为主明显不同(Liu et al., 2014)。“G”铝土矿中岩浆锆石的晚

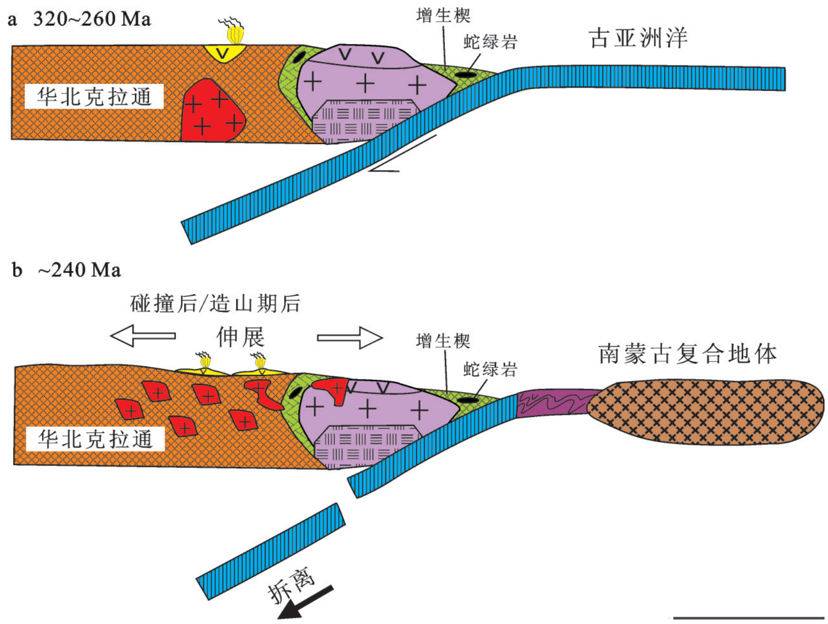

图5 华北克拉通北缘晚古生代—早中生代构造演化示意图

Fig.5 Schematic maps showing evolution of the northern margin of the North China Craton during Late Paleozoic−Early Mesozoic period

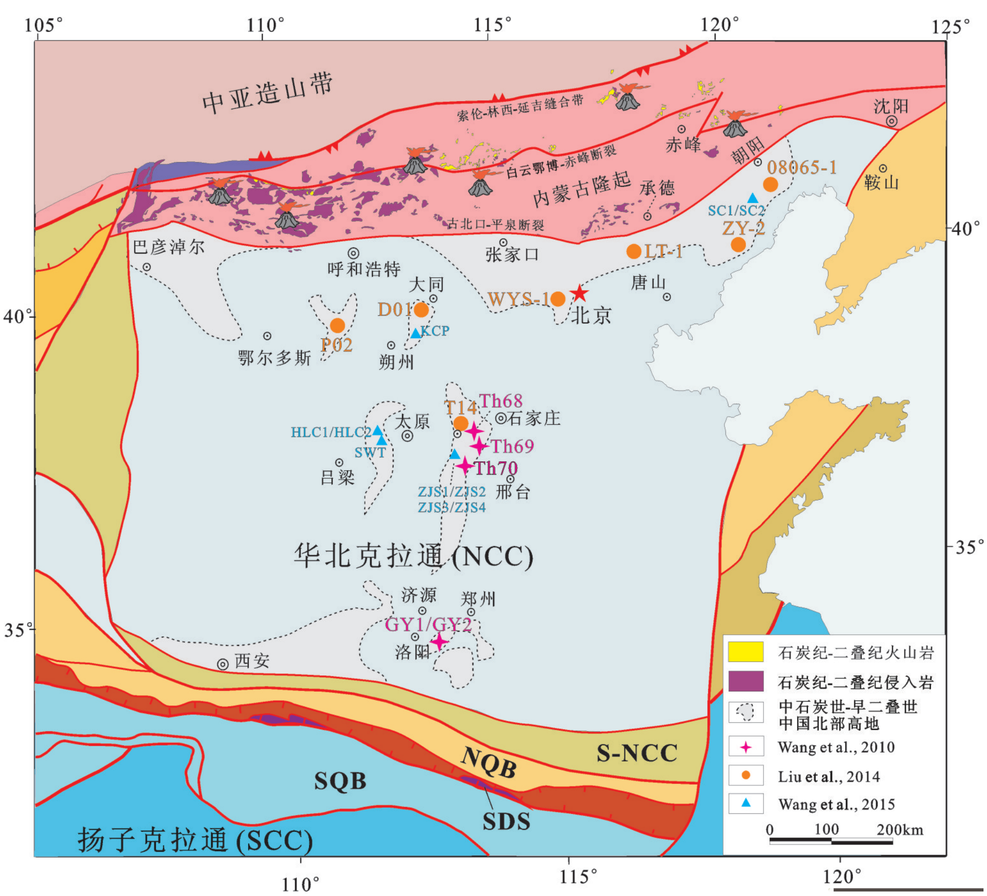

图6 华北克拉通晚古生代古地理示意图及铝土矿样品采样点

Fig.6 Late Paleozoic paleogeographical map of the North China Craton

石炭世—早二叠世年龄也与华北北缘内蒙古隆起上晚古生代弧岩浆岩的形成时代相一致。因此,我们认为华北北缘铝土矿的物源主要是华北北缘内蒙古隆起上晚石炭世—早二叠世火山弧喷发的火山凝灰(Liu et al., 2014),大规模的火山喷发甚至形成了植物的庞贝(Wang et al., 2012)。

华北克拉通“G”铝土矿之上,晚石炭世—早二叠世煤系地层主要为煤层、砂岩、泥岩、薄层灰岩或透镜夹层。前人研究结果显示,在这些煤系地层中存在有大量的凝灰岩夹层(钟蓉等, 1995; 贾炳文等, 1999; 周安朝等, 2001; Zhang et al., 2007b),表明华北克拉通晚石炭世—早二叠世海陆交互相沉积与火山弧相伴,其特征与早二叠世晚期以陆相沉积为主的环境明显不同。

3.2 北缘及中亚造山带南部

泥盆纪是华北克拉通北缘及中亚造山带(兴蒙造山带)南部构造转化的关键时期。如前所述,志留纪末—泥盆纪初具有磨拉石或类磨拉石性质的西别河组被认为与华北克拉通与白乃庙岛弧带之间的弧-陆碰撞有关(Zhao et al., 2010; Zhang et al., 2014)或者与陆-陆碰撞及古亚洲洋关闭有关(徐备和陈斌, 1997; Xu et al., 2013)。早—中泥盆世期间,在华北北缘有较多碱性岩(正长岩、二长岩及碱性花岗岩)及少量基性-超基性岩侵位(罗镇宽等, 2001; Jiang, 2005; Zhang et al., 2007a, 2009a; X.H. Zhang et al., 2010; Shi et al., 2010; 王惠初等, 2012)。近年来在内蒙古赤峰地区还发现了一些以流纹岩或流纹斑岩为主的火山岩(刘建峰等, 2013; 叶浩等, 2014a; 孙立新等, 2015)。

从早石炭世晚期开始,由于古亚洲洋板块沿索伦缝合带向南俯冲,华北地块北缘(包括华北克拉通北缘及白乃庙岛弧带)演化成活动大陆边缘(图7)。在华北地块北缘发育了大量的石炭纪—二叠纪侵入岩并构成了一条延伸超过1000 km、宽度超过120 km的近东-西向侵入岩带。此外,近年来在华北克拉通北缘以往所认为的新太古代—古元古代结晶基底岩系内发现了大量早石炭世晚期—早二叠世侵入体(张拴宏等,2004; Zhang et al., 2004, 2007c, 2009b, 2009c; 王惠初等, 2007)。这些侵入岩岩石类型主要包括闪长岩、石英闪长岩、花岗岩闪长岩及花岗岩,另外还包括少量辉长岩及英云闪长岩,具有钙碱性或高钾钙碱性、准铝质或弱过铝质岩石地球化学特征,被认为代表了与安第斯型活动大陆边缘俯冲相关的岩浆活动(Wang and Liu, 1986; Xiao et al., 2003, 2009; Li, 2006; 王惠初等, 2007; Zhang et al., 2007c, 2009b, 2009c; Bai et al., 2013; 马旭等, 2012)。近期对华北克拉通北缘断裂(白云鄂博—多伦—赤峰—开原断裂)两侧晚古生代火山岩研究结果表明,这些火山岩喷发时代介于(347±3) Ma~(258±1) Ma,即早石炭世—晚二叠世,其岩石组合主要为玄武岩、玄武安山岩、安山岩、英安岩、流纹岩、凝灰岩及凝灰质砂岩等(Zhang et al., 2016)。岩石学及岩石地球化学结果显示,华北北缘石炭纪—二叠纪火山岩不具有双峰式火山岩特征,其中—基性组分(玄武岩、玄武安山岩)在微量元素蛛网图上表现出明显的Nb、Ta负异常,表明这些火山岩的形成于安第斯型活动大陆边缘弧。

古亚洲洋最终沿索伦缝合带闭合和华北克拉

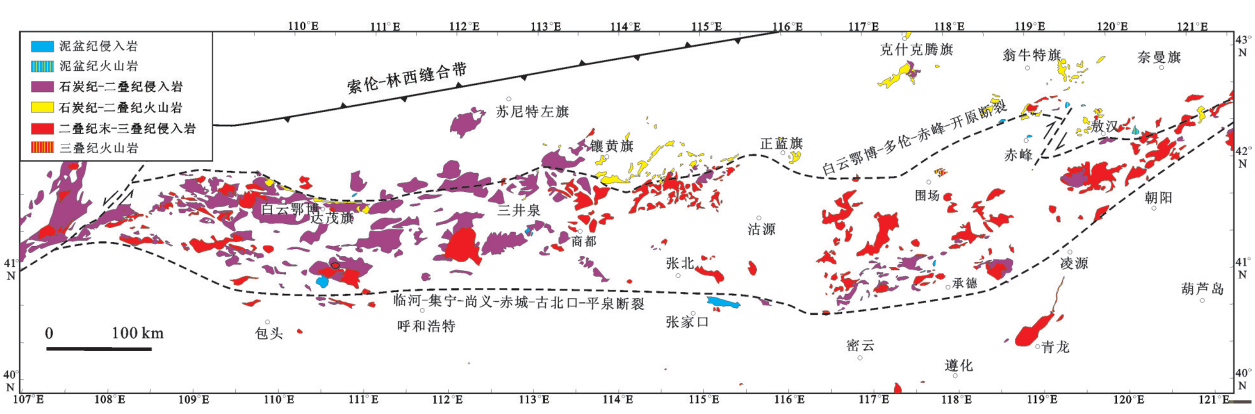

图7 华北克拉通北缘晚古生代岩浆岩空间分布示意图(据Zhang et al., 2016修改)
Fig.7 Sketch map showing distribution of the Late Paleozoic magmatic rocks in northern NCC (modified from Zhang et al., 2016)

通北缘与西伯利亚克拉通南侧增生陆缘(南蒙古复合地体)的碰撞发生在晚二叠世至三叠纪初期(Wang and Liu, 1986; Xiao et al., 2003, 2009; Li, 2006; Windley et al., 2007; Wu et al., 2007; S.H. Zhang et al., 2007c, 2009b, 2009c; Miao et al., 2008; 李锦轶等, 2009; Chen et al., 2009; Eizenhöfer et al., 2014)。由于华北克拉通北缘晚古生代沉积地层中与俯冲有关火山岩的上限有从西向东逐渐变年轻的趋势,据此推测古亚洲洋中—西段闭合的时间可能比起东段稍早(Zhang et al., 2016)。

3.3 南缘及秦岭造山带

依据南秦岭构造带在中泥盆世至早三叠世期间为连续沉积,结合构造变形特征及变质和冷却年龄,董云鹏等(Dong and Santosh, 2016)质疑北秦岭构造带在晚古生代期间抬升剥蚀。他们指出商丹洋闭合之后南秦岭与北秦岭并没有完全碰撞。志留纪初期双峰式火山岩的出现预示着勉略洋的打开(图8)。火山岩内硅质岩夹层中获得的晚泥盆世—石炭纪放射虫(王宗起等, 1999)及勉略带蛇绿岩内硅质岩夹层中放射虫(冯庆来等, 1996)的存在表明勉略洋存在于泥盆纪—石炭纪期间(图8, Dong and Santosh, 2016)。南秦岭构造带蛇绿岩中弧火山岩代表了勉略洋向北的俯冲(赖绍聪等, 1997; Liu et al., 2015; Dong and Santosh, 2016),并一直持续到古生代末期(图8)。

4 早中生代

4.1 南缘及秦岭造山带

三叠纪期间最为重要的构造事件是华北克拉通与华南克拉通沿秦岭造山带发生碰撞,并形成了红安—大别—苏鲁高压—超高压变质岩。红安—大别—苏鲁高压—超高压变质岩的形成与勉略洋最后消减殆尽,并在220~210 Ma闭合,导致华南克拉通与南秦岭构造带碰撞有关(图8c, Dong and Santosh, 2016)。红安—大别—苏鲁造山带榴辉岩相进变质作用及超高压峰期变质作用的时代分别为(246±7) Ma和(234±4) Ma(Liu et al., 2006; Liu et al., 2015)。在241~231 Ma和225~215 Ma与超高压—高压变质作用同期,指向南东的推覆作用形成了一系列复杂堆叠的构造岩片(Li et al., 2010)。随后在215~205 Ma发生角闪岩相条件下指向南东的褶皱作用。200~184 Ma在浅部条件下形成第三期弯曲褶皱。这两期挤出变形可以与大陆碰撞过程中大别高压—超高压变质岩在三叠纪期间的两期剥露过程对应(Li et al., 2010)。这一大陆碰撞还导致了地壳加厚及地壳局部熔融并形成了南秦岭构造带大量220~210 Ma的花岗岩。在200 Ma左右,加厚地壳及造山带快速垮塌,导致了210~200 Ma后碰撞的、具有环斑结构的花岗质岩石侵位,及类高压麻粒岩于199~192 Ma的抬升剥露(Dong and Santosh, 2016)。

4.2 北缘

晚二叠世—三叠纪初期古亚洲洋最终沿索伦缝合带闭合及华北北缘及西伯利亚南侧增生陆缘(南蒙古复合地体)的碰撞-拼合伴随有大量与后碰撞/后造山伸展相关的岩浆活动及地壳增生(Zhang et al., 2009; 2014)。早古生代期间华北北缘经历了从后碰撞/后造山伸展向陆内伸展的转变(Yang et

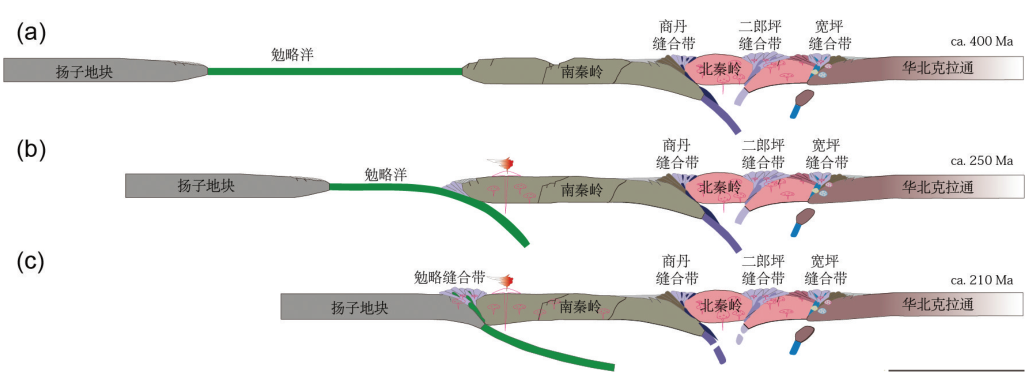

图8 晚古生代期间勉略缝合带构造演化示意图(据Dong and Santosh, 2016修改)
Fig.8 Schematic maps showing evolution along the Mianlue suture between South Qinling Belt and South China Craton, respectively, during Late Paleozoic period (modified from Dong and Santosh, 2016)

al. 2012, 叶浩等, 2014b)。与典型的大陆碰撞造山带(如阿尔卑斯及喜马拉雅等)明显不同,华北北缘及西伯利亚南侧增生陆缘(南蒙古复合地体)的碰撞−拼合为软碰撞或弱碰撞,因此普遍缺少同碰撞强过铝质S型花岗岩浆作用及高压—超高压变质作用(如:Zhang et al., 2009b)。从二叠纪末至中—晚三叠世,华北北缘岩浆岩岩石组合有明显的变化;而构造变形样式在早—中三叠世与晚三叠世—早侏罗世期间有明显的差异(Zhang et al., 2014)。早三叠世岩浆岩主要由二长花岗岩、正长花岗岩、二长岩、流纹质熔结凝灰岩、流纹岩及凝灰质砂岩组成,另外包括少量基性—超基性岩及花岗闪长岩。中—晚三叠世主要由闪长岩、花岗闪长岩二长花岗岩、正长花岗岩、二长岩、正长岩、基性—超基性岩及安山岩、粗安岩及粗安质火山角砾岩等中性火山岩组成(Zhang et al., 2009a, 2012; Yang et al., 2012; 陈斌等, 2013; 叶浩等, 2014b)。地球化学结果显示在中—晚三叠世正长岩及基性—超基性岩形成中明显有软流圈物质参与,表明华北克拉通北缘岩石圈在这一时期已经开始减薄(Zhang et al., 2009a, 2012; 叶浩等, 2014b)。

盘山地区位于华北克拉通北缘燕山褶断带南部,马兰峪复背斜西侧。盘山地区最主要的构造特征是围绕盘山岩体周缘分布的环状褶皱(图9)。该区庄果峪向斜和府君山向斜南部被蓟县断裂冲断,但蓟县断裂又被盘山岩体所侵入。沿蓟县断裂可以清楚地看到中元古代长城系及蓟县系地层逆冲在其上的蓟县系及青白口系沉积地层之上。盘山

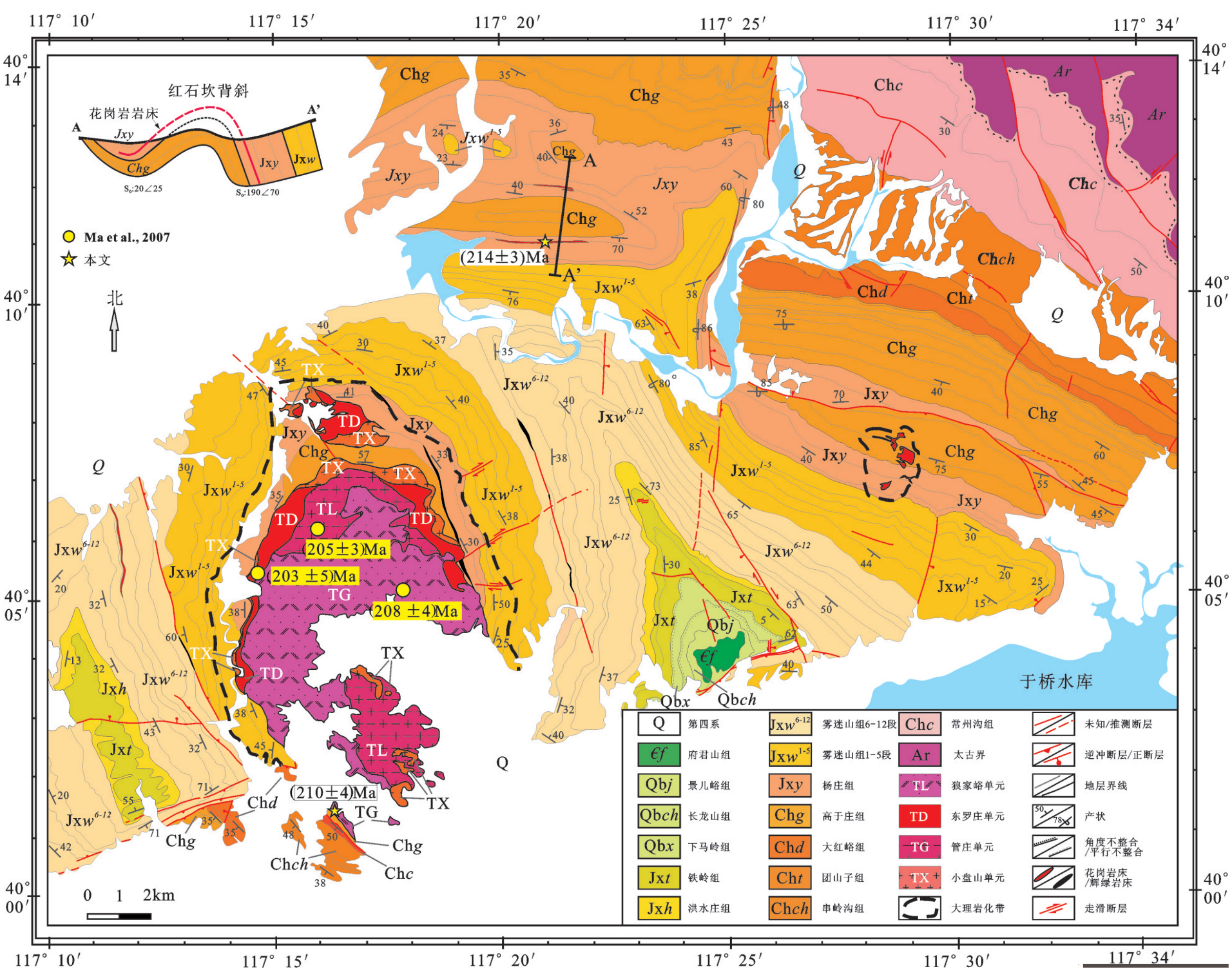

图9 盘山地区地质图及晚三叠世盘山岩体与其周围构造变形
Fig.9 Geological map of the Panshan region of northern North China Craton, showing Late Triassic deformation and plutons

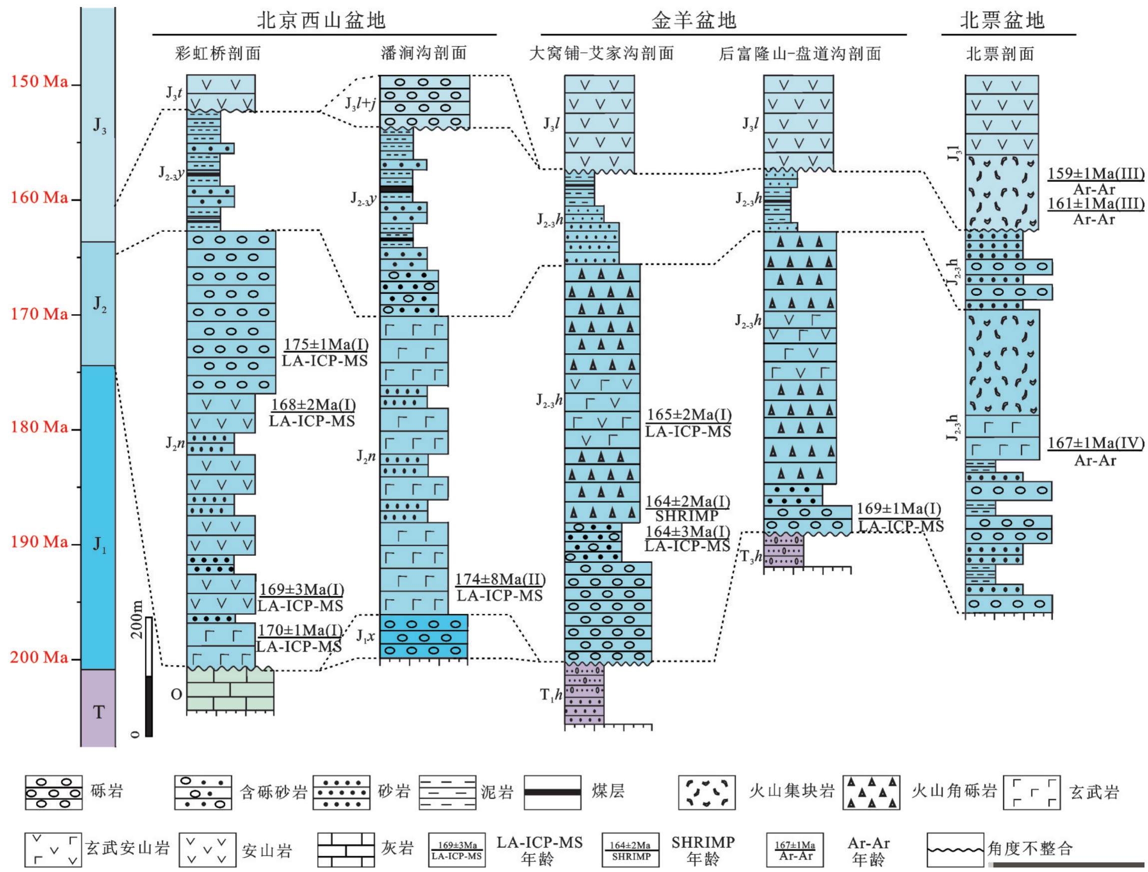

图10 北京西山和辽西早—中侏罗世地层对比图(高海龙等,待发表)

Fig.10 Lower−middle Jurassic stratigraphy of western Beijing and western Liaoning (after Gao Hailong et al., in preparation)

岩体北侧,红石坎背斜南北两翼杨庄组内同一地层内被花岗斑岩脉侵入(图9)。红石坎背斜南翼花岗岩岩系的锆石U−Pb年龄为(214±3)Ma(赵越等,2010),表明盘山地区褶皱及逆冲变形发生在214 Ma之后。盘山岩体管庄单元花岗岩的锆石U−Pb年龄为(210±4)Ma~(208±4)Ma。野外观察及年代学结果显示盘山岩体及其外围褶皱、逆冲变形及岩浆侵位发生在214 ~ 210 Ma,即晚三叠世。结合辽西牛营子地区、华北下板城及冀东都山地区晚三叠世—早侏罗世构造变形分析结果(Hu et al., 2010; Liu et al., 2012; 叶浩等, 2014b),笔者认为华北克拉通北缘在210 Ma前后发生了强烈的区域构造变形。至少自此时,华北克拉通已经遭受了破坏。

燕山期开始,华北克拉通的构造变形日趋强烈。根据最近的研究结果(图10,高海龙等未刊资料),如果以北京西山南大岭组火山岩的开始作为标志,这一时代在174 Ma前后,即早−中侏罗世之交。这与我们曾经的推测一致(赵越等,2006)。

5 小 结

(1) 华北克拉通及邻区古生代早期的主要构造事件发生于大约520 Ma,与冈瓦纳古陆聚合峰期时代基本一致。中奥陶世马家沟期开始的华北克拉通海退及区域性抬升和463~470 Ma的含金刚石金伯利岩以及华北克拉通430 Ma前后深部岩浆活动与全球构造事件时限相一致,表明早古生代期间华北克拉通的演化与全球构造的重大事件密切相关。

(2) 位于不整合覆盖在马家沟组灰岩之上,石炭系底部的"G"层铝土矿,其物源主要来自晚古生代华北克拉通北缘活动大陆边缘火山喷发产生的火山凝灰。晚石炭世—早二叠世海陆交互相煤系地层中夹灰岩薄层或透镜体及大量火山物质,与其北缘火山弧环境吻合。

(3) 晚三叠世210 Ma左右华北克拉通北缘发

生了强烈的构造变形并伴随有强烈的岩浆活动。这表明华北克拉通在晚三叠世已经不具有稳定克拉通的性质。

致谢:李建锋及刘健绘制了部分图件,在此表示感谢。

注释

❶赵越, 等.2010.“北山造山带重大地质事件与成矿背景”课题973项目内部报告.

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