1000-0569/2010/026(08)-2233-46 *Acta Petrologica Sinica* 岩石学报

“钉合岩体”与新疆北部主要缝合带的形成时限*

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2010-05-01 收稿, 2010-07-01 改回.

Han BF, Guo ZJ and He GQ. 2010. Timing of major suture zones in North Xinjiang, China: Constraints from stitching plutons. *Acta Petrologica Sinica*, 26(8):2233 – 2246

Abstract This study introduces the concept of stitching pluton because a stitching pluton can provide an upper-age bound for the timing of an accretionary or a collisional event in orogens, with an emphasis on the geochronological constraints from the stitching plutons crosscutting major suture zones on the timing of accretionary and collisional events in North Xinjiang. A combination of the oldest stitching plutons and the youngest ophiolitic rocks within the major suture zones in North Xinjiang may tightly constrain the timing of these major suture zones. The Irtysh-Zaysan suture zone between the Altai terrane in the north and the Zharma-Saur magmatic arc in the south, the North Tian Shan suture zone between the Junggar terrane in the north and the Kazakhstan-Yili terrane in the south, and the South Tian Shan suture zone between the Kazakhstan-Yili terrane in the north and the Tarim craton in the south were formed during the Late Carboniferous, whereas the other ophiolite zones in East Junggar and West Junggar during the Early Carboniferous or earlier. The western Junggar accretionary complex was commonly crosscut by many Late Carboniferous stitching plutons, but it is unclear that these plutons were generated by either subduction-related or post-collisional magmatism during the Late Carboniferous so that more work needs to be done in the future in order to eliminate the uncertainty. The pre-existing data are in support of Late Paleozoic orogens, without evidence for Triassic collision, in North Xinjiang. Particularly, the stitching plutons within the South Tian Shan provide an upper-age bound for the timing of the South Tian Shan suture zone and strong evidence against the suspected Late Permian radiolarians from the Baleigong ophiolite, and they also help re-interpret the Triassic zircon U-Pb ages from the high and ultrahigh pressure metamorphic rocks within the suture zone.

Key words Stitching pluton; Post-accretion; Post-collision; Suture zone; North Xinjiang

摘 要 本文介绍了钉合岩体的概念,强调钉合岩体在造山带研究中具有重要的大地构造意义。在科迪勒拉增生造山带中,钉合岩体是在增生事件之后形成的;而在喜马拉雅碰撞造山带中,钉合岩体是在碰撞事件之后形成的。因此可以区分后增生和后碰撞两类钉合岩体,它们可以为限定增生或碰撞事件的时间上限提供年代学约束。特别是在缝合带被钉合岩体侵入的情况下,缝合带的形成时限(即增生或碰撞事件的起止时间)可以根据缝合带中最年轻的蛇绿岩质岩石和最老的钉合岩体给予严格限定。应用这种方法,能够限定新疆北部的主要缝合带(如额尔齐斯-斋桑缝合带、北天山缝合带和南天山缝合带等,东准噶尔和西准噶尔的蛇绿岩带)最晚是在晚石炭世形成的。西准噶尔增生杂岩也是在在晚石炭世形成的,但当时是否存在洋壳俯冲还需要进一步研究。目前的资料显示,虽然新疆北部各主要缝合带的形成时限存在一定差异,但没有三叠纪形成的缝合带。特别是南天山缝合带内发育的钉合岩体不但有效地限定了缝合带的时间上限,而且还从地质上约束了受到质疑的晚二叠世放射虫化石的可靠性和高压-超高压变质岩中三叠纪锆石 U-Pb 年龄的解释的合理性。

关键词 钉合岩体;后增生;后碰撞;缝合带;新疆北部
中图法分类号 P542.4; P597.3

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* 本文受国家重点基础研究规划项目(2007CB411305)、国家科技支撑计划重点项目(2006BAB07B08)、国家自然科学基金项目(40772141)和中国地质调查局项目(1212010611803)联合资助.
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1 引言

中亚造山带是全球规模最大的显生宙增生造山带,它位于东欧、西伯利亚、华北和塔里木等4个克拉通之间广大区域。中亚造山带的历史以弧、增生杂岩、海山和大洋高原的增生为主(Coleman, 1989; Zonenshain *et al.*, 1990; Mossakovsky *et al.*, 1993; Fedorovskii *et al.*, 1995; Buslov *et al.*, 2001, 2004; Khain *et al.*, 2002, 2003; Kheraskova *et al.*, 2003),涉及了各种地体(包括前寒武纪微大陆)之间的拼贴碰撞(Badarch *et al.*, 2002; Buchan *et al.*, 2002; Yakubchuk, 2004; Briggs *et al.*, 2007; Windley *et al.*, 2007; Kelty *et al.*, 2008; Xiao *et al.*, 2008, 2009)。这种复杂的增生过程被认为与古亚洲洋的闭合有关,并最终导致了全球规模最大的大陆和大洋地体的构造拼合体和显生宙大陆生长区的形成(Coleman, 1989; Zonenshain *et al.*, 1990; Mossakovsky *et al.*, 1993; Sengör *et al.*, 1993; Sengör and Natal'in, 1996; Jahn *et al.*, 2000; Kovalenko *et al.*, 2004; Windley *et al.*, 2007)。显然,单一弧长期持续向洋生长和后来走滑作用导致多个弧段堆叠(Sengör *et al.*, 1993; Sengör and Natal'in, 1996)的模式并不能够合理解释中亚造山带极其复杂的演化历史(Bykadorov *et al.*, 2003; Windley *et al.*, 2007)。

新疆北部是中亚造山带的重要组成部分,主要表现为增生杂岩和岩浆弧等地体之间的拼贴碰撞,留下很多以蛇绿岩或蛇绿混杂岩为标志的缝合带。长期以来,新疆北部一直被认为是古生代造山带,但对造山事件的时限还存在不同的认识,近年还提出了新疆北部是三叠纪造山带的新观点。显然,有效地限定地体拼贴碰撞事件(或缝合带形成)的时限是讨论这个问题的关键所在。地体拼贴碰撞事件(或缝合带形成)的时间下限可以由缝合带中最年轻的蛇绿岩组成部分来约束,而"钉合岩体"则是建立地体拼帖碰撞事件(或缝合带形成)的时间上限最好的标志之一。

2 "钉合岩体"的概念及其构造意义

20世纪80年代初期,美国和加拿大的地质学家在研究科迪勒拉增生造山带的基础上,提出了构造地层地体的概念和分析方法(Coney *et al.*, 1980; Jones *et al.*, 1983),并引入了一些重要的概念。如果在地体增生到大陆边缘上之前,单个的地体互相连接成复合地体,称之为拼贴,而后单个的或复合的地体与大陆碰撞和焊接,则称为增生。确定地体拼贴和增生的时限主要有三种标志(Jones *et al.*, 1983; Schermer *et al.*, 1984),但以已经拼贴或增生的地体被继承盆地的超覆岩系所覆盖或被花岗质侵入体所焊接等两种标志最为有效(Dickinson, 2008),侵入体与地体的关系称为 pluton stitching(图1)。这类侵入体是地体拼贴或增生之后侵入到

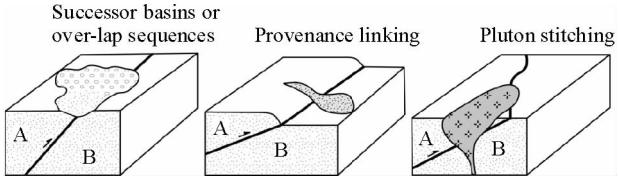


图1 限定地体拼帖和增生时限的地质关系(据 Jones *et al.*, 1983)

Fig. 1 Geologic relations that help establish the timing of terrane amalgamation and accretion (after Jones *et al.*, 1983)

地体边界之中的,还可以大致同时出现在相邻的地体之中,它们限定了地体拼贴或增生的时间上限,因而具有特殊的构造年代学意义。由于这类侵入体的作用就像钉书钉一样,因此在后来的文献中被称为 stitching pluton。Stitch 的原意为缝或缝合,pluton 为火成侵入体或深成岩体,为了与 suture 的汉译相区别和译名简洁,建议将 stitching pluton 译作"钉合岩体"。

显然,野外地质关系和同位素年龄测定相结合,使得那些直接侵入在地体边界的钉合岩体的大地构造意义最为明确和重要。例如,在中阿拉斯加,一个二长岩-正长岩-碱性花岗岩杂岩体侵入了 Alexander 和 Wrangellia 两个地体的边界及其两侧地体的基底岩石,岩体的锆石 U-Pb 年龄为309Ma,指示这两个地体在晚石炭世已经拼贴在一起(Gardner *et al.*, 1988)。而 Alexander-Wrangellia 复合地体又在晚侏罗世早期(159~151Ma)和 Peninsular 地体拼贴,因为覆盖在这些地体上的上侏罗统具有相似的沉积特征,而且这些地体又都被晚侏罗世早期(158~156Ma)花岗质侵入体所侵入(Trop *et al.*, 2005)。在科迪勒拉的 Klamath 山,由于洋壳向大陆块下的俯冲,各种地体增生到被俯冲陆块的前缘。在俯冲带向洋后退的情况下,岩浆弧向洋迁移,弧岩浆活动形成的中侏罗世(170~160Ma)后增生花岗质深成岩将增生的地体和大陆焊接起来,形成陆缘的增生造山带(Dickinson, 2008)。这些花岗质深成岩是地体增生之后侵位的,所以能够有效地限定科迪勒拉增生造山事件的时间上限(Dickinson, 2008),而增生造山事件的时限可由卷入造山作用的最年轻的岩石和最老的钉合岩体一起给予严格限定(Reese *et al.*, 2000)。

在中爱达荷(Fleck and Criss, 1985)、南阿帕拉契亚(Mittwede, 1988)、北阿帕拉契亚(van Staal *et al.*, 1998)和澳大利亚拉克伦造山带(Gray and Foster, 1997),钉合岩体为限定拼贴、增生和碰撞事件的时间上限提供了非常重要的年代学依据。而有些非造山侵入岩也可以是钉合岩体。例如在东加拿大地盾的北 Labrador,与中元古代大陆裂谷作用相关的 Nain 侵入岩(1350~1290Ma)作为钉合岩体出现在早元古代 Nain-Churchill 缝合带(1860~1740Ma)的两侧(Ryan, 2000)。显然,由非造山钉合岩体限定的增生或碰撞造山事件的时限可能跨度比较大。

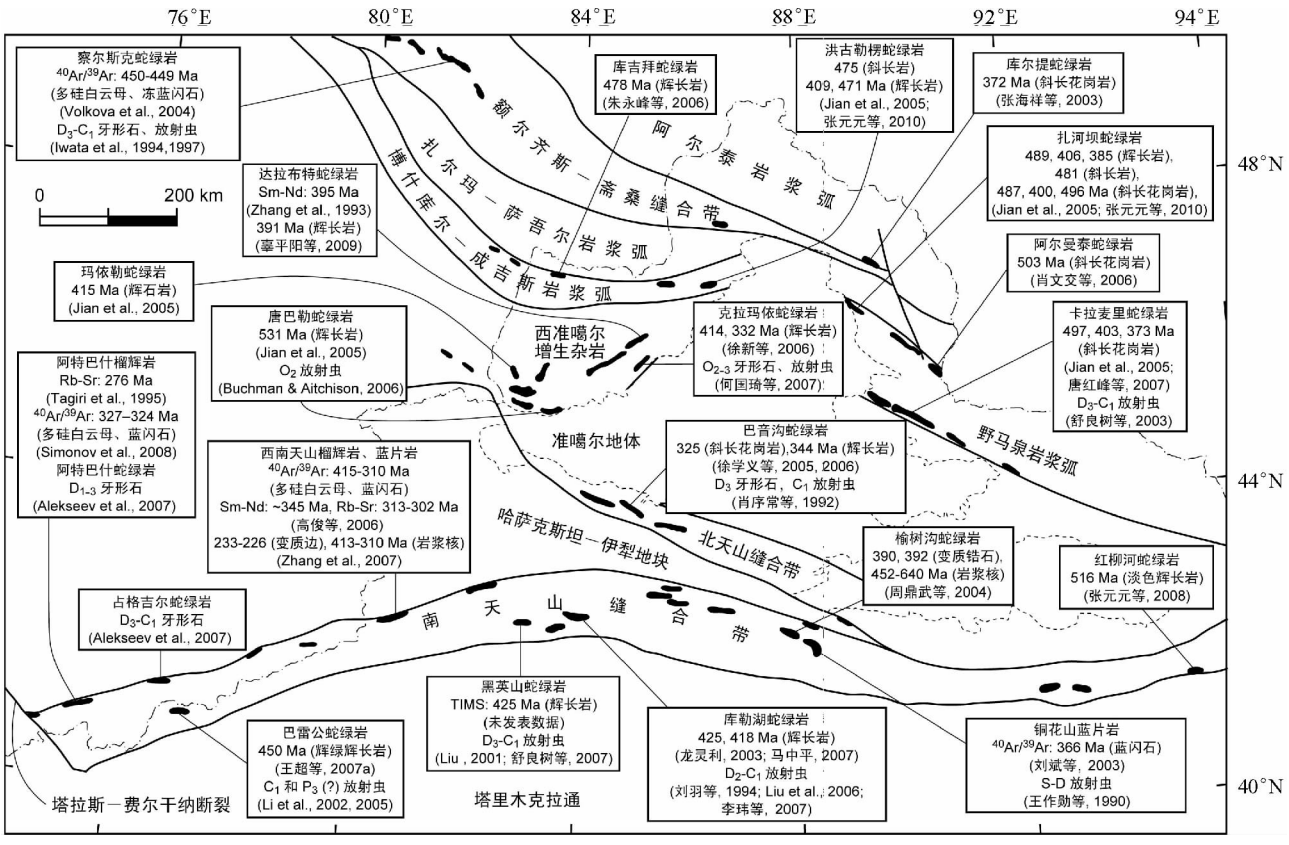


图 2 新疆北部的主要缝合带及蛇绿岩的年代学资料

Fig. 2 Major suture zones and geochronological data for ophiolites in North Xinjiang and adjacent regions

在有些情况下,岩脉可能具有钉合岩体的大地构造意义。例如,在新西兰北岛蛇绿岩中,辉长岩和斜长花岗岩的锆石 U-Pb 年龄分别为 31.8Ma 和 28.3Ma,而切割了蛇绿岩的钙碱性岩脉的锆石 U-Pb 年龄约为 20Ma,提供了新西兰北岛蛇绿岩侵位时代的上限。所以,新西兰北岛蛇绿岩是在 28~20Ma 之间侵位的(Wattmam *et al.*, 2006)。再如,新疆-甘肃交界处的红柳河蛇绿岩中堆晶辉长岩的锆石 U-Pb 年龄为 516Ma,代表红柳河蛇绿岩的形成年龄;而侵入到红柳河蛇绿岩中未变形变质的黑云母花岗岩脉的锆石 U-Pb 年龄为 405Ma,限定了红柳河蛇绿岩侵位的时代上限(张元元和郭召杰,2008)。此外,钉合岩体或具有钉合岩体构造意义的岩脉还能够为断裂活动(Glen and VandenBerg, 1987)或者褶皱作用(张继恩等,2009)提供上限时间约束。

需要特别强调的是,钉合岩体是一个构造概念,强调的是岩体与其它构造(板块缝合带、地体边界、断层和褶皱等)之间的侵入关系,它的重要性在于能够限定构造事件(板块碰撞、地体拼合与增生、断裂活动和褶皱作用)的时间上限。显然,在限定板块缝合带的形成时代的上限时,那些直接侵入在缝合带的蛇绿岩或蛇绿混杂岩中的岩体的构造意义最为明确。如果准确测定了这些岩体的锆石 U-Pb 年龄,就能够限定缝合带形成时代的上限,以其中时代最老的岩体限定板块缝合带形成时代的上限最为有效。再结合蛇绿岩或蛇绿混杂岩中最年轻的年代学资料,进而就能够限定缝合带的形成时限。此外,钉合岩体的岩性可以变化很大,可以具有多样的地球化学特征。

3 新疆北部主要缝合带的形成时限

作为中亚造山带的重要组成部分,新疆北部及邻区发育众多的蛇绿岩或蛇绿混杂岩,构成了多条重要的缝合带。近年来获得的大量的年代学资料显示,新疆北部及邻区普遍发育古生代蛇绿岩或蛇绿混杂岩(图 2)和以晚古生代石炭-二叠纪为主的花岗岩类,其中有些花岗岩直接侵入到缝合带和增生杂岩之中。目前,根据已有资料就能够对额尔齐斯-斋桑、北天山和南天山等主要缝合带的形成时代给予限定。

3.1 额尔齐斯-斋桑缝合带的形成时代

额尔齐斯-斋桑缝合带位于阿尔泰山南缘,在东哈萨克斯坦和中国境内,大部分沿着额尔齐斯河展布,呈北西西-南东东方向延伸,具有西宽东窄的特点。额尔齐斯-斋桑缝合带构成了阿尔泰和哈萨克斯坦-准噶尔之间一条重要的构造界线,是一条古生代的增生碰撞带(Windley *et al.*, 2007)。它的北东侧为西伯利亚南缘的古生代阿尔泰岩浆弧,南西侧

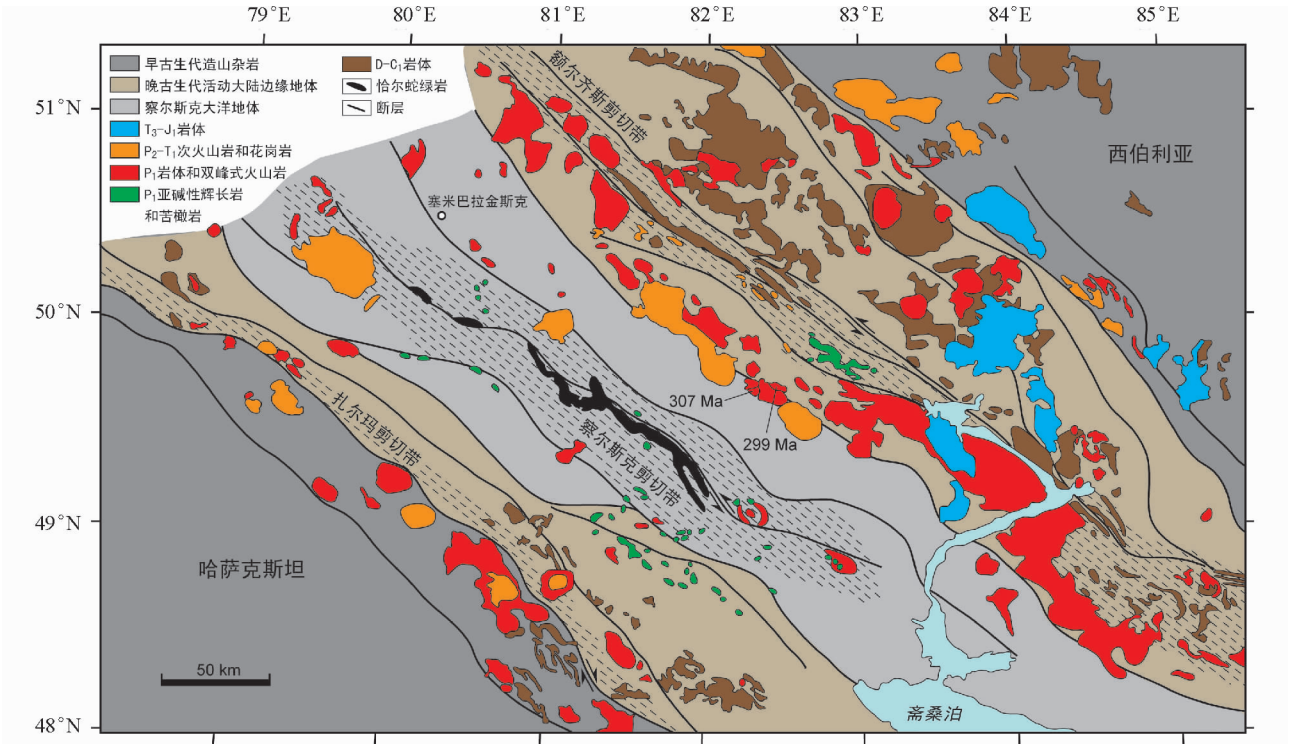


图 3 东哈萨克斯坦额尔齐斯-斋桑缝合带的地质简图(据 Vladimirov *et al.*, 2008 简化)和后碰撞钉合岩体的锆石 U-Pb 年龄(据 Kuibida *et al.*, 2009)

Fig. 3 Sketch map showing tectonic subdivision and distributions of granitoids in East Kazakhstan (simplified from Vladimirov *et al.*, 2008) and zircon SHRIMP U-Pb ages from two of post-collisional stitching plutons (after Kuibida *et al.*, 2009)

依次为泥盆-石炭纪扎尔玛-萨吾尔岩浆弧和晚志留世-早泥盆世博什库尔-成吉斯岩浆弧(图 2)。在东哈萨克斯坦,额尔齐斯-斋桑洋的残余以位于额尔齐斯-斋桑缝合带中部的察尔斯克蛇绿岩为代表(图 3),其中蓝片岩的$^{40}Ar/^{39}Ar$ 年龄为 450~449Ma(Volkava and Sklyarov, 2007),硅质岩含有丰富的晚泥盆世和早石炭世放射虫和牙形石化石(Iwata *et al.*, 1994, 1997)。蛇绿岩带的两侧分别为西伯利亚和哈萨克斯坦的晚古生代活动大陆边缘,以发育泥盆纪-早石炭世花岗岩类为特征,再向外则是早古生代造山带。

值得特别注意的是,早二叠世岩浆活动在东哈萨克斯坦广泛发育,形成了花岗岩类和亚碱性辉长岩等侵入体和双峰式火山岩组合。它们不但出现在早古生代造山带和晚古生代活动大陆边缘内,切割了区域大型断裂,还出现在以察尔斯克蛇绿岩为代表的大洋地体之中,表明这些早二叠世侵入体是在额尔齐斯-斋桑缝合带形成之后侵位的。如果额尔齐斯-斋桑缝合带代表着阿尔泰和哈萨克斯坦-准噶尔之间的晚古生代增生碰撞带(Windley *et al.*, 2007),那么早二叠世侵入体就属于后碰撞钉合岩体。在这些钉合岩体中,Zhilandy 和 Tochka 岩体的锆石 U-Pb 谐和年龄分别为 307 Ma 和 299Ma,表明最早的钉合岩体是在晚石炭世形成的,与岛弧或早期碰撞岩浆作用无关(Kuibida *et al.*, 2009)。再结合察尔斯克蛇绿岩内的微体化石资料,可以限定额尔齐斯-斋桑缝合带是在 307Ma 之前的晚石炭世形成的。此外,东哈萨克斯坦的扎尔玛-萨吾尔岩浆弧向东延伸到中哈边境的塔尔哈巴台山-萨吾尔山一带。在中国境内,塔尔哈巴台山-萨吾尔山的花岗岩类是两个阶段岩浆活动的产物,早期以闪长岩、花岗闪长岩、二长花岗岩和钾长花岗岩为特征,它们的锆石 U-Pb 年龄在 346~321Ma 之间,可能与额尔齐斯-斋桑洋向哈萨克斯坦陆缘下的俯冲过程有关,而晚期岩体以钾长花岗岩和碱性花岗岩等为主,它们的锆石 U-Pb 年龄在 304~263Ma 之间,是后碰撞岩浆活动的产物(Chen *et al.*, 2010)。整合上述的地质关系和锆石年代学资料,可以认为额尔齐斯-斋桑缝合带是在 321~307Ma 之间形成的。这同时表明,在额尔齐斯-斋桑缝合带内及其南侧的扎尔玛-萨吾尔岩浆弧和博什库尔-成吉斯岩浆弧中,307Ma 之后形成的晚石炭世和二叠纪花岗岩体是后碰撞岩浆活动的产物(Chen *et al.*, 2010),而东哈萨克斯坦的晚三叠世和侏罗纪花岗岩则可能产生于非造山阶段,是阿尔泰-萨彦岭-外贝加尔中生代岩浆带的一部分(图 3)。

3.2 北天山缝合带的形成时代

北天山缝合带以介于哈萨克斯坦-伊犁地块和准噶尔早古生代地体之间的蛇绿混杂岩带为标志,是北天山洋向哈萨克斯坦-伊犁地块下俯冲消亡之后产生的缝合带。北天山蛇

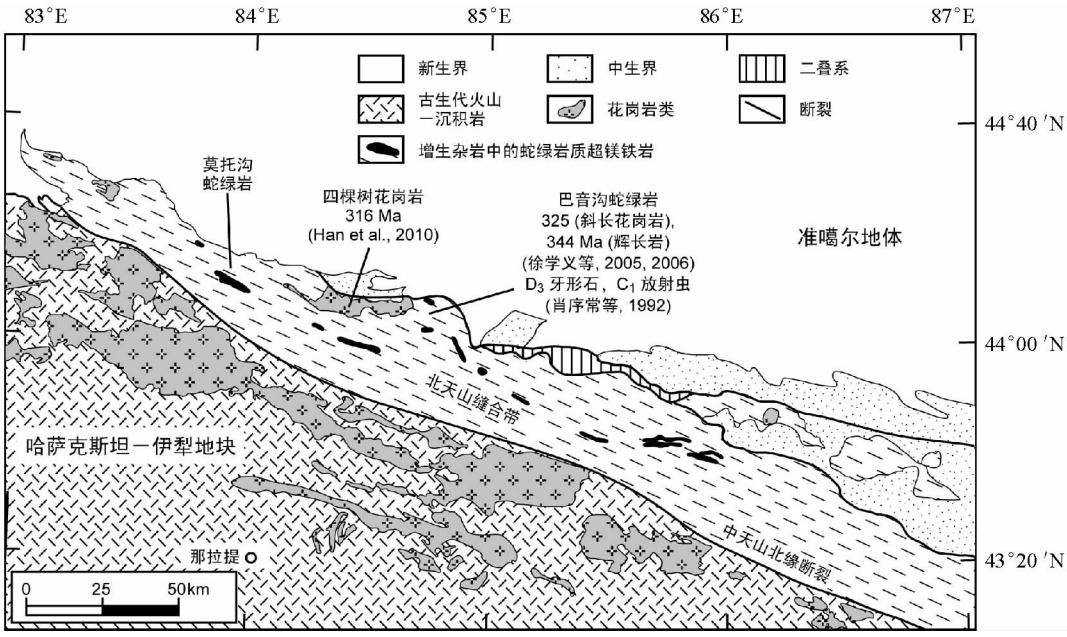


图 4 北天山缝合带的地质简图和四棵树钉合岩体的锆石 U-Pb 年龄(据 Han *et al.*, 2010 简化)

Fig. 4 Sketch map showing the North Tian Shan suture zone crosscut by the Sikeshu stitching pluton with a zircon U-Pb age of 316Ma (modified from Han *et al.*, 2010)

绿混杂岩带沿着北天山呈北西西-南东东方向延伸,长约300km(图2)。蛇绿混杂岩带由泥盆纪和早石炭世增生杂岩和蛇绿岩组成。增生杂岩主要是火山沉积岩,而蛇绿岩则包括蛇纹石化橄榄岩、辉长岩、斜长花岗岩、枕状熔岩和深海硅泥质岩石等岩块组成,构造混杂在增生杂岩之中。在其中的巴音沟蛇绿岩中,辉长岩和斜长花岗岩的锆石 U-Pb 年龄分别为 344Ma(徐学义等,2006)和 325Ma(徐学义等,2005),从硅质岩中曾获得法门阶牙形石 *Palmatolepis* sp. 和 *Polygnathus* sp. 以及早石炭世放射虫 *Ceratoikicum* sp. 等化石(肖序常等,1992)。这些资料表明,巴音沟蛇绿岩是新疆北部时代最年轻的蛇绿岩,它所代表的北天山洋是在早石炭世之后才闭合的。

北天山蛇绿混杂岩带被数个花岗岩体侵入(图4),其中以位于乌苏县城南的四棵树岩体规模最大,出露面积达到 200km^2。四棵树岩体的西侧有莫托沟蛇绿岩,东侧是巴音沟蛇绿岩,南侧也有蛇绿岩质超镁铁岩产出。四棵树岩体由多种岩性组成,包括闪长岩、花岗闪长岩和花岗岩。除被断层切割之外,岩体内部没有变形和变质的迹象。岩体和被其切割的增生杂岩围岩一起向北逆冲在三叠纪-侏罗纪含煤地层之上。野外地质关系表明,四棵树岩体是在北天山蛇绿混杂岩带形成之后侵位的,是一个钉合岩体,而岩体中心部位花岗闪长岩的锆石 U-Pb 年龄限定北天山蛇绿混杂岩带是在316Ma 之前形成的。如果以巴音沟蛇绿岩中年轻的锆石 U-Pb 年龄和早石炭世放射虫作为北天山蛇绿混杂岩带形成时代的下限,而将四棵树岩体的锆石 U-Pb 年龄作为上限,则可以限定北天山蛇绿混杂岩形成时代可能是在早-晚石炭世之交,即介于 325~316Ma 之间(Han *et al.*, 2010)。

3.3 南天山缝合带的形成时代

南天山造山带是介于塔里木克拉通和哈萨克斯坦-伊犁地块之间的南天山洋向哈萨克斯坦-伊犁地块下俯冲消亡之后产生的蛇绿混杂岩带,是新疆北部另一条具有相当规模的缝合带。总体上呈向北凸出的弧形,东段为北西西-南东东走向,西端为北东东-南西西走向,向西经过吉尔吉斯斯坦南天山,直抵北西-南东向的塔拉斯-费尔干纳右旋走滑断裂带。沿着南天山蛇绿混杂岩带北缘发育高压-超高压变质岩,如吉尔吉斯斯坦阿特巴什山和中国西南天山的榴辉岩和蓝片岩以及铜花山蓝片岩等,而蛇绿岩的分布则较为分散(图2)。

尽管对于塔里木克拉通和哈萨克斯坦-伊犁地块碰撞的时间存在不同的认识,但长期以来,南天山被认为是晚古生代造山带。可是,这样的认识近年来受到了三叠纪碰撞造山的挑战(Li *et al.*, 2002, 2005;李曰俊等,2002,2005;Zhang *et al.*, 2007; Xiao *et al.*, 2008, 2009)。作为三叠纪碰撞造山的关键证据均来自中国境内南天山缝合带的西段,如晚二叠世的放射虫化石(Li *et al.*, 2002, 2005;李曰俊等,2002,2005)和榴辉岩的锆石 U-Pb 年龄(Zhang *et al.*, 2007)。因此,在中国和毗邻的吉尔吉斯斯坦境内的南天山缝合带部分也就成为限定南天山缝合带何时形成的最关键的地区。

作为二叠纪南天山洋依然存在、南天山是三叠纪碰撞造山带的关键证据之一是两个放射虫化石 *Albaillella excelsa* Ishiga, Kito and Imoto (?) 和 *Albaillella* sp. cf. *albaillela*

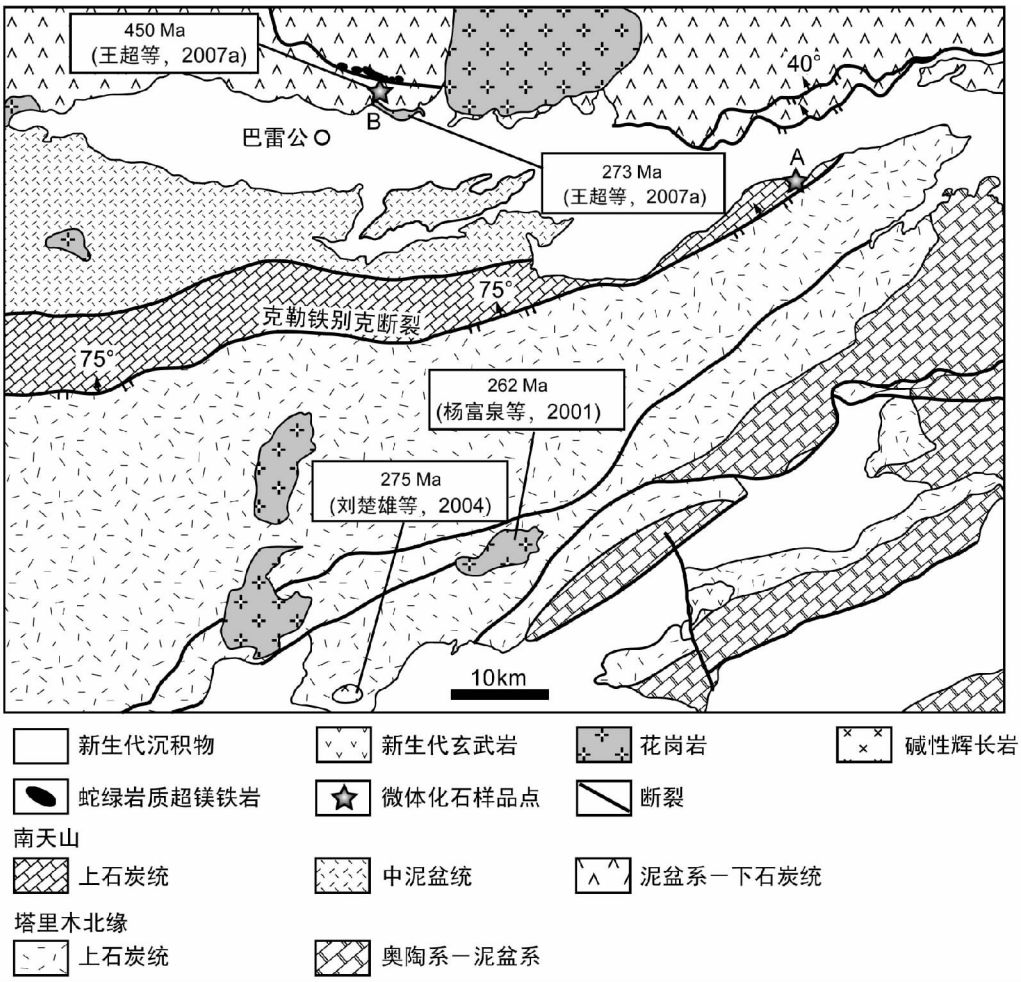


图 5 南天山缝合带中巴雷公地区地质简图及年代学资料

Fig. 5 Sketch map showing ophiolites and stitching plutons in Baleigong area within the South Tian Shan suture zone

excelsa Ishiga, Kito and Imoto(Li *et al.*, 2002, 2005;李曰俊等,2002,2005),它们采自中国南天山西段的巴雷公地区(图 5),其中一个晚二叠世放射虫化石 *Albaillella excelsa* Ishiga, Kito and Imoto (?)采自托什罕河上游南岸的哈拉道克冲沟沟口(图 5 中 A 点,Li *et al.*, 2002;李曰俊等,2002),但从该点获得的晚二叠世放射虫"仅有一颗化石,且保存不甚理想,所以存疑;其余化石可以划分出早石炭世早期和晚期两个放射虫化石组合"(李曰俊等,2002),另一个晚二叠世放射虫化石 *Albaillella* sp. cf. *albaillela excelsa* Ishiga, Kito and Imoto 采自托什罕河上游北岸的齐齐尔加纳克苏河剖面(图 5 中 B 点,Li *et al.*, 2005;李曰俊等,2005)。

这两个化石的可靠性备受质疑(舒良树等,2007; Gao *et al.*, 2009)。舒良树等(2007)曾明确指出,这两个比较种放射虫化石中的一个保存不完整,缺少腹翼,难以鉴定,而另一个则保存更差,出现可疑的背翼,无腹翼,也很难鉴定。除这两个受质疑的晚二叠世放射虫化石和其它 7 个长寿命(志留纪-二叠纪和石炭纪-二叠纪)分子外,剩余的 19 个放射虫化石的时代仅局限于早石炭世,这与南天山其它地区获得的大量放射虫化石所指示的最年轻的时代相似(图 2)。尽管受到质疑,这两个晚二叠世放射虫化石却依然被作为"南天山碰撞造山不早于晚二叠世"的关键证据之一(李曰俊等,2009)。显然,南天山是三叠纪碰撞造山带的认识还有需要其它地质证据的支持。

近南北向的齐齐尔加纳克苏河揭示了横过巴雷公蛇绿混杂岩的剖面,北端出露有变长石石英砂岩和蛇纹石化橄榄岩,向南出露有泥灰岩、砂岩、辉绿辉长岩、玄武岩和硅质岩等,而且辉绿辉长岩、玄武岩和硅质岩在剖面南段重复出现,其中辉绿辉长岩的锆石 U-Pb 年龄为 450Ma(王超等,2007a),硅质岩中除含有 *Albaillella* sp. cf. *albaillela excelsa* Ishiga, Kito and Imoto 外,其它放射虫化石组合的时代为早石炭世(Li *et al.*, 2005;李曰俊等,2005)。重要的是,巴雷公蛇绿混杂岩剖面的南端被没有明显变形变质的早二叠世花岗岩(锆石 U-Pb 年龄为 273Ma)所侵入(王超等,2007b)。此外,巴雷公蛇绿混杂岩向东延伸的部分还被另一个规模更大的花岗岩体所侵入(图 5)。花岗岩与蛇绿混杂岩的侵入关系清楚地表明,巴雷公蛇绿混杂岩不但在 273Ma 之前就已经

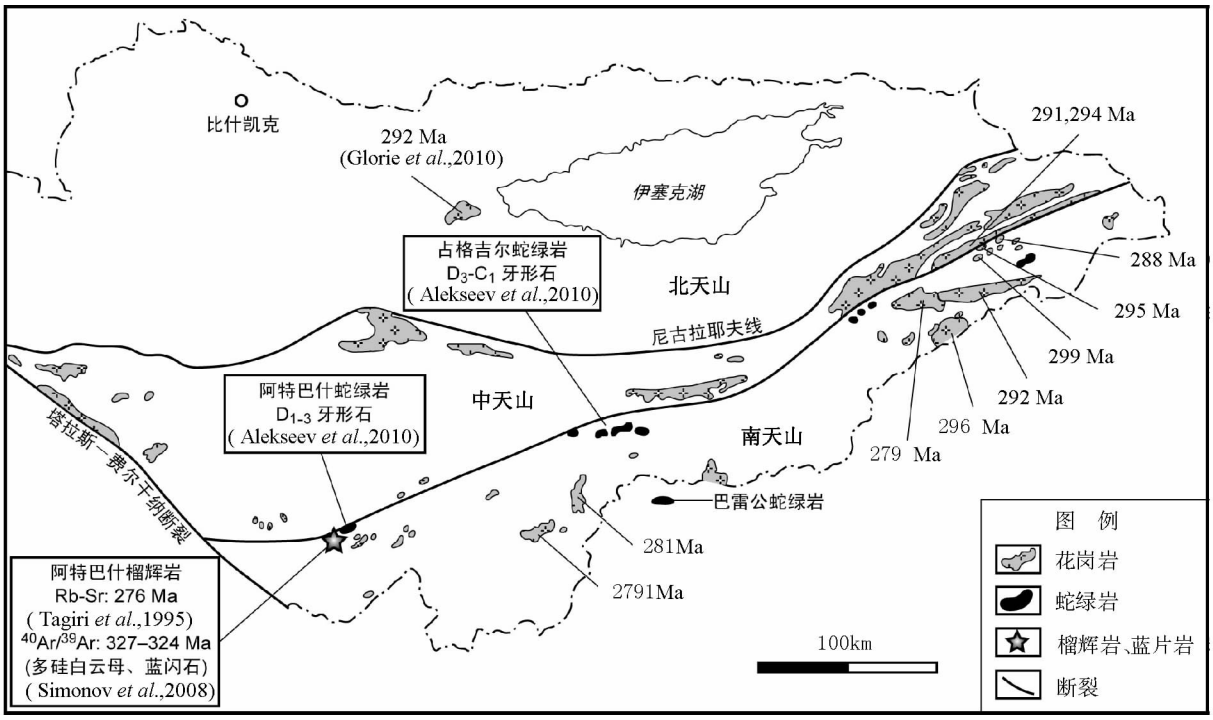


图 6 吉尔吉斯斯坦南天山中蛇绿岩、榴辉岩-蓝片岩和后碰撞钉合岩体的分布(据 Igemberdiyev *et al.*, 1980 简化)及年代学资料(Konopelko *et al.*, 2007, 2009; Glorie *et al.*, 2010)

Fig. 6 Sketch map showing the distribution of ophiolite, eclogite-blueschist, and post collisional stitching pluton, with chronological data from Konopelko *et al.* (2007, 2009) and Glorie *et al.* (2010), in the South Tian Shan of Kyrgyzstan

构造侵位,而且其各组成部分的时代不应该比花岗岩还年轻。在这个剖面中获得的惟一的晚二叠世放射虫化石不但保存状况差,不具有可靠的可鉴定性(舒良树等,2007),而且与地质体之间的关系相互矛盾。

在巴雷公地区,二叠纪岩浆活动形成的花岗岩在克勒铁别克断层的南北两侧均有产出,不但侵入在断层以北的蛇绿混杂岩和火山沉积组合之中,也侵入了断层以南的塔里木北缘稳定沉积的地层之中(图 5)。如果塔里木北缘稳定沉积地层代表了南天山洋的被动陆缘沉积,那么克勒铁别克断层以南的花岗岩和碱性辉长岩只能是在南天山缝合带形成之后侵位的,类似于在印度板块被动陆缘一侧的高喜马拉雅和特提斯喜马拉雅出现的后碰撞花岗岩类。所以,巴雷公地区的这些侵入岩属于后碰撞钉合岩体,它们限定了南天山碰撞事件发生在 275Ma 之前。然而,在吉尔吉斯斯坦,早二叠世后碰撞花岗岩不但出现南天山,也出现在哈萨克斯坦-伊犁地块(包括中天山和北天山)内(Abeleira *et al.*, 2000; Konopelko *et al.*, 2007, 2009; Glorie *et al.*, 2010),特别是在吉尔吉斯斯坦阿特巴什和中国西南天山的两处高压-超高压变质带的中间部位,后碰撞花岗岩在中天山和南天山毗邻区域内呈面状分布,在巴雷公蛇绿岩以西也有产出(图 6)。这些后碰撞花岗岩就是钉合岩体,其中时代最老的钉合岩体限定南天山洋闭合发生在 300Ma 之前。因此,塔里木克拉通和哈萨克斯坦-伊犁地块的碰撞事件一定发生在蛇绿混杂岩中可靠的早石炭世放射虫化石之后和最老的钉合岩体侵位之前,即晚石炭世期间,推测在 320~300Ma 之间。

这样的认识与区域地质资料是吻合的。在中国南天山南坡,最早的磨拉石出现在早二叠世,并被上二叠统和三叠系陆相沉积所覆盖(舒良树等,2007);陆相的上二叠统和三叠系砂岩和砾岩不整合覆盖在更老的岩石之上(Carroll *et al.*, 1995),而它们的古流向和沉积物散布型式一致指示来自天山的趋势,塔里木北缘的中生代砂岩成分多样,来自天山的源区(Hendrix *et al.*, 1992; Hendrix, 2000)。此外,二叠纪小提坎里克组广泛超覆于下石炭统之上,以陆相酸性火山岩为主,局部下伏河流相砾岩。其中火山岩的锆石 U-Pb 年龄为 296~289Ma,火山岩之上不整合覆盖上二叠统或下三叠统(罗金海等,2008;李建兵等,2009)。而中生代含煤磨拉石建造中的三叠系和侏罗系砾岩均为成熟度很低的不等粒复成份砾岩(李曰俊等,2004)。在吉尔吉斯斯坦境内,至二叠纪时,洋盆已经完全消失,陆块增生和碰撞已经完成,并伴有二叠纪磨拉石(Bakirov and Kakitaev,2000)和后碰撞花岗岩(Solomovich and Trifonov, 2002; Solomovich, 2007; Konopelko *et al.*, 2007, 2009)的广泛发育,而晚二叠世-早三叠世则完全处于陆内环境(Bakirov and Kakitaev,2000)。总之,如果南天山造山带的高压-超高压峰期变质作用与碰撞事件是同期的,这个事件应该发生在 320~300Ma 期间,这是由蛇绿混杂岩中时代最新、最可靠的放射虫化石和时代最老

的后碰撞钉合岩体所限定的时限。

在区域上,一般认为中国西天山高压-超高压变质岩向西可与吉尔吉斯斯坦阿特巴什山榴辉岩-蓝片岩带连接和对比,但是,在阿特巴什山,含榴辉岩的杂岩被上古生界石炭纪末期磨拉石不整合覆盖(Tagiri *et al.*, 1995; Hegner *et al.*, in press),并且磨拉石中含有大量的榴辉岩砾石(Baslakunov *et al.*, 2007)。这证明至少部分的阿特巴什榴辉岩-蓝片岩在晚古生代的某个时间已经被折返到地表,并遭受剥蚀。这与阿特巴什和占格吉尔蛇绿岩中硅质岩含有丰富的泥盆纪-早石炭世杜内期牙形石(Alekseev *et al.*, 2007)的事实非常吻合。在阿特巴什榴辉岩中,白云母和蓝闪石$^{40}Ar/^{39}Ar$年龄为324~327Ma,被解释为折返年龄(Simonov *et al.*, 2008)。早期获得的阿特巴什榴辉岩的矿物-全岩 Rb-Sr 等时线年龄(267Ma,Tagiri *et al.*, 1995)可能并不能指示高压峰期变质作用的时代,因为定年样品中的石榴石变斑晶具有清晰的化学成分分带现象(Tagiri *et al.*, 1995),而这样的现象是样品还没有达到化学平衡、因而 Rb-Sr 等时线年龄不可靠的重要标志(Zhang *et al.*, 2007)。在中国西南天山榴辉岩中,曾获得三叠纪的锆石 U-Pb 年龄,被认为代表了高压-超高压峰期变质作用的年龄(Zhang *et al.*, 2007)。根据文字描述,虽然榴辉岩的定年锆石与绿辉石和石榴石共生,但锆石中仅有金红石包体,并没有发现柯石英和绿辉石等指示高压-超高压峰期变质作用的矿物包体(Zhang *et al.*, 2007)。没有柯石英和绿辉石等矿物包体,就很难确定变质锆石是在高压-超高压峰期变质作用期间生长的还是在退变质作用期间形成的,因为锆石变质边既可以形成于成岩过程的任何阶段(Hoskin and Black, 2000),也可以是后期受流体作用的结果(Ayers *et al.*, 2003)。因此,三叠纪锆石 U-Pb 年龄(Zhang *et al.*, 2007)很有可能是高压-超高压变质岩折返到地壳层次以后,锆石受到流体作用影响的结果(高俊等,2006;de Jong *et al.*, 2008)。特别重要的是,最新的锆石 U-Pb 定年结果(Su *et al.*, 2010)表明,在榴辉岩的具有核边结构的锆石中,仅在锆石的边部含有绿辉石、多硅白云母和金红石等矿物包体,表明锆石边部是在榴辉岩相峰期变质作用期间生长的。两个榴辉岩样品的锆石变质边的 U-Pb 年龄均为 319Ma(Su *et al.*, 2010)。此外,Hegner *et al.*(in press)等最近获得的阿特巴什榴辉岩的矿物-全岩 Sm-Nd 等时线年龄为 319±4Ma,并解释为代表榴辉岩相变质作用的时代。如此看来,中国西天山高压-超高压变质岩和吉尔吉斯斯坦阿特巴什山榴辉岩-蓝片岩带的榴辉岩相变质作用的时代几乎完全一致,指示与碰撞相关的变质作用发生在早石炭世末期,而非在三叠纪(Su *et al.*, 2010; Hegner *et al.*, in press)。这一认识不但与区域地质资料吻合得很好,也与根据蛇绿混杂岩中时代最新、最可靠的放射虫化石和时代最老的后碰撞钉合岩体所限定的时限一致,还得到了流经中国西天山高压-超高压变质岩带的4条重要河流的碎屑锆石 U-Pb 年龄研究结果的支持(Ren *et al.*, 2010)。

3.4 东准噶尔蛇绿岩带的形成时代

东准噶尔地区存在两条蛇绿岩带,蛇绿岩的锆石 U-Pb 年龄在 503~373Ma 之间(图2)。北侧的扎河坝-阿尔曼泰蛇绿岩带的形成不晚于卡拉麦里蛇绿岩带(李锦轶,2004),而南侧的卡拉麦里蛇绿岩带硅质岩中含有泥盆纪至早石炭世杜内期放射虫化石(李锦轶等,1990;舒良树和王玉净,2003),缝合带附近的下侏罗统中,来自卡拉麦里蛇绿岩的紫红色硅质岩砾石中含有泥盆纪至早石炭世维宪期的放射虫化石(杨品荣等,2007)。在蛇绿岩带内,早石炭世晚期地层不整合覆盖在卡拉麦里蛇绿岩之上(李锦轶等,1989),蛇绿岩带的西段被老鸭泉后碰撞花岗岩侵入(韩宝福等,2006),表明卡拉麦里洋盆于早石炭世晚期闭合(舒良树和王玉净,2003;李锦轶,2004)。重要的是晚石炭世-早二叠世后碰撞花岗岩在东准噶尔地区两条蛇绿岩带的两侧都广泛发育(如韩宝福等,2006;苏玉平等,2006a),而它们的时空分布特征表明这些花岗岩是后碰撞钉合岩体。

3.5 西准噶尔蛇绿岩带的形成时代

在西准噶尔北部,库吉拜-洪古勒楞蛇绿岩带是博什库尔-成吉斯岩浆弧与扎尔玛-萨吾尔岩浆弧的缝合带,蛇绿岩的锆石 U-Pb 年龄 478~409Ma 之间(图2)。库吉拜蛇绿岩之上发育下石炭统,底砾岩中含有大量蛇绿岩砾石(朱永峰等,2008),上部地层中含有早石炭世化石,指示库吉拜-洪古勒楞蛇绿岩带是在早石炭世前形成的。

西准噶尔南部以发育增生杂岩为特征,唐巴勒、玛依勒、达拉布特、克拉玛依等蛇绿岩产出在由奥陶系-下石炭统组成的增生杂岩之中,蛇绿岩的锆石 U-Pb 年龄在 531~391Ma 之间(图2),其中克拉玛依蛇绿岩中辉长岩还有一组年轻的锆石 U-Pb 年龄(332Ma,徐新等,2006),可能代表后期某个事件的年龄(朱永峰等,2008)。现有资料显示,达拉布特蛇绿岩是西准噶尔最年轻的蛇绿岩, Sm-Nd 等时线年龄为395Ma (Zhang *et al.*, 1993),锆石 U-Pb 年龄为 391Ma(辜平阳等,2009)。唐巴勒、达拉布特和克拉玛依蛇绿岩中的硅质岩均含有奥陶纪放射虫化石(Buckman and Aitchison, 2001;舒良树和王玉净,2003;何国琦等,2007),而玛依勒蛇绿岩附近原化为泥盆系巴尔雷克组的紫色凝灰质粉砂岩含有丰富的中志留世放射虫化石(李红生,1994)。增生杂岩中最年轻的地层为下石炭统火山沉积岩,其中火山岩的锆石 U-Pb 年龄在 357~328Ma(王瑞和朱永峰,2007;安芳和朱永峰,2009;佟丽莉等,2009;郭丽爽等,2010)。下石炭统火山沉积岩被晚石炭世-早二叠世后碰撞花岗岩侵入(如韩宝福等,2006;苏玉平等,2006b)的同时,达拉布特蛇绿岩也被锆石 U-Pb 年龄为 308Ma 的花岗岩直接侵入(陈石等,2010)。地质关系和花岗岩的定年结果不但表明达拉布特蛇绿岩至少是在 308Ma 之前侵位的(陈石等,2010),这与达拉布特蛇绿岩的 Sm-Nd 等时线年龄(Zhang *et al.*, 1993)和锆石 U-Pb 年龄

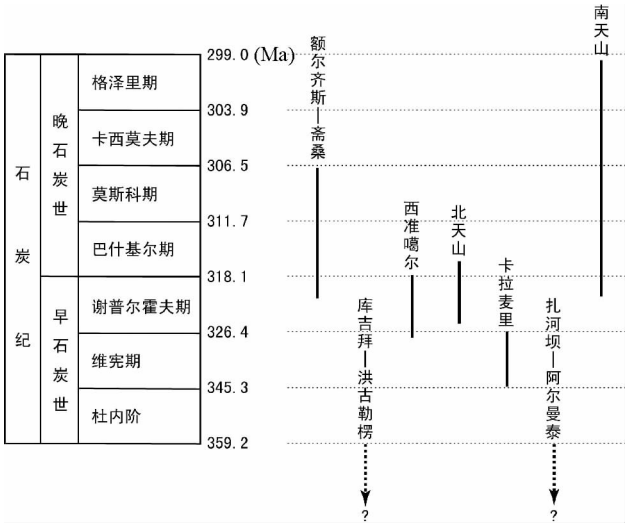


图 7 新疆北部主要缝合带的形成时限

Fig. 7 Timing of major suture zones in North Xinjiang

(辜平阳等,2009)是相容的,同时还说明锆石 U-Pb 年龄为 302Ma 的浅色辉长岩(刘希军等,2009)是在达拉布特蛇绿岩构造侵位后形成的,与达拉布特蛇绿岩两侧的辉长闪长岩、闪长质包体和钾长花岗岩等具有几乎相同的时代(Chen and Arakawa,2005; Geng *et al.*, 2009)。关于浅色辉长岩是否是达拉布特蛇绿岩的组成部分,朱永峰(2009)曾指出,"这些作者提供的照片显示,年龄为 302 Ma 的辉长岩没有变形变质,与达拉布特蛇绿混杂岩达中的变质辉长岩差别很大"。刘希军等(2009)也注意到了浅色辉长岩与研究区内分布较广的碱性花岗岩的时代相近,但认为这些具有 N-MORB、E-MORB 和 OIB 地球化学特征的镁铁质岩石代表了在弧前增生杂岩中形成的海山,与洋壳俯冲作用有关。按照板块构造模式,增生杂岩发育在弧前的弧-沟间隙的构造部位,而这个构造部位一般不会受到与俯冲相关的岩浆作用的影响,除非在(1)俯冲带向洋后退或者俯冲的洋壳板片后退(slab rollback)导致弧岩浆带向洋迁移或(2)碰撞之后俯冲板片断离(slab breakoff)或拆沉等两种可能的动力学背景下,弧前增生杂岩中才可能出现岩浆活动。如果侵入西准噶尔增生杂岩中的年龄约为 300Ma 的侵入岩体与洋壳俯冲过程有关(刘希军等,2009;Geng *et al.*, 2009),说明当时仍然存在着一定规模的洋盆,并意味着区域内应存在更年轻的蛇绿岩或蛇绿混杂岩。然而,在西准噶尔地区目前还没有发现 300Ma 以后的蛇绿岩或蛇绿混杂岩,增生杂岩以北的库吉拜-洪古勒楞蛇绿岩带和额尔齐斯-斋桑缝合带是分别在早石炭世前和晚石炭世形成的,增生杂岩内部的唐巴勒、玛依勒和克拉玛依等蛇绿岩的时代均较老(图 2),而增生杂岩以南的北天山缝合带在 325~316Ma 之间也已经形成。更为重要的是,在西准噶尔地区,约 300Ma 的侵入岩体是呈面状分布的,不但在达拉布特蛇绿混杂带的两侧均有产出,即使在额尔齐斯-斋桑缝合带内以及南至北天山两条缝合带之间的广大区域内,在不同时期形成的各个构造单元中均大量出现,明显不同于由洋壳俯冲作用产生的弧岩浆岩的时空分布特征。

目前的资料显示,侵入西准噶尔增生杂岩中最老的花岗岩的锆石 U-Pb 年龄在 318~315Ma 之间(韩宝福等,2006;陈晔等,2006)。因此,西准噶尔增生杂岩是在 328~318Ma 之间形成的,晚石炭世-早二叠世花岗岩作为钉合岩体产出在增生杂岩之中,这些钉合岩体限定西准噶尔增生杂岩与毗邻地体至少在晚石炭世已经完成了拼合增生过程。当然,西准噶尔增生杂岩中的钉和岩体是后增生的还是后碰撞的,还需要进一步研究才能确定,其中最重要的是要确凿无疑地证实区域内是否存在晚石炭世甚至更年轻的洋壳残余(蛇绿岩或蛇绿混杂岩)或缝合带。

4 结论

造山带中的增生和碰撞事件的时间上限都可以根据最老的钉合岩体来限定,特别是那些直接侵位在缝合带之中的钉合岩体对于限定缝合带的形成时代具有非常重要的大地构造意义。根据重要缝合带中最年轻的蛇绿岩质岩石和最早侵入缝合带的钉合岩体,就能够限定缝合带的形成时代。现有的资料表明新疆北部的主要缝合带的形成时代存在差异,其中额尔齐斯-斋桑缝合带和南天山缝合带都是在晚石炭世形成的,北天山缝合带是在晚石炭世早期形成的,东准噶尔的扎河坝-阿尔曼泰和卡拉麦里蛇绿岩带和西准噶尔的库吉拜-洪古勒楞蛇绿岩带的形成要早些(早石炭世前或更早),西准噶尔增生杂岩也是在晚石炭世形成的(图 7)。但是,西准噶尔晚石炭世-二叠纪是否存在洋壳俯冲还需要进一步研究。即使晚石炭世存在洋壳俯冲,也不能证明新疆北部的造山带形成于中生代。

此外,钉合岩体还有助于判别某些有争议的年代学资料及其解释的合理性,特别是现有的地质资料不支持"南天山西部在晚二叠世仍然有一定规模的(残余)古洋盆的存在",因而南天山是三叠纪碰撞造山带的结论。

致谢 作者感谢评审人对本文提出的意见和建议。

References

Abeleira A, Ansdell KM and Heaman L. 2000. U-Pb and Nd isotope constraints on the evolution of the Tien Shan, Kumtor region, Kyrgyzstan. Geological Society of America Abstracts with Programs, 32: A-32

Alekseev DV, Aristov VA and Degtyarev KE. 2007. The age and tectonic setting of volcanic and cherty sequences in the ophiolite complex of the Atbashe Ridge (Southern Tien Shan). Doklady Earth Sciences, 413A: 380-383

An F and Zhu YF. 2009. SHRIMP U-Pb zircon ages of tuff in Baogutu Formation and their geological significances. Acta Petrologica Sinica, 25: 1437-1445 (in Chinese with English abstract)

Ayers JC, Delacruz K, Miller C *et al.* 2003. Experimental study of zircon

coarsening in quartzite ± H_2O at 1.0GPa and 1000℃, with implications for geochronological studies of high-grade metamorphism. American Mineralogist, 88: 365 – 376

Badarch G, Cunningham WD and Windley BF. 2002. A new terrane subdivision for Mongolia: Implications for the Phanerozoic crustal growth of Central Asia. Journal of Asian Earth Sciences, 21: 87 – 110

Bakirov AB and Kakitaev K. 2000. Information about geology of the Kyrgyz Republic (Kyrgyzstan). International Consortium of Geological Surveys Asia-Pacific Newsletter, No.3: 4 – 12

Baslakunov J, Takasu A, Tagiri M *et al.* 2007. Two modes of occurrence of eclogites from the Atbashy Range, southern Tien-Shan, Kyrgyzstan. 2007AGUFM. V41C0730B

Briggs SM, Yin A, Manning CE *et al.* 2007. Late Paleozoic tectonic history of the Ertix Fault in the Chinese Altai and its implications for the development of the Central Asian Orogenic System. Geological Society of America Bulletin, 119: 944 – 960

Buchan C, Pfänder J, Kröner A *et al.* 2002. Timing of accretion and collisional deformation in the Central Asian orogen: Implications of granite geochronology in the Bayankhongor ophiolite zone. Chemical Geology, 192: 23 – 45

Buckman S and Aitchison JC. 2001. Middle Ordovician (Llandeilan) radiolarians from West Junggar, Xinjiang, China. Micropaleontology, 47: 359 – 367

Buslov MM, Saphonova IYu, Watanabe T *et al.* 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. Geosciences Journal, 5: 203 – 224

Buslov MM, Watanabe T, Fujiwara Y *et al.* 2004. Late Paleozoic faults of the Altai region, Central Asia: Tectonic pattern and model of formation. Journal of Asian Earth Sciences, 23: 655 – 671

Bykadorov VA, Bush VA, Fedorenko OA *et al.* 2003. Ordovician-Permian palaeogeography of central Eurasia: Development of Palaeozoic petroleum-bearing basins. Journal of Petroleum Geology, 26: 325 – 350

Carroll AR, Graham SA, Hendrix MS *et al.* 1995. Late Paleozoic tectonic amalgamation of northwestern China: Sedimentary record of the northern Tarim, northwestern Turpan, and southern Junggar Basins. Geological Society of American Bulletin, 107: 571 – 594

Charvet J, Shu LS and Laurent-Charvet S. 2007. Paleozoic structural and geodynamic evolution of eastern Tianshan (NW China): Welding of the Tarim and Junggar plates. Episodes, 30: 162 – 186

Chen B and Arakawa Y. 2005. Elemental and Nd-Sr isotopic geochemistry of granitoids from the West Junggar foldbelt (NW China), with implications for Phanerozoic continental growth. Geochimica et Cosmochimica Acta, 69: 1307 – 1320

Chen JF, Han BF, Ji JQ *et al.* 2010. Zircon U-Pb ages and tectonic implications of Paleozoic plutons in northern West Junggar, North Xinjiang, China. Lithos, 115: 137 – 152

Chen S and Guo ZJ. 2010. Time constraint and tectonic implication of Dalabute ophiolite and its significance for Late Paleozoic tectonic evolution in West Junggar. Acta Petrologica Sinica, 26: 2336 – 2344 (in Chinese with English abstract)

Chen Y, Sun MX and Zhang XL. 2006. SHRIMP U-Pb dating of zircons from quartz diorite at the southeast side of the Ba'erluke fault, western Junggar, Xinjiang, China. Geological Bulletin of China, 25: 992 – 994 (in Chinese with English abstract)

Coleman RG. 1989. Continental growth of Northwest China. Tectonics, 8: 621 – 635

Coney PJ, Jones DL and Monger JWH. 1980. Cordilleran suspect terranes. Nature, 288: 329 – 333

de Jong K, Wang B, Faure M *et al.* 2008. New $^{40}Ar/^{39}Ar$ age constraints on the Late Palaeozoic tectonic evolution of the western Tianshan (Xinjiang, northwestern China), with emphasis on Permian fluid ingress. International Journal of Earth Sciences, doi 10.1007/s00531 – 008 – 0338 – 8

Dickinson WR. 2008. Accretionary Mesozoic-Cenozoic expansion of the Cordilleran continental margin in California and adjacent Oregon. Geosphere, 4: 329 – 353

Fedorovskii VS, Khain EE, Vladimirov AG *et al.* 1995. Tectonics, metamorphism, and magmatism of collisional zones of the Central Asian Caledonides. Geotectonics, 29: 193 – 212

Fleck RJ and Criss RE. 1985. Strontium and oxygen isotopic variations in Mesozoic and Tertiary plutons of central Idaho. Contributions to Mineralogy and Petrology, 90: 291 – 308

Gao J, Li MS, Xiao XC *et al.* 1998. Paleozoic tectonic evolution of the Tianshan orogen, northwestern China. Tectonophysics, 287: 213 – 231

Gao J, Long LL, Qian Q *et al.* 2006. South Tianshan: A Late Paleozoic or a Triassic orogen? Acta Petrologica Sinica, 22: 1049 – 1061 (in Chinese with English abstract)

Gao J, Long LL, Klemd R *et al.* 2009. Tectonic evolution of the South Tianshan orogen and adjacent regions, NW China: Geochemical and age constraints of granitoid rocks. International Journal of Earth Sciences, doi 10.1007/s00531 – 008 – 0370 – 8

Gardner MC, Bergman SC, Cushing GW *et al.* 1988. Pennsylvanian pluton stitching of Wrangellia and the Alexander terrane, Wrangell Mountains, Alaska. Geology, 16: 967 – 971

Geng HY, Sun M, Yuan C *et al.* 2009. Geochemical, Sr-Nd and zircon U-Pb-Hf isotopic studies of Late Carboniferous magmatism in the West Junggar, Xinjiang: Implications for ridge subduction? Chemical Geology, 266: 364 – 389

Glen RA and VandenBerg AHM. 1987. Thin-skinned tectonics in part of the Lachlan Fold Belt near Delegate, southeastern Australia. Geology, 15: 1070 – 1073

Glorie S, De Grave J, Buslov MM *et al.* 2010. Multi-method chronometric constraints on the evolution of the Northern Kyrgyz Tien Shan granitoids (Central Asian Orogenic Belt): From emplacement to exhumation. Journal of Asian Earth Sciences, 38: 131 – 146

Gray DR and Foster DA. 1997. Orogenic concepts-application and definition: Lachlan fold belt, eastern Australia. American Journal of Science, 297: 859 – 891

Gu PY, Li YJ, Zhang B *et al.* 2009. LA-ICP-MS zircon U-Pb dating of gabbro in the Darbut ophiolite, western Junggar, China. Acta Petrologica Sinica, 25: 1364 – 1372 (in Chinese with English abstract)

Guo LS, Liu YL, Wang ZH *et al.* 2010. The zircon U-Pb LA-ICP-MS geochronology of volcanic rocks in Baogutu area, western Junggar. Acta Petrologica Sinica, 26: 471 – 477 (in Chinese with English abstract)

Han BF, Ji JQ, Song B *et al.* 2006. Late Paleozoic vertical growth of continental crust around the Junggar Basin, Xinjiang, China (Part Ⅰ): Timing of post-collisional plutonism. Acta Petrologica Sinica, 22: 1077 – 1086 (in Chinese with English abstract)

Han BF, Guo ZJ, Zhang ZC *et al.* 2010. Age, geochemistry, and tectonic implications of a Late Paleozoic stitching pluton in the North Tian Shan suture zone, western China. Geological Society of America Bulletin, 122: 627 – 640

He GQ, Liu JB, Zhang QY *et al.* 2007. Keramay ophiolitic mélange formed during Early Paleozoic in western Junggar basin. Acta Petrologica Sinica, 23: 1573 – 1576 (in Chinese with English abstract)

Hegner E, Klemd R, Kröner A *et al.* Mineralogy ages and *P-T* conditions of Late Paleozoic high-pressure eclogite and provenance of mélange sediments in the South Tianshan Orogen of Kyrgyzstan. American Journal of Science (in press)

Hendrix MS, Dumitru TA and Graham SA. 1994. Late Oligocene-Early Miocene unroofing in the Chinese Tien Shan: An early effect of the India-Asia collision. Geology, 22: 487 – 490

Hendrix MS. 2000. Evolution of Mesozoic sandstone compositions, southern Junggar, northern Tarim, and western Turpan basins, Northwest China: A detrital record of the ancestral Tian Shan. Journal of Sedimentary Research, 70: 520 – 532

Hoskin PWO and Black LP. 2000. Metamorphic zircon formation by solid-state recrystallization of protolith igneous zircon. Journal of Metamorphic Geology, 18: 423 – 439

Igemberdiyev SA *et al*. 1980. Geological Map of Kyrgyzstan SSR (in Russian)

Iwata K, Watanabe T, Akiyama M *et al*. 1994. Paleozoic microfossils from the Chara Belt (eastern Kazakhstan). Russian Geology and Geophysics, 35: 145 – 151 (in Russian)

Iwata K, Obut OT and Buslov MM. 1997. Devonian and Lower Carboniferous radiolarian from the Chara ophiolite belt, East Kazakhstan. News of Osaka Micropaleontologist, 10: 27 – 32

Jahn BM, Wu FY and Chen B. 2000. Massive granitoid generation in Central Asia: Nd isotope evidence and implication for continental growth in the Phanerozoic. Episodes, 23: 82 – 92

Jian P, Liu DY, Shi YR *et al*. 2005. SHRIMP dating of SSZ ophiolites from northern Xinjiang Province, China: Implications for generation of oceanic crust in the Central Asian orogenic belt. In: Sklyarov EV (ed.). Structural and Tectonic Correlation across the Central Asia Orogenic Collage: North-Eastern Segment. Guidebook and Abstract Volume of the Siberian Workshop IGCP-480: Irkutsk, Institute of the Earth Crust, Siberian Branch of Russian Academy of Sciences, 246

Jones DL, Howell DG, Coney PJ *et al*. 1983. Recognition, character and analysis of techonostratigraphic terranes in western North America. In: Hashimoto M and Uyeda S (eds.). Accretion Tectonics in the Circum-Pacific Regions. Tokyo: Terra Scientific Publishing Company, 21 – 35

Kelty TK, Yin A, Dash B *et al*. 2008. Detrital-zircon geochronology of Paleozoic sedimentary rocks in the Hangay-Hentey basin, north-central Mongolia: Implications for the tectonic evolution of the Mongol-Okhotsk Ocean in central Asia. Tectonophysics, 451: 290 – 311

Khain EV, Bibokova EV, Kröner A *et al*. 2002. The most ancient ophiolites of the Central Asian fold belt: U-Pb and Pb-Pb zircon ages for the Dunzhugur complex, Eastern Sayan, Siberia, and geodynamic implications. Earth and Planetary Science Letters, 199: 311 – 325

Khain EV, Bibikova EV, Salnikova EE *et al*. 2003. The Palaeo-Asian ocean in the Proterozoic and Early Palaeozoic: New geochronologic data and palaeotectonic reconstructions. Precambrian Research, 122: 329 – 358

Kheraskova TN, Didenko AN, Bush VA *et al*. 2003. The Vendian-Early Paleozoic history of the continental margin of eastern Paleogondwana, Paleoasian Ocean, and Central Asian foldbelt. Russian Journal of Earth Sciences, 5: 165 – 184

Konopelko D, Biske G, Seltmann R *et al*. 2007. Hercynian post-collisional A-type granites of the Kokshaal Range, Southern Tien Shan, Kyrgyzstan. Lithos, 97: 140 – 160

Konopelko D, Seltmann R, Biske G *et al*. 2009. Possible source dichotomy of contemporaneous post-collisional barren I-type versus tin-bearing A-type granites, lying on opposite sides of the South Tien Shan suture. Ore Geology Reviews, 35: 206 – 216

Kovalenko VI, Yarmolyuk VV, Kovach VP *et al*. 2004. Isotopic provinces, mechanism of generation and sources of the continental curst in the Central Asian mobile belt: Geological and isotopic evidence. Journal of Asian Earth Sciences, 23: 605 – 627

Kuibida ML, Kruk NN, Vladimirov AG *et al*. 2009. U-Pb isotopic age, composition, and sources of the plagiogranites of the Kalba Range, Eastern Kazakhstan. Doklady Earth Sciences, 424: 72 – 76

Li HS. 1994. Middle Silurian radiolarians from Keerhada, Xinjiang. Acat Micropalaeontology Sinica, 11: 259 – 272 (in Chinese with English abstract)

Li JB, Wei YF, Du HX *et al*. 2009. Geochemical characteristics of the Lower Permian Xiaotikanlike Formation volcanic rocks in southwestern Tianshan. Xinjiang Geology, 27: 315 – 319 (in Chinese with English abstract)

Li JY, Zhu BQ and Feng YM. 1989. Discovery of the unconformity between the Nanmingshui Formation and ophiolites and their significance. Regional Geology of China, 8(3): 250 – 255 (in Chinese with English abstract)

Li JY, Xiao XC, Tang YQ *et al*. 1990. Main characteristics of Late Paleozoic plate tectonics in the southern part of East Junggar, Xinjiang. Geological Review, 36(4): 305 – 315 (in Chinese with English abstract)

Li JY. 2004. Late Neoproterozoic and Paleozoic tectonic framework and evolution of eastern Xinjiang, NW China. Geological Review, 50: 304 – 322 (in Chinese with English abstract)

Li W, Hu JM, Gao W *et al*. 2007. Discovery of a Devonian-Lower Carboniferous radiolarian assemblage in the Korgan area, South Tianshan Mountains. Geology in China, 34: 584 – 591 (in Chinese with English abstract)

Li YJ, Wang ZM, Wu HR *et al*. 2002. Discovery of radiolarian fossils from the Aiketik Group distributed at the western end of the South Tianshan Mountains of China and its implications. Acta Geologica Sinica, 76: 146 – 153

Li YJ, Wang ZM, Mai GR, Wu HR, Huang ZB and Tan ZJ. 2002. New discovery of radiolarian fossils from Aiktik Group at in Tarim Basin and its significance. Xinjiang Petroleum Geology, 23(6): 496 – 500 (in Chinese with English abstract)

Li YJ, Sun LD, Wu HR *et al*. 2004. Radiolarian fossils from chert gravels of Triassic conglomerate in NW margin of the Tarim Basin and their geological significance. Chinese Journal of Geology, 39: 153 – 158 (in Chinese with English abstract)

Li YJ, Sun LD, Wu HR *et al*. 2005. Permo-Carboniferous radiolarians from the Wupata'erkan Group, western South Tianshan, Xinjiang, China. Acta Geologica Sinica, 79: 16 – 23

Li YJ, Sun LD, Wu HR, Wang GL, Yang CS and Peng GX. 2005. Permo-Carboniferous radiolarian from the Wupatarkan Group, west terminal of Chinese South Tianshan. Chinese Journal of Geology, 40(2): 220 – 226, 236 (in Chinese with English abstract)

Li YJ, Yang HJ, Zhao Y *et al*. 2009. Tectonic framework and evolution of South Tianshan, NW China. Geotectonica et Metallogenia, 33: 94 – 104 (in Chinese with English abstract)

Liu B and Qian YX. 2003. The geologic characteristics and fluid evolution in the three high-pressure metamorphic belts of eastern Tianshan. Acta Petrologica Sinica, 19: 283 – 292 (in Chinese with English abstract)

Liu CX, Xu BL and Zhou TR. 2004. Petrochemistry and tectonic significance of Hercynian alkaline rocks along the northern margin of the Tarim platform and its adjacent area. Xinjiang Geology, 22: 43 – 49 (in Chinese with English abstract)

Liu XJ, Xu JF, Wang SQ *et al*. 2009. Geochemistry and dating of E-MORB type mafic rocks from the Dalabute ophiolite in West Junggar, Xinjiang and geological implications. Acta Petrologica Sinica, 25: 1373 – 1389 (in Chinese with English abstract)

Liu Y, Wang NW and Yao JX. 1994. New data of radiolarian and its significance in the Kuqa area, Xinjiang. Xinjiang Geology, 12: 344 – 350 (in Chinese with English abstract)

Liu Y. 2001. Early Carbonferous radiolarian Fauna from Heiyingshan, south of the Tianshan Mountains and its geotectonic significance. Acta Geologica Sinica, 75: 101 – 108

Liu Y and Hao SG. 2006. Evolutionary significance of pylentonemid radiolarians and their Late Devonian species from southwestern Tianshan, China. Acta Geologica Sinica, 80: 647 – 655

Long LL, Gao J, Xiong XM *et al*. 2006. The geochemical characteristics and the age of the Kule Lake ophiolite in the southern Tianshan. Acta Petrologica Sinica, 22: 65 – 73 (in Chinese with English abstract)

Luo JH, Che ZC, Cao YZ *et al*. 2008. Geochemical and geochronological characteristics and its tectonic significance of Early Permian acid volcanic tocks of Xiaotikanlike Formation in the southern margin of South Tianshan orogen, NW China. Acta Petrologica Sinica, 24: 2281 – 2288 (in Chinese with English abstract)

Ma ZP, Xia LQ, Xu XY *et al*. 2007. Dating for zircons of gabbro from Kulehu ophiolite, southern Tianshan, and its geological implication. Journal of Northwest University (Natural Science Edition), 37: 107 – 110 (in Chinese with English abstract)

Mittwede SK. 1988. Ultramafites, melanges, and stitching granites as suture markers in the central Piedmont of the southern Appalachians. Journal of Geology, 96: 693 – 707

Mossakovsky AA, Ruzhentsev SV, Samygin SG *et al.* 1993. Central Asian fold belt: Geodynamic evolution and history of formation. Geotectonics, 6: 3 – 33

Murphy JB and Nance RD. 1991. Supercontinent model for the contrasting character of Late Proterozoic orogenic belts. Geology, 19: 469 – 472

Reese JF, Mosher S, Connelly J *et al.* 2000. Mesoproterozoic chronostratigraphy of the southeastern Llano uplift, central Texas. Geological Society of America Bulletin, 112: 278 – 291

Ren R, Han BF, Ji JQ *et al.* 2010. U-Pb age spectra of detrital zircon from the Tekes River, Xinjiang, China, and implications for tectonomagmatic evolution of the South Tian Shan Orogen. Gondwana Research, doi:10.1016/j.gr.2010.07.005

Ryan B. 2000. The Nain-Churchill boundary and the Nain plutonic suite: A regional perspective on the geologic setting of the Voisey's Bay Ni-Cu-Co deposit. Economic Geology, 95: 703 – 724

Schermer ER, Howell DG and Jones DL. 1984. The origin of allochthonous terranes: Perspectives on the Growth and Shaping of Continents. Annual Review of Earth and Planetary Sciences, 12: 107 – 131

Sengör AC, Natal'in BA and Burtman VS. 1993. Evolution of the Altaid tectonic collage and Palaeozoic crustal growth in Eurasia. Nature, 364: 299 – 306

Sengör AC and Natal'in BA. 1996. Turkic-type orogeny and its role in the making of continental crust. Annual Review of Earth and Planetary Sciences, 24: 263 – 337

Shu LS and Wang YJ. 2003. Late Devonian-Early Carboniferous radiolarian fossils from siliceous rocks of the Kelameili ophiolite, Xinjiang. Geological Review, 49: 408 – 412 (in Chinese with English abstract)

Shu LS, Wang B and Zhu WB. 2007. Age and tectonic significance of radiolarian fossils from the Heiyingshan ophiolitic mélange, southern Tianshan Belt, NW China. Acta Geologica Sinica, 81: 1 – 8 (in Chinese with English abstract)

Simonov VA, Sakiev KS, Volkova NI *et al.* 2008. Conditions of formation of the Atbashi Ridge eclogites (South Tien Shan). Russian Geology and Geophysics, 49: 803 – 815

Solomovich LI and Trifonov BA. 2002. Postcollisional granites in the South Tien Shan Variscan collisional belt, Kyrgyzstan. Journal of Asian Earth Sciences, 21: 7 – 21

Solomovich LI. 2007. Postcollisional magmatism in the South Tien Shan Variscan Orogenic Belt, Kyrgyzstan: Evidence for high-temperature and high-pressure collision. Journal of Asian Earth Sciences, 30: 142 – 153

Su W, Gao J, Klemd R *et al.* 2010. U-Pb zircon geochronology of Tianshan eclogites in NW China: Implication for the collision between the Yili and Tarim blocks of the southwestern Altaids. European Journal of Mineralogy, 22(4): doi: 10.1127/0935 – 1221/2010/0022 – 2040

Su YP, Tang HF, Liu CQ *et al.* 2006a. The determination and a preliminary study of Sujiquan aluminous A-type granites in East Junggar, Xinjiang. Acta Petrologica et Mineralogica, 25: 175 – 184 (in Chinese with English abstract)

Su YP, Tang HF, Hou GS *et al.* 2006b. Geochemistry of aluminous A-type granites along Darabut tectonic belt in West Junggar, Xinjiang. Geochimica, 35: 55 – 67 (in Chinese with English abstract)

Tagiri M, Yano T, Bakirov A *et al.* 1995. Mineral parageneses and metamorphic *P-T* paths of ultrahigh-pressure eclogites from Kyrghyzstan Tien-Shan. Island Arc, 4: 280 – 292

Tang HF, Su YP, Liu CQ *et al.* 2007. Zircon U-Pb age of the plagiogranite in Kalamaili belt, northern Xinjiang, and its tectonic implications. Geotectonica et Metallogenia, 31: 110 – 117

Tong LL, Li YJ, Zhang B *et al.* 2009. Zircon LA-ICP-MS U-Pb dating and geologic age of the Baogutu Formation andesite in the south of Daerbute faulted zone, western Junggar. Xinjiang Geology, 27: 226 – 230 (in Chinese with English abstract)

Trop JM, Szuch DA, Rioux M *et al.* 2005. Sedimentology and provenance of the Upper Jurassic Naknek Formation, Talkeetna Mountains, Alaska: Bearings on the accretionary tectonic history of the Wrangellia composite terrane. Geological Society of America Bulletin, 117: 570 – 588

van Staal CR, Dewey JF, MacNiocaill C *et al.* 1998. The Cambrian-Silurian tectonic evolution of the northern Appalachians and British Caledonides: History of a complex, west and southwest Pacific-type segment of Iapetus. In: Blundell DJ and Scott AC (eds.). Lyell: The Past is the Key to the Present. Geological Society, London, Special Publications, 143: 199 – 242

Vladimirov AG, Kruk NN, Khromykh SV *et al.* 2008. Permian magmatism and lithospheric deformation in the Altai caused by crustal and mantle thermal processes. Russian Geology and Geophysics, 49: 468 – 479

Volkova NI and Sklyarov EV. 2007. High-pressure complexes of Central Asian fold belt: Geologic setting, geochemistry, and geodynamic implications. Russian Geology and Geophysics, 48: 83 – 90

Wang C, Liu L, Che ZC *et al.* 2007a. Geochronology, petrogenesis and significance of Baleigong mafic rocks in Kokshal segment, southwestern Tianshan Mountains. Geological Review, 53: 743 – 753 (in Chinese with English abstract)

Wang C, Liu L, Luo JH *et al.* 2007b. Late Paleozoic post-collisional magmatism in the southwestern Tianshan orogenic belt, take the Baleigong pluton in the Kokshal region as an example. Acta Petrologica Sinica, 23: 1830 – 1740 (in Chinese with English abstract)

Wang R and Zhu YF. 2007. Geology of the Baobei gold deposit in western Junggar and zircon SHRIMP age of its wall-rocks, western Junggar (Xinjiang, NW China). Geological Journal of China Universities, 13: 590 – 602 (in Chinese with English abstract)

Wang ZX, Wu JY, Lu XC *et al.* 1990. Polycyclic Tectonic Evolution and Metallogeny of the Tianshan Mountains. Beijing: Science Press, 1 – 217 (in Chinese)

Whalen JB, McNicoll VJ, van Staal CR *et al.* 2006. Spatial, temporal and geochemical characteristics of Silurian collision-zone magmatism, newfoundland appalachians: An example of a rapidly evolving magmatic system related to slab break-off. Lithos, 89: 377 – 404

Whattam SA, Malpas J, Smith IEM *et al.* 2006. Link between SSZ ophiolite formation, emplacement and arc inception, Northland, New Zealand: U-Pb SHRIMP constraints; Cenozoic SW Pacific tectonic implications. Earth and Planetary Science Letters, 250: 606 – 632

Windley BF, Allen MB, Zhang C *et al.* 1990. Paleozoic accretion and Cenozoic redeformation of the Chinese Tien Shan range, central Asia. Geology, 18: 128 – 131

Windley BF. 1992. Proterozoic collisional and accretionary orogens. In: Condie KC (ed.). Proterozoic Crustal Evolution: Developments in Precambrian Geology. Amsterdam: Elsevier, 419 – 446

Windley BF, Alexeiev D, Xiao WJ *et al.* 2007. Tectonic models for accretion of the Central Asian Orogenic Belt. Journal of the Geological Society of London, 164: 31 – 47

Xiao WJ, Windley BF, Yan QR *et al.* 2006. SHRIMP zircon age of the Aermantai ophiolite in the North Xinjiang area, China and its tectonic implications. Acta Geologica Sinica, 80: 32 – 37 (in Chinese with English abstract)

Xiao WJ, Han CM, Yuan C *et al.* 2008. Middle Cambrian to Permian subduction-related accretionary orogenesis of northern Xinjiang, NW China: Implications for the tectonic evolution of central Asia. Journal of Asian Earth Sciences, 32: 102 – 117

Xiao WJ, Windley BF, Huang BC *et al.* 2009. End-Permian to Mid-Triassic termination of the accretionary processes of the southern Altaids: Implications for the geodynamic evolution, Phanerozoic continental growth, and metallogeny of Central Asia. International Journal of Earth Sciences, doi 10.1007/s00531 – 008 – 0407 – z

Xiao XC, Tang YQ, Feng YM *et al.* 1992. Tectonic Evolution of Northern Xinjiang and Its Adjacent Regions: Beijing: Geological Publishing House, 1 – 169 (in Chinese)

Xu X, He GQ, Li HQ *et al.* 2006. Basic characteristics of the Karamay ophiolitic mélange, Xinjiang, and its zircon SHRIMP dating. Geology in China, 33: 470 – 475 (in Chinese with English abstract)

Xu XY, Ma ZP, Xia LQ *et al*. 2005. SHRIMP dating of plagiogranites from Bayingou ophiolite in the northern Tianshan Mountains. Geological Review, 22: 523 – 527 (in Chinese with English abstract)

Xu XY, Li XM, Ma ZP *et al*. 2006. LA-ICPMS zircon U-Pb dating of gabbro from the Bayingou ophiolite in the northern Tianshan Mountains. Acta Geologica Sinica, 80: 1168 – 1176 (in Chinese with English abstract)

Yakubchuk A. 2004. Architecture and mineral deposit settings of the Altaid orogenic collage: A revised model. Journal of Asian Earth Sciences, 23: 761 – 779

Yang FQ, Wang LB, Ye JH *et al*. 2001. Zircon U-Pb ages of granites in the Huoshi Bulak area, Xinjiang. Regional Geology of China, 20: 267 – 273 (in Chinese with English abstract)

Yang PR, Gu SZ, Zhu ZM *et al*. 2007. Pebbles in radiolarian cherts from the Lower Jurassic in the Kamustte area at the northeastern margin of the Junggar basin, Xinjiang, China and the radiolarian fauna therein. Geological Bulletin of China, 26: 472 – 475 (in Chinese with English abstract)

Zhang C, Zhai MG, Allen MB *et al*. 1993. Implications of Palaeozoic ophiolites from Western Junggar, NW China, for the tectonics of Central Asia. Journal of the Geological Society, London, 150: 551 – 561

Zhang HX, Niu HC, Terada K *et al*. 2003. Zircon SHRIMP U-Pb dating on plagiogranite from the Kuerti ophiolite in Altay, North Xinjiang. Chinese Science Bulletin, 48: 2231 – 2235

Zhang JE, Xiao WJ, Han CM *et al*. 2009. Fold- and thrust- structure in Yeyagou area, western Junggar, China and its implication. Geological Bulletin of China, 28: 1894 – 1903 (in Chinese with English abstract)

Zhang LF, Ai YL, Li XP *et al*. 2007. Triassic collision of western Tianshan orogenic belt, China: Evidence from SHRIMP U-Pb dating of zircon from HP/UHP eclogitic rocks. Lithos, 96: 266 – 280

Zhang YY and Guo ZJ. 2008. Accurate constraint on formation and emplacement age of Hongliuhe ophiolite, boundary region between Xinjiang and Gansu provinces and its tectonic implications. Acta Petrologica Sinica, 24: 803 – 809 (in Chinese with English abstract)

Zhang YY and Guo ZJ. 2010. New constraints on formation ages of ophiolites in northern Junggar and comparative study on their connection. Acta Petrologica Sinica, 26: 421 – 430 (in Chinese with English abstract)

Zhou DW, Su L, Jian P *et al*. 2004. Zircon U-Pb SHRIMP ages of high-pressure granulite in Yushugou ophiolitic terrane in southern Tianshan and their tectonic implications. Chinese Science Bulletin, 49: 1415 – 1419

Zhu YF and Xu X. 2006. The discovery of Early Ordovician ophiolite mélange in Taerbahatai Mts., Xinjiang, NW China. Acta Petrologica Sinica, 22: 2833 – 2842 (in Chinese with English abstract)

Zhu YF, Xu X, Chen B *et al*. 2008. Dolomite marble and garnet amphibolite in the ophiolitic mélange in western Junggar: Relics of the Early Paleozoic oceanic crust and its deep subduction. Acta Petrologica Sinica, 24: 2767 – 2777 (in Chinese with English abstract)

Zhu YF. 2009. Some important issues for the studies on the Central Asian Metallogeny Domain. Acta Petrologica Sinica, 25: 1297 – 1302 (in Chinese with English abstract)

Zonenshain LP, Kuzmin MI and Natapov LM. 1990. Geology of the USSR: A Plate-Tectonic Synthesis. American Geophysical Union, Washington D. C., 1 – 242

附中文参考文献

安芳,朱永峰. 2009. 新疆西准噶尔包古图组凝灰岩锆石 SHRIMP 年龄及其地质意义. 岩石学报,25(6): 1437 – 1445

陈石,郭召杰. 2010. 达拉布特蛇绿岩带的时限和属性以及对西准晚古生代构造演化的讨论. 岩石学报,26(8): 2336 – 2344

陈晔,孙明新,张新龙. 2006. 西准噶尔巴尔鲁克断裂东南侧石英闪长岩锆石 SHRIMP U-Pb 测年. 地质通报,25(8): 992 – 994

高俊,龙灵利,钱青,黄德志,苏文, Klemd R. 2006. 南天山:晚古生代还是三叠纪碰撞造山带? 岩石学报,22(5): 1049 – 1061

辜平阳,李永军,张兵,佟丽莉,王军年. 2009. 西准达尔布特蛇绿岩中辉长岩 LA-ICP-MS 锆石 U-Pb 测年. 岩石学报,25(6): 1364 – 1372

郭丽爽,刘玉琳,王政华,宋达,许发军,苏犁. 2010. 西准噶尔包古图地区地层火山岩锆石 LA-ICP-MS U-Pb 年代学. 岩石学报,26(2): 471 – 477

韩宝福,季建清,宋彪,陈立辉,张磊. 2006. 新疆准噶尔晚古生代陆壳垂向生长(Ⅰ)——后碰撞深成岩浆活动的时限. 岩石学报,22(5): 1077 – 1086

何国琦,刘建波,张越迁,徐新. 2007. 准噶尔盆地西缘克拉玛依早古生代蛇绿混杂岩带的厘定. 岩石学报,23(7): 1573 – 1576

李红生. 1994. 新疆克尔哈达中志留世放射虫. 微体古生物学报,11(2): 259 – 272

李建兵,魏永峰,杜红星,孙涛. 2009. 西南天山下二叠统小提坎立克组火山岩地球化学特征. 新疆地质,27(4): 315 – 319

李锦轶,朱宝清,冯益民. 1989. 南明水组和蛇绿岩之间不整合关系的确认及其意义. 中国区域地质,8(3): 250 – 255

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. 地质论评,36(4): 305 – 315

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. 地质论评,50(3): 304 – 322

李玮,胡健民,高卫,李红生,朱志新. 2007. 新疆南天山库尔干一带泥盆纪-早石炭世放射虫组合的发现. 中国地质,34(4): 584 – 591

李曰俊,王招明,买光荣,吴浩若,黄智斌,谭泽金. 2002. 塔里木盆地艾克提克群中放射虫化石及其意义. 新疆石油地质,23(6): 496 – 500

李曰俊,孙龙德,吴浩若,王国林,苏玉山,黄智斌. 2004. 塔里木盆地西北缘三叠系硅岩砾石中的放射虫化石及其地质意义木. 地质科学,39(2): 153 – 158

李曰俊,孙龙德,吴浩若,王国林,杨朝世,彭更新. 2005. 南天山西端乌帕塔尔坎群发现石炭-二叠纪放射虫化石. 地质科学,40(2): 220 – 226, 236

李曰俊,杨海军,赵岩,罗俊成,郑多明,刘亚雷. 2009. 南天山区域大地构造与演化. 大地构造与成矿学,33(1): 94 – 104

刘斌,钱一雄. 2003. 东天山三条高压变质带地质特征和流体作用. 岩石学报,19(2): 283 – 296

刘楚雄,许保良,邹天人,路凤香,童英,蔡剑辉. 2004. 塔里木北缘及邻区海西期碱性岩岩石化学特征及其大地构造意义. 新疆地质,22(1): 43 – 49

刘希军,许继峰,王树庆,侯青叶,白正华,雷敏. 2009. 新疆西准噶尔达拉布特蛇绿岩 E-MORB 型镁铁质岩的地球化学、年代学及其地质意义. 岩石学报, 25(6): 1373 – 1389

刘羽,王乃文,姚建新. 1994. 新疆库车地区放射虫新资料及其意义. 新疆地质,12(4): 344 – 350

龙灵利,高俊,熊贤明,钱青. 2006. 南天山库勒湖蛇绿岩地球化学特

征及其年龄. 岩石学报,22(1): 65 -73
罗金海,车自成,曹远志,张敬艺. 2008. 南天山南缘早二叠世酸性火山岩的地球化学、同位素年代学及其构造意义. 岩石学报,24(10): 2281 -2288
马中平,夏林圻,徐学义,李向民,夏祖春,王立社. 2007. 南天山库勒湖蛇绿岩锆石年龄及其地质意义. 西北大学学报(自然科学版),37(1): 107 -110
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. 地质论评,49(4): 408 -412
舒良树,王博,朱文斌. 2007. 南天山蛇绿混杂岩中放射虫化石的时代及其构造意义. 地质学报,81(9): 1161 -1168
苏玉平,唐红峰,刘丛强,侯广顺,梁莉莉. 2006a. 新疆西准噶尔达拉布特构造带铝质 A 型花岗岩的地球化学研究. 岩石矿物学杂志,25(3): 175 -184
苏玉平,唐红峰,侯广顺,刘丛强. 2006b. 新疆西准噶尔达拉布特构造带铝质 A 型花岗岩的地球化学研究. 地球化学,35(1): 55 -67
唐红峰,苏玉平,刘丛强,侯广顺,王彦斌. 2007. 新疆北部卡拉麦里斜长花岗岩的锆石 U-Pb 年龄及其构造意义. 大地构造与成矿学,31(1): 110 -117
佟丽莉,李永军,张兵,刘静,庞振甲,王军年. 2009. 新疆西准噶尔达尔布特断裂带南包古图组安山岩 LA-ICP-MS 锆石 U-Pb 测年及地质时代. 新疆地质,27(3): 226 -230
王超,刘良,车自成,罗金海,张静艺. 2007a. 西南天山阔克萨彦岭巴雷公镁铁质岩石的地球化学特征、LA-ICP-MS U-Pb 年龄及其大地构造意义. 地质论评,53(6): 743 -754
王超,刘良,罗金海,车自成,滕志宏,曹宣铎,张静艺. 2007b. 西南天山晚古生代后碰撞岩浆作用:以阔克萨彦岭地区巴雷公花岗岩为例. 岩石学报,23(8): 1830 -1840
王瑞,朱永峰. 2007. 西准噶尔宝贝金矿地质与容矿火山岩的锆石 SHRIMP 年龄. 高校地质学报,13(3): 590 -602
王作勋,邬继易,吕喜期,张经国,刘成德. 1990. 天山多旋回构造深化及成矿. 北京:科学出版社,1 -217
肖文交, Windley BF, 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. 地质学报,80(1): 32 -37
肖序常, 汤耀庆, 冯益民, 朱宝清, 李锦轶, 赵民. 1992. 新疆北部及邻区大地构造. 北京: 地质出版社, 1 -169
徐新,何国琦,李华芹,丁天府,刘兴义,梅绍武. 2006. 克拉玛依蛇绿混杂岩带的基本特征和锆石 SHRIMP 年龄信息. 中国地质,33(3): 470 -475
徐学义,马中平,夏林圻,王彦斌,李向民,夏祖春,王立社. 2005. 北天山巴音沟蛇绿岩斜长花岗岩锆石 SHRIMP 测年及其意义. 地质论评,51(5): 523 -527
徐学义,李向民,马中平,夏林圻,夏祖春,彭素霞. 2006. 北天山巴音沟蛇绿岩形成于早石炭世:来自辉长岩 LA-ICPMS 锆石 U-Pb 年龄的证据. 地质学报,80(8): 1168 -1176
杨富全,王立,叶锦华,傅旭杰,李惠民. 2001. 新疆霍什布拉克地区花岗岩锆石 U-Pb 年龄. 地质通报,20(3): 267 -273
杨品荣,顾松竹,朱宗敏,林文娇,冯庆来. 2007. 准噶尔盆地东北缘卡姆斯特地区下侏罗统中的放射虫硅质岩砾石及其放射虫动物群. 地质通报,26(4): 472 -475
张海祥,牛贺才,于学元. 2003. 新疆北部阿尔泰地区库尔提蛇绿岩中斜长花岗岩的 SHRIMP 年代学研究. 科学通报,48(12): 1350 -1354
张继恩,肖文交,韩春明,毛启贵,敖松坚他,郭谦谦. 2009. 西准噶尔野鸭沟地区褶皱冲断构造的特征及意义. 地质通报,28(12): 1894 -1903
张元元,郭召杰. 2008. 甘新交界红柳河蛇绿岩形成和侵位年龄的准确限定及大地构造意义. 岩石学报,24(4):803 -809
张元元,郭召杰. 2010. 准噶尔北部蛇绿岩形成时限新证据及东、西准噶尔蛇绿岩的对比研究. 岩石学报,26(2):421 -430
周鼎武,苏犁,简平,王润三,柳小明,陆关祥,王居里. 2004. 南天山榆树沟蛇绿岩地体中高压麻粒岩 SHRIMP 锆石 U-Pb 年龄及构造意义. 科学通报,49(14): 1411 -1415
朱永峰,徐新. 2006. 新疆塔尔巴哈台山发现早奥陶世蛇绿混杂岩. 岩石学报,22(12): 2833 -2842
朱永峰,徐新,陈博,薛云兴. 2008. 西准噶尔蛇绿混杂岩中的白云石大理岩和石榴角闪岩:早古生代残余洋壳深俯冲的证据. 岩石学报,24(12): 2767 -2777
朱永峰. 2009. 中亚成矿域地质矿产研究的若干重要问题. 岩石学报,25(6): 1290 -1302