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吉中地区晚古生代腕足动物古生物地理与环境的协同演化*

李　宁**　王成文
(吉林大学地球科学学院，长春 130061，lining@jlu.edu.cn)

提要　吉中地区发育了普里道利期—洛霍考夫期 *Retziella*、杜内期通气沟组以及空谷期—沃德期哲斯等腕足动物群。前两者属于“暖水”动物群、后者属于“凉水”动物群。同时参考珊瑚和䗴等动物群分析，说明吉中地区从普里道利期至阿瑟尔期发育“暖水”动物群，从空谷期到沃德期发育“凉水”动物群。“凉、暖”转换是以寿山沟组的 *Monodiexodina* 动物群为代表，发生在萨克马尔期。“凉、暖”水动物群的发育及其转换是构造古地理与气候变化双重因素导致的结果。晚志留世—早泥盆世，西伯利亚板块、哈萨克斯坦板块、佳-蒙地块均位于中—低纬度带。吉中地区晚志留世—早泥盆世(乃至中泥盆世)腕足动物群属于“暖水”动物群，古生物地理区划属于中-澳生物地理区。石炭纪，东欧板块东北缘、哈萨克斯坦板块大部分地区、佳-蒙地块南缘属于特提斯洋北缘构造域，发育了特提斯洋北缘腕足动物群，形成了特提斯北缘生物地理区，吉中地区腕足动物群属于这一生物地理区。空谷期—沃德期凉水型哲斯腕足动物群的形成是由于佳-蒙地块西端与塔里木板块以及华北板块西端拼合，形成了西拉木伦洋构造域，以及此时期全球降温事件导致的结果。古生物地理、构造古地理以及古气候之间的协同演化关系表明吉中地区晚古生代地层应属于佳-蒙地块南缘的大陆边缘沉积。

关键词　腕足动物　古生物地理　构造古地理　卡鲁冰期　佳-蒙地块　吉中

吉中地区晚古生代地层的大陆边缘归属备受关注，认识多有不同乃至相左。在西拉木伦河-延吉缝合线通过吉中的具体位置、地层区划归属、古生物地理性质等众多方面均存争议。

任纪舜等(1999)、王友勤等(1997)将西拉木伦河-延吉缝合线置于长春以北，认为(或暗示)吉中地区属于华北板块(北缘)。王成文等(2008)、李宁等(2010)将该缝合线置于长春以南的桦甸-磐石一线，认为吉中地区属于佳-蒙地块南缘。迄今为止在本地区仍未发现可靠的蛇绿岩套、混杂堆积等缝合线的直接证据，上述结论多出于对地层、古生物地理性质分析的结果。

李文国等(1996)、李东津(1997)等将吉中地区晚古生代地层归入华北地层大区，王成文等(2008)、Wang 等(2009)、李宁等(2010)将其归入佳-蒙地层大区，问题的焦点依然是吉中地区的大陆边缘归属。众所周知，华北板块之上缺失志留纪—早石炭世沉积，二叠纪沉积均为陆相，岩石地层发育的总体特征与吉中地区没有可比性；对应的华北北缘亦缺少确切的晚古生代地层(或是原来就不发育；或是消减掉了；或是强烈的变质、变形已经面目全非而无法识别，至少目前仍未可知)。所以将吉中地区晚古生代地层划归华北地层大区并不是岩石地层特征对比的结果，而是更多的考虑了古生物地理信息。

主张吉中地区属于华北北缘的核心理由是：早泥盆世—晚石炭世这一地区出现了“暖水”动物群。廖卫华等(1995)将吉中上志留统西别河组腕足动物群称为 *Retziella* 动物群，认为：“正好是在华北板块的北缘”。王成文等(2008)、Wang 等(2009，2012)根据中二叠世哲斯腕足动物群属于“凉水”动物群、自成一个地理区等特征，认为哲斯组及其相当的地层属于佳-蒙地块南缘大陆边缘沉积。同一地区不同时期出现了“凉水”、“暖水”不同性质动物群的形成机制就成为解决问题的关键。

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** 通讯作者。

古生物地理学为大陆漂移和板块构造理论的发展提供了关键证据(Hallam,1981;王乃文,1984)。古生物地理信息在大陆岩石圈板块重建中具有重要作用(王鸿祯,1981;王鸿祯等,1990;殷鸿福,1988;Scotese and McKerrow,1990;陈旭等,2001;Boucot 等,2009)。岩石圈板块构造演化如何控制古生物地理分布是古生物地理信息在大陆岩石圈板块重建中应用的前提。由于缺乏对古生物地理区系成因的研究,将古生物地理信息机械套用而导致偏差的现象比比皆是,吉中地区的问题可能就是一例。近年来提出的地球系统科学和地球生物学的理念对于解决此类问题提供了重要思路。地球系统科学将地球各圈层作为一个系统,研究各圈层的相互作用过程。地球生物学是研究地球生物圈与其它圈层相互作用的科学(Noffke, 2005; Bottjer, 2005; 谢树成等, 2006;殷鸿福等,2009)。

构造古地理和全球气候(纬度-温度)是古生物地理形成的最重要的环境控制因素(王成文,1994)。通过古生物地理与构造古地理和全球气候变化的协同演化关系研究,搞清吉中地区晚古生代古生物地理演化的形成机制,从而确定吉中地区晚古生代地层大陆边缘归属是本文的整体思路。本文主要讨论吉中地区"暖水"到"凉水"腕足动物群的转换与佳-蒙地块古纬度位置变化之间的协同演化关系,研究区位置及动物群分布如插图 1。由于时代跨度较大,所含内容丰富,本文对几个重要的节点进行详细论述,其它则概述为主。另外,西别河组腕足动物群为一跨时代动物群,本文亦涉及晚志留世。

1　晚志留世—泥盆纪

1.1　腕足动物古生物地理特征

西别河组张家屯段含腕足动物 *Nucleospira*, *Retziella*, *Orbiculoidea*, *Protoreticularia*, *Lingula*, *Skenidioides*, *Salopina*, *Yangjia*, '*Amphistrophia*', *Jonesea*, *Mesoleptostrophia*, *Iridistrophia*, *Coelospira*, *Atrypa*, *Eospirifer*, *Striispirifer*, *Dongbeiispirifer*, *Nikiforovaena*, *Howellella* 和 *Delthyris* 等,称之为 *Retziella* 动物群,时代属于晚志留世拉得洛(Ludlow)晚期—普里多利(Pridoli)早期(廖卫华等,1995)。

Retziella 动物群广泛发育在吉中、内蒙古巴特敖包、西秦岭、滇东、川北、川西二郎山、广西东部及越南北部、北朝鲜、南天山西部、帕米尔、阿富汗和澳大利亚东南部等地区,称中-澳生物地理区(Rong *et al.*,1995)。与之对应的是 *Tuvaella* 动物群,分布在西伯利亚板块东北缘、哈萨克斯坦板块东北缘及佳-蒙地块北缘,其分布区称蒙古-鄂霍次克生物地理区(Wang *et al.*,2011)。古地理上,*Retziella* 动物群分布于志留纪晚期的热带和亚热带,大多位于古赤道附近,常见的 *Nikiforovaena*, *Tadschia*, *Spirinella* 和 *Protathyris* 等属未见于 *Tuvaella* 动物群。*Tuvaella* 动物群位于北半球的亚热带范围内,常见分子 *Tannuspirifer* 和 *Meristina* 等从未在 *Retziella* 动物群中出现(Rong *et al.*,1995)。上述 *Tuvaella* 动物群和 *Retziella* 动物群虽然属于两个地理区,但均位于与古赤道平行的热带、亚热带。只是 *Retziella* 动物群更偏于古赤道带,而 *Tuvaella* 动物群更偏于亚热带;同时后者与其半封闭的环境有关(Wang *at el.*,2011)。此时北方生物地理大区并未出现(插图 2)。

上述情况一直延续到下泥盆统小绥河段,小绥河段含腕足动物 *Isorthis* (*Protocortezorthis*), *Plectodonta*, *Mesodouvillina*, *Strophochonetes*, *Notoparmella*, *Gypidula*, *Lissatrypa*, *Coelospira*, *Atrypa*, *Striispirifer* 和 *Howellella* 共 11 属(廖卫华等,1995)。又如二道沟段(Lochkovian)腕足动物群包括 *Nucleospira*, *Retziella*?, *Isorthis* (*Protocortezorthis*), *Salopina*, *Dicoelosia*, *Mesodouvillina*, *Iridistrophia*?, *Strophochonetes*?, *Gypidula*, *Lissatrypa*, *Coelospira*, *Atrypa*, *Eospirifer*, *Striispirifer* 以及 *Howellella* 等(廖卫华等,1995)。*Iridistrophia*, *Retziella*, *Salopina* 等的出现说明与 *Retziella* 动物群有着密切的关系。

中泥盆统王家街组腕足动物稀少,但是含大量的埃菲尔期—吉维特期(Eifelian—Givetian)珊瑚动物,说明其属于老世界大区(廖卫华,2000),亦称赤道大区。

概括地说,吉中地区晚志留世—早泥盆世(乃至中泥盆世)腕足动物群属于"暖水"动物群。

1.2　古生物地理与环境的协同演化

晚志留世—早泥盆世,西伯利亚板块、哈萨克斯坦板块、佳-蒙地块均位于中—低纬度带,北方大陆的几个主要板块(地块)均未进入北纬中—高纬度带(Scotese and McKerrow, 1990; 陈旭等, 2001; Gordienko,2006; Boucot *et al.*,2009),其上尚未出现温凉环境,亦不可能发育凉水腕足动物群。

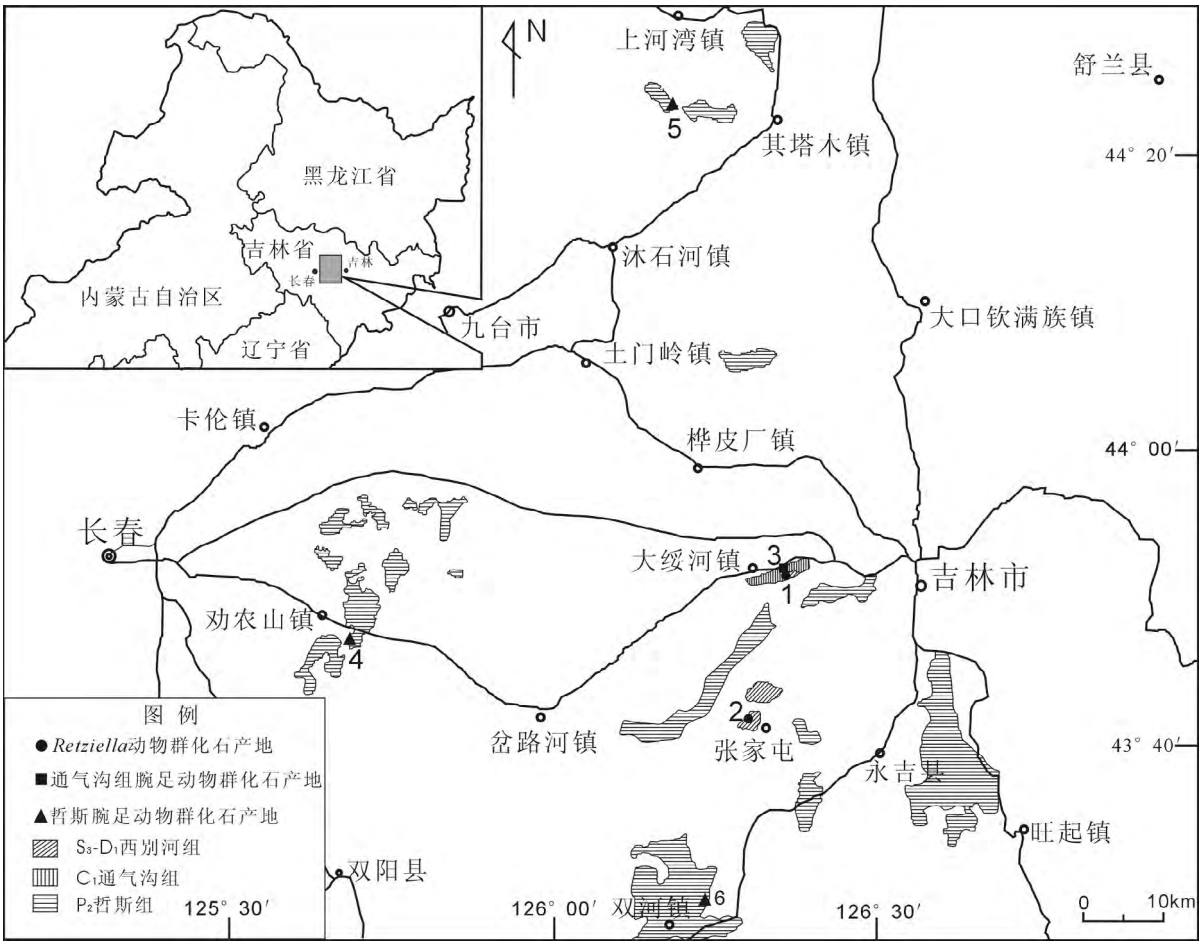

插图 1 研究区位置及化石分布

Index map showing area of study and locations of brachiopod faunas

1. **永吉县张家屯**；2. **大绥河**；3. **通气沟**；4. **劝农山周家窑**；5. **上河湾于家店**；6. **永吉县双河镇**。

1. Zhangjiatun, Yongji County; 2. Dasuihe Town; 3. Tongqigou; 4. Zhoujiayao, Quannongshan Town; 5. Yujiadian, Shanghewan Town; 6. Shuanghe Town, Yongji County.

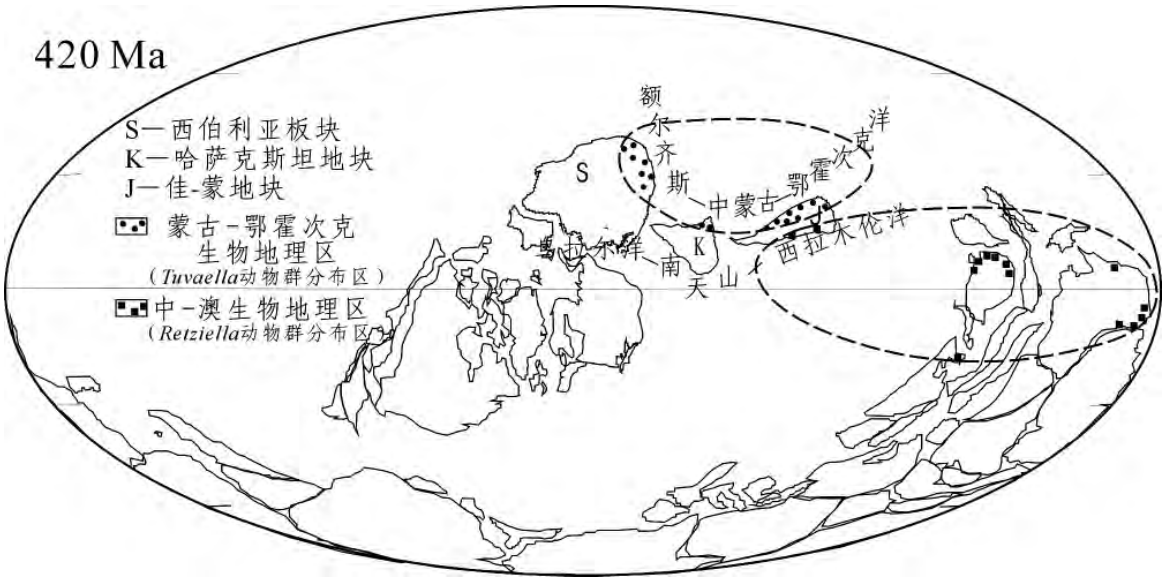

插图 2 晚志留世蒙古-鄂霍次克生物地理区与中-澳生物地理区的分布图(Wang *et al.*, 2011; Rong *et al.*, 1995)

Distribution of the Mongolia-Okhotsk Paleobiogeographic Province and China-Australia Paleobiogeographic Province during late Silurian (Wang *et al.*, 2011; Rong *et al.*, 1995)

晚志留世，西伯利亚板块、哈萨克斯坦板块、佳-蒙地块相对靠拢，形成了由西伯利亚板块东北缘、哈萨克斯坦板块东北缘和佳-蒙地块北缘组成的额尔齐斯-中蒙古-鄂霍次克洋构造域，出现了相对封闭的环境，发育了 *Tuvaella* 动物群（插图 2），形成了巴尔喀什-蒙古-鄂霍次克生物地理区（Wang *et al.*，2011）。由于西伯利亚板块自中生代以来顺时针旋转 180°（Zonenshain *et al.*，1990；Zorin *et al.*，1995；Gordienko，2006），当时的西伯利亚东北缘亦即现代的西伯利亚东南缘（主要含阿勒泰、萨彦等地区）。晚志留世，佳-蒙地块南缘、华南、乃至澳大利亚等地区位于赤道带的东段，发育了 *Retziella* 动物群，形成了中-澳生物地理区（Rong *et al.*，1995）。一个有意义的现象是佳-蒙地块的“陆障”作用开始显现，分隔了 *Tuvaella* 和 *Retziella* 动物群。

晚志留世—早泥盆世，西伯利亚与东欧板块之间的乌拉尔洋、哈萨克斯坦板块南缘的南天山洋、佳-蒙地块南缘的西拉木伦洋等可能连为一体。早泥盆世西伯利亚板块东缘、东欧板块北缘乃至哈萨克斯坦板块的西缘均属于乌拉尔-南天山洋构造域，发育了乌拉尔-南天山腕足动物群，形成了乌拉尔-南天山生物地理区（Wang *et al.*，2013a）。

2　石炭纪

2.1　腕足动物古生物地理特征

刘发（1988）描述了吉中地区下石炭统通气沟组（Tournaisian）腕足动物，包括 *Schizophoria*，*Rhipidomella*，*Schuchertella*，*Plicochonetes*，*Marginatia*，*Scutepustula*，*Eumetria*，*Retzia*，*Cyrtospirifer*，*Tylothyris*，*Syringothyris*，*Fusella*，*Imbrexia*，*Brachythyris*，*Punctospirifer*，*Nebenothyris* 及 *Camarotoechia* 共 17 属，并认为这个腕足动物群是以 *Tylothyris*，*Syringothyris*，*Fusella* 等为特征，属于北美-西伯利亚生物地理区。杨式溥（1990）将吉中地区腕足动物群归入北方大区哈萨克斯坦-内蒙古区，亦即 *Syringothyris-Giganto-productus* 分布区，并认为属于天山-西拉木伦洋分布区。

实际上，*Tylothyris*，*Syringothyris*，*Fusella* 等几属均为北方大区，特提斯大区和冈瓦纳大区常见的世界性广布分子（插图 3）。此外，*Brachythyris*，*Rhipidomella*，*Punctospirifer*，*Schizophoria* 和 *Schuchertella* 等亦为世界性分布的分子。*Camaro-toechia*，*Cyrtospirifer*，*Eumetria*，*Imbrexia*，*Marginatia* 和 *Plicochonetes* 等是特提斯与北方大区的常见分子。

与晚志留世—早泥盆世不同，早石炭世北方大区（亦称西伯利亚大区）已经形成（Wang *et al.*，2013a），北方大区的一些特征属，如：*Absenticosta*，*Lanipustula*，*Levipustula*，*Martiniopsis*，*Mucro-spirifer*，*Orulgania*，*Plactospira*，*Paeckelmanella*，*Praehorridonia*，*Sajakella*，*Septosyringothyris*，*Sphenospira*，*Taimyrella*，*Tomiopsis*，*Verkhojania* 和 *Zaissania* 等（Wang *et al.*，2014）并未在吉中地区出现。所以这个腕足动物群难以归入北方大区。

引人注目的是通气沟组上覆的鹿圈屯组出现大量的 *Gigantoproductus*，已知该属在特提斯东部域有着广泛的分布（插图 3），并且是特提斯北缘区与华南区最重要的特征属。综合分析，吉中地区早石炭世腕足动物古生物地理划归特提斯北缘区为宜。

吉中地区的上石炭统磨盘山组腕足动物资料很少，但是这一地区䗴类非常发育，自下而上可以划分为 *Profusulinella* 带、*Fusulina-Fusulinella* 带、*Triticites* 带和 *Pseudoschwagerina* 带（Wang *et al.*，2013b），时代为莫斯科期—阿瑟尔期（Moscovian—Asselian），明显属于暖水型的特提斯生物地理大区。

2.2　古生物地理与环境的协同演化

早石炭世，西伯利亚板块、哈萨克斯坦板块北缘、佳-蒙地块处于中—高纬度带，东欧板块等亦相对北移（Scotese and McKerrow，1990；陈旭等，2001；Boucot *et al.*，2009），几个板块（地块）相对靠拢，在其北部形成了半封闭的蒙古-鄂霍次克洋构造域。在蒙古-鄂霍次克洋的南缘——即西伯利亚板块的东缘、哈萨克斯坦板块北缘、佳-蒙地块北缘，发育了蒙古-鄂霍次克腕足动物群，形成了蒙古-鄂霍次克生物地理区（Wang *et al.*，2013a）。佳-蒙地块的北缘上俄罗斯赤塔地区腕足动物群属于这一生物地理区。蒙古-鄂霍次克与维尔霍杨-泰梅尔生物地理区组成了北方生物地理大区。

东欧板块东北缘、哈萨克斯坦板块大部分地区、佳-蒙地块南缘属于特提斯洋北缘构造域，发育了特提斯洋北缘腕足动物群，形成了特提斯北缘生物地理区（亦称乌拉尔-西拉木伦生物地理区）（Wang *et al.*，2013a）。吉中地区通气沟组—鹿圈屯组腕足动物群明显属于这一生物地理区（插图 3）。

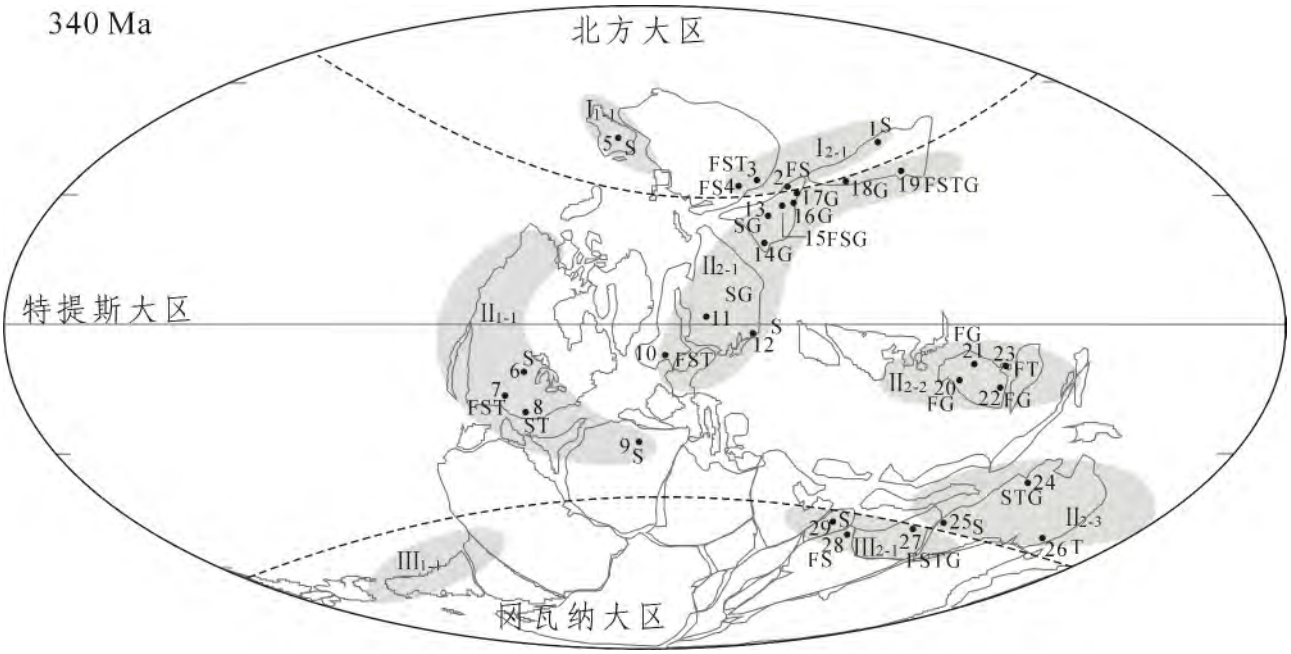

插图 3 吉中地区早石炭世几个腕足动物属在古地理区划中的分布

Paleogeographic distribution of a few early Carboniferous brachiopod genera of central Jilin

(1)**构造古地理图根据** Boucot **等**(2009),**略修改**。(2)**化石产地及资料来源**:1. **赤塔**(Kotlyar,2002),2. **北准噶尔**(**张川等**,1983),3. **矿山阿尔泰**(Gretchishnikova,1966),4. **库兹涅兹盆地**(Sarycheva *et al*.,1963),5. **维尔霍杨**(Abramov and Grigoryeva,1986),6. **美国中部**(Carter,1968),7. **美国西南部**(Stainbrook,1947;Carter,1967),8. **墨西哥**(Sour-Tovar *et al*.,2005),9. **马达马**(Mergl and Plauchut,2001),10. **英国**(Bassett and Bryant,2006),11. **莫斯科近郊**(Sarytcheva and Solkolskaya,1952),12. **阿塞拜疆**(Grechishnikova and Levitskii,2011),13. **阿斯塔纳**(Litvinovich,1962),14. **吉尔吉斯斯坦**(Galitzkaja,1977),15. **波罗霍洛山**(**杨式溥**,1964),16. **干草湖**(**张川等**,1983),17. **哈密**(**张川等**,1983),18. **北山**(**丁培榛**,1985),19. **吉中**(**刘发**,1988),20. **湖北**(**王淑敏**,1984),21. **湖南**(**柳祖汉等**,1982),22. **云贵**(**杨式溥**,1978),23. **海南**(**廖卓庭**、**张仁杰**,2006),24. **波拿巴湾盆地**(Roberts,1971),25. **新南威尔士**(Cvancara,1958),26. **卡那封盆地**(Thomas,1971),27. **珠峰地区**(**杨式溥**、**范影年**,1983;**张守信**、**金玉玕**,1976),28. **尼泊尔**(Waterhouse,1966),29. **西喀喇昆仑**(Gaetani *et al*.,2004)。(3)**生物地理区代号**:Ⅰ. **北方大区**,I_1. **巴伦支域**,I_{1-1}. **维尔霍杨-泰梅尔区**,I_2. **中亚域**,I_{2-1}. **蒙古-鄂霍次克区**;Ⅱ. **特提斯大区**,II_1. **特提斯西部域**,II_{1-1}. **北美区**,II_2. **特提斯东部域**,II_{2-1}. **特提斯北缘区**,II_{2-2}. **华南区**,II_{2-3}. **澳大利亚区**;Ⅲ. **冈瓦纳大区**,III_1. **冈瓦纳西部域**,III_{1-1}. **卡林加斯塔区**,III_2. **冈瓦纳东部域**,III_{2-1}. **喜马拉雅区**(**古生物地理区划详见另文**)。(4)**属代号**:F = *Fusella*,G = *Gigantoproductus*,S = *Syringothyris*,T = *Tylothyris*。

(1)The paleogeographic map is based on Boucot *et al*. (2009), with some modifications. (2)Fossil localities and material sources: 1. Chita(Kotlyar,2002),2. North Junggar(Zhang *et al*.,1983),3. Rudny Altay(Gretchishnikova,1966),4. Kuznetsk Basin(Sarycheva *et al*.,1963),5. Verkhoyansk(Abramov and Grigoryeva,1986),6. central America(Carter,1968),7. southwest of America(Stainbrook,1947;Carter,1967),8. Mexico(Sour-Tovar *et al*.,2005),9. Madama(Mergl and Plauchut,2001),10. England(Bassett and Bryant,2006),11. environs of Moscow(Sarytcheva and Solkolskaya,1952),12. Azerbaijan(Grechishnikova and Levitskii,2011),13. Astana(Litvinovich,1962),14. Kyrgyzstan(Galitzkaja,1977),15. Poluokenushan(Yang,1964),16. Gancaohu(Zhang *et al*.,1983),17. Hami(Zhang *et al*.,1983),18. Beishan(Ding,1985),19. central Jilin(Liu,1988),20. Hubei Province(Wang,1984),21. Hunan Province(Liu *et al*.,1982),22. Yunnan-Guizhou(Yang,1978),23. Hainan Province(Liao and Zhang,2006),24. Bonaparte Gulf Basin(Roberts,1971),25. New South Wales(Cvancara,1958),26. Carnarvon Basin(Thomas,1971),27. The Mount Jolmo Lungma region(Yang and Fan,1983;Zhang and Jin,1976),28. Nepal(Waterhouse,1966),29. West Karakoram(Gaetani *et al*.,2004). (3)Paleobiogeographic subdivisions: I. Boreal Realm, I_1. Barents Region, I_{1-1}. Verkhoyansk-Taymyr Province, I_2. Central Asia Region, I_{2-1}. Mongolia-Okhotsk Province; II. Tethys Realm, II_1, West Tethys Region, II_{1-1}. North America Province, II_2. East Tethys Region, II_{2-1}. Northern Margin of Tethys Province, II_{2-2}. South China Province, II_{2-3}. Australia Province; III. Gondwana Realm, III_1. West Gondwana Region, III_{1-1}. Calingasta Province, III_2. East Gondwana Region, III_{2-1}. Himalaya Province (Detailed discussion for early Carboniferous brachiopod biogeography can be found in another paper). (4)Abbreviations for genera: F=*Fusella*, G=*Gigantoproductus*, S=*Syringothyris*, T=*Tylothyris*.

值得注意的是,类似佳-蒙地块这样中等规模的地块,当其长轴方向与纬度带近平行,并处于中—高纬度带时,其地理障碍的隔绝作用尤其明显。地块两侧的大陆边缘上可以发育完全不同的生物地理区系。这点与赤道带上的一些地块(如华南地块)情景截然不同。

3　早—中二叠世

3.1　早—中二叠世的古生物地理特征

3.1.1　萨克马尔期的 *Monodiexodina* 动物群

吉中地区古生物从“暖水”到“凉水”的明显变化出现在早二叠世萨克马尔期(Sakmarian)，对应的地层单位为寿山沟组。寿山沟组虽然少含腕足动物，但其下部灰岩含 *Pseudofusulina-Parafusulina* 组合带和 *Monodiexodina* 组合带(李东津，1997)，目前已知 *Monodiexodina* 动物群仅出现在北方大区与特提斯大区以及冈瓦纳大区与特提斯大区的“凉水”和“暖水”过渡带(Ueno，2006)。*Monodiexodina* 动物群的出现代表了吉中地区古生物地理性质转换的开始。Ueno(2006)认为北方大区与特提斯大区过渡带上，*Monodiexodina* 在日本出现较早，时代为罗德期(Roadian)，我国的全部层位均置于沃德期(Wordian)。王成文和张松梅(2003)指出哲斯腕足动物群的最低层位是空谷期(Kungurian)，而含有 *Monodiexodina* 动物群的寿山沟组在哲斯组和大石寨组之下，其时代最可能为萨克马尔期(Sakmarian)。

3.1.2　哲斯期腕足动物群

在东北地区，哲斯腕足动物群产于哲斯组和大石寨组上部(王成文、张松梅，2003)。在吉中地区仅见于哲斯组(原称范家屯组)。哲斯组与下伏大石寨组(原称大河深组)整合接触，与上覆林西组(原称杨家沟组)平行不整合接触。

吉中地区哲斯组腕足动物不及哲斯、西乌旗、得伯斯等地区的丰富，但是哲斯动物群的面貌还是较为清晰的。如：在双阳县周家窑哲斯组含有 *Kochiproductus*，*Anidanthus*，*Attenuatella*；九台县上河湾哲斯组含有 *Kochiproductus*，*Yakovlevia*，*Attenuatella*，*Spiriferella*；永吉县双河镇哲斯组含有 *Spiriferella*。尽管吉中地区哲斯腕足动物群尚需深入的研究，但是上述 *Anidanthus*，*Attenuatella*，*Kochiproductus*，*Spiriferella* 和 *Yakovlevia* 等均为哲斯腕足动物群的重要分子；并且这些属在北方大区有广泛分布(插图 4)，亦是北方大区的特征分子。吉中地区的哲斯腕足动物群亦属于凉水腕足动物群。

3.2　古生物地理与环境的协同演化

3.2.1　古生物地理与构造古地理的协同演化

在早—中二叠世，随着北美、东欧、西伯利亚等板块持续北移(Scotese and McKerrow，1990；陈旭等，2001；Boucot 等，2009)，更多的区域进入中—高纬度区，北方生物地理大区规模不断扩大。与石炭纪不同，佳-蒙地块北移规模可能不大，但是，此时期佳-蒙地块西端可能与塔里木板块以及华北板块西端拼合，形成了西拉木伦洋构造域(插图 4)。该构造域的构造古地理特征为哲斯腕足动物群的发育创造了必要的条件。

早—中二叠世，佳-蒙地块上为一长时间经受风化剥蚀的古陆——克鲁伦-佳木斯古陆(Wang *et al.*，2009)。克鲁伦-佳木斯古陆对于哲斯腕足动物群向北迁移以及北方生物地理大区其它区域腕足动物物种的迁入构成了明显的“陆障”。西拉木伦洋应该有足够宽度，随着纬度降低，洋温逐渐升高，以至于华北板块北缘不适于凉水腕足动物的生存与繁衍。向南逐渐升温的洋盆对凉水型腕足动物的南向迁移构成了另一类天然屏障——“洋障”。关于哲斯腕足动物群发育的独特的构造古地理环境，王成文等(Wang *et al.*，2012)已有较详论述，这里不再赘述。

3.2.2　古生物地理与全球气候变化的协同演化

除了构造古地理环境，全球气候变化对哲斯腕足动物群的发育亦具有制约作用。从本文的插图 3 和 4 不难发现，早石炭世，佳-蒙地块已经位于中—高纬度带，直到中二叠世，纬度位置变化不大。那么，佳-蒙地块南缘的吉中地区为什么在石炭纪发育“暖水”动物群，早二叠世才开始发育“凉水”动物群。这里涉及另外一个重大环境因素——即石炭-二叠纪卡鲁冰期(Caroo Glaciation)的控制作用。

卡鲁冰期持续时间为 360—260 Ma(Fielding *et al.*，2008；Katupotha，2013)。有关卡鲁冰期，南方大陆研究较多，如：澳大利亚(Fielding *et al.*，2008；Waterhouse and Shi，2010)、斯里兰卡(Katupotha，2013)、巴基斯坦(Ghazi *et al.*，2012)等地区。北方大陆研究近年亦有一些成果，如：中亚的蒙古(Fujimoto *et al.*，2012)等。通过与已有的卡鲁冰期资料的对比研究，我们不难发现：1)吉中地区古生物地理从“暖水”到“凉水”的明显变化出现在早二叠世萨克马尔期，可能与卡鲁冰期的几次重大降温事件中的萨克马尔期降温事件(Waterhouse and Shi，2010)有某种对应关系。2)哲斯腕足动物群开始出现在空谷期(王成文、张松梅，2003)，与卡鲁冰期的几次重大降温事件中的空谷期降温事件(Waterhouse and Shi，2010)相关联。3)罗德期的降温事件

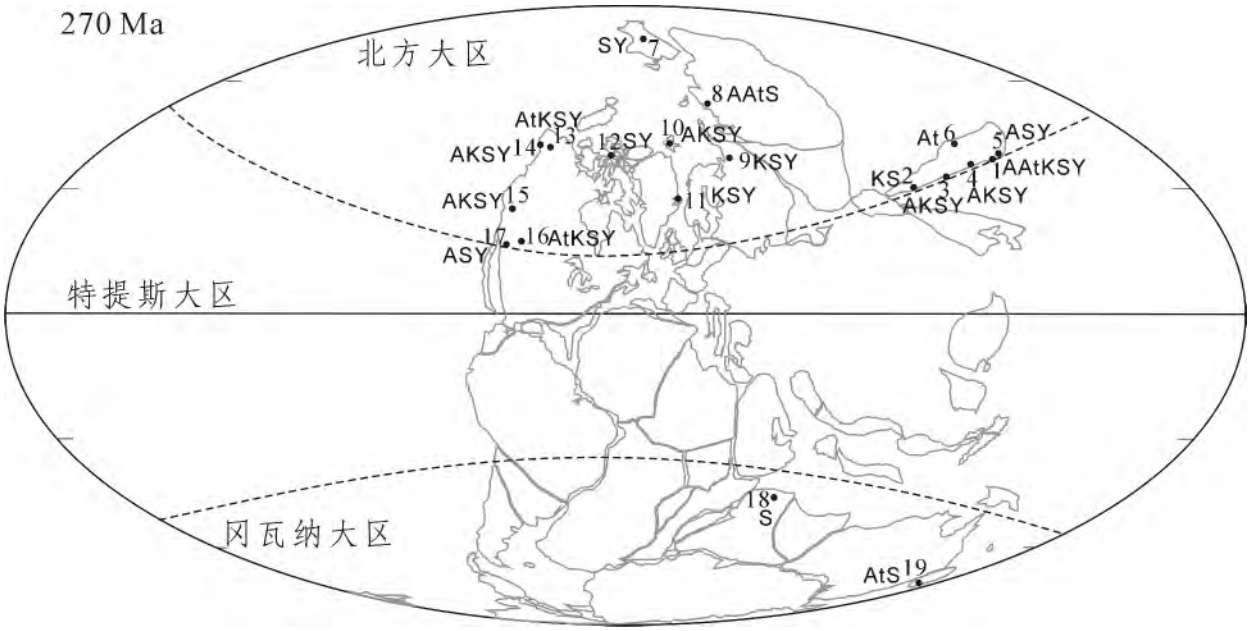

插图 4 吉中地区哲斯腕足动物群几个属的古生物地理分布

Paleogeographic distribution of a few genera of Zhesi brachiopod fauna in central Jilin

(1)**古地理图根据** Boucot **等**(2009),**略修改**。(2)**化石产地及资料来源**:1. **吉中地区**(**本文**),2. **北山**(**乌斯特利茨基**,1963),3. **哲斯-南蒙**(**王成文、张松梅**,2003;Pavlova *et al*.,1991),4. **西乌旗-得伯斯**(**王成文、张松梅**,2003),5. **乌苏里斯克**(Licharew and Kotlyyar,1978),6. **博尔贾**(Kotlyar,2002),7. **维尔霍杨**(Kashirtsev,1959;Abramov and Grigoryeva,1988),8. **泰梅尔**(Ustritsky and Chernyak,1963),9. **提曼-伯朝拉**(Kalashnikov,1993,1998),10. **斯瓦尔巴群岛**(Gobbett,1963),11. **格陵兰**(Dunbar,1955),12. **阿克塞尔海伯格岛**(Stehli and Grant,1971),13. **育空**(Bamber and Waterhouse,1971),14. **阿拉斯加中东部**(Brabb and Grant,1971),15. **俄勒冈**(Cooper,1957),16. **德克萨斯**(Cooper and Grant,1972-1976),17. **卡沃尔卡**(Cooper,1953),18. **多尔波**(Waterhouse,1978),19. **塔基蒂莫山**(Waterhouse,1982)。(3)**各属代号**:A-*Anidanthus*,At-*Attenuatella*,K-*Kochiproductus*,S-*Spiriferella*,Y-*Yakovlevia*。

(1)The paleogeographic map is based on Boucot *et al*. (2009),with some modifications. (2)Fossil locations and material sources:1. central Jilin (this paper),2. Beishan(Ustritsky,1963),3. Zhesi-southern Mongolia(Wang and Zhang,2003;Pavlova *et al*.,1991),4. Xi Ujimuqin Banner-Debaisi(Wang and Zhang,2003),5. Ussuriysk(Licharew and Kotlyyar,1978),6. Borzya(Kotlyar,2002),7. Verkhoyansk(Kashirtsev,1959;Abramov and Grigoryeva,1988),8. Taymyr(Ustritsky and Chernyak,1963),9. Timan-Pechora(Kalashnikov,1993,1998),10. Svalbard (Gobbett,1963),11. Greenland(Dunbar,1955),12. Axel Heiberg Island(Stehli and Grant,1971),13. Yukon(Bamber and Waterhouse,1971),14. central and eastern Alaska(Brabb and Grant,1971),15. Oregon(Cooper,1957),16. Texas(Cooper and Grant,1972-1976),17. Caborca (Cooper,1953),18. Durham(Waterhouse,1978),19. Takitimu Mountains(Waterhouse,1982). (3)Abbreviations for genera:A-*Anidanthus*, At-*Attenuatella*,K-*Kochiproductus*,S-*Spiriferella*,Y-*Yakovlevia*.

有利于促进哲斯腕足动物群的进一步发展。4)哲斯腕足动物群的鼎盛期在沃德期(王成文、张松梅,2003),此时期仍在卡鲁冰期结束(260Ma)之前。尽管按照澳大利亚的情况(Waterhouse and Shi,2010),**沃德期很可能为冰期回暖的时期,但是,蒙古中部抗爱-肯特**(Khangai-Khentei)**地区卡匹敦期降温事件**(Fujimoto *et al*.,2012)**的发现,说明卡鲁冰期末期的详情还有待进一步的研究和探讨。**

概括地说,中二叠世为北方生物地理大区的鼎盛时期(Wang *et al*.,2014),**其表现之一为地理范围最广。除了北方大陆的一些陆块(北美北部、东欧、西伯利亚、佳-蒙地块等)相继进入北纬中—高纬度带外;北方生物地理大区的南界亦有大幅度的南移(对比本文的插图 3、4 亦可得知)。后者最可能为降温事件导致的结果。因此,哲斯腕足动物群的出现应该是构造古地理与全球气候变化叠加的结果。**

4 结 语

吉中地区晚古生代腕足动物由"暖水"向"凉水"的转换发生在萨克马尔期,这种古生物地理性质的转换是由于构造古地理与古气候变化双重因素导致的结果,即由于佳-蒙地块西端与塔里木地块以及华北板块西端拼合,形成了西拉木伦洋构造域,以及石炭-二叠纪的全球降温事件卡鲁冰期。吉中地区晚古生代古生物地理与构造古地理及古气候变化之间的协同演化关系表明吉中地区晚古生代地层属于佳-蒙地块南缘的大陆边缘沉积。

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COEVOLUTION BETWEEN BRACHIOPOD PALEOBIOGEOGRAPHY OF CENTRAL JILIN AND ENVIRONMENT DURING THE LATE PALEOZOIC

LI Ning and WANG Cheng-wen

(*College of Earth Sciences, Jilin University, Changchun* 130061, *China*)

Key words Brachiopod, paleobiogeography, tectonopaleogeography, Caroo Glaciation, central Jilin, Jiamusi-Mongolia Block

Abstract

During the Late Paleozoic, brachiopod faunas of *Retziella* (Pridoli-Lochkovian), Tongqigou Formation (Tournaisian) and Zhesi (Kungurian-Wordian) appeared in central Jilin. *Retziella* and Tongqigou Formation brachiopod faunas were 'warm-water' brachiopods, and Zhesi brachiopod fauna was a 'cool-water' fauna. Meanwhile, we refer to the characteristics of coral and fusulinid faunas. These show that the faunas of central Jilin from Pridoli to Asselian belonged to 'warm-water' type, and from Kungurian to Wordian belonged to 'cool-water' type. This conversion from 'warm-water' to 'cool-water' occurred in the Sakmarian, represented by the *Monodiexodina* fauna of Shoushangou Formation. The development and conversion of 'warm-water' and 'cool-water' faunas were caused by tectonopaleogeography and climate change. During the late Silurian-Early Devonian, the Siberian Plate, Kazakhstan Plate and Jiamusi-Mongolia Block were located at low northern latitudes. The late Silurian-Early Devonian (even to Middle Devonian) brachiopod fauna of central Jilin belongs to 'warm-water' fauna and its paleobiogeography falls within the China-Australia Paleobiogeographic Province. During the Carboniferous, the northeastern margin of the Eastern European Plate, most areas of the Kazakhstan Plate, and the southern margin of the Jiamusi-Mongolia Block comprised the North Margin of Tethys Ocean tectonic domain and its brachiopods, the North Margin of Tethys Ocean brachiopod fauna, comprised the North Margin of Tethys Ocean Province. The Carboniferous brachiopod fauna of central Jilin belonged to this province. During Kungurian-Wordian, the western margin of the Jiamusi-Mongolia Block probably coalesced with the Tarim Plate and the western tip of the North China Plate to form the Xar Moron Ocean tectonic domain. The formation of 'cool-water' Zhesi brachiopod fauna were caused by the Xar Moron Ocean tectonic domain and global cooling event (Caroo Glaciation). The coevolution between paleobiogeography, tectonopaleogeography and paleoclimate indicates that the Late Paleozoic strata of central Jilin should belong to the southern margin continental deposition of Jiamusi-Mongolia Block.