

# 北祁连山东段晚石炭世巴什基尔期植物群

## ——兼论华夏植物群起源中心

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**内容提要:** 北祁连山东段纳谟尔晚期(相当于巴什基尔期)植物群,共33属95种植物,其中地方性的土著分子(属/种)占有整个植物群总数的80%以上,华夏植物群(Cathaysia Flora)的典型特征分子较多,如①东方型鳞木类占植物群总数的25%左右,包括从早石炭世延续下来的华夏木(*Cathaysiodendron*)、多种东方型鳞木(*Lepidodendron*)、窝木(*Bothrodendron*)及扁圆封印木(*Sigillaria brardii*);②由晚泥盆世开始出现的龙潭楔叶(*Sphenophyllum lungtanense*)、长沙楔叶? (*Sphenophyllum*? (*Tetrafolia*) *changshaense*)、早石炭世的靖远楔叶(*Sphenophyllum jingyuanense*)到纳谟尔晚期的微缺楔叶(*Sphenophyllum emarginatum*),这类具有长楔形叶的植物出现得比欧美地区早许多,可能是二叠纪瓣轮叶(*Lobatannularia*)的最早祖先;③齿叶属(*Tingia*)在早石炭世晚期已经出现,到纳谟尔晚期(红土洼组)已有三种之多,加上贝叶属(*Conchophyllum*),这两属一直被认为是华夏植物群的典型代表;④多种早石炭世中、晚期繁盛的真蕨类植物偶脉羊齿(*Paripteris*)及网羊齿(*Linopteris*)到晚石炭世早、中期仍十分发育,是华夏植物群早期最显著的特征;⑤早石炭世的畸羊齿(*Mariopteris*(*Karinopteris*))继续发育,而后可能演化成大羽羊齿类植物(*Gigantopterids*)的先祖。本文通过对比研究证实,北祁连山东段的纳谟尔晚期植物群已经进入华夏植物群的早期演化阶段;自从晚泥盆世的沙流水组开始,先后经历了早石炭世的臭牛沟组,靖远组及晚石炭世红土洼组和羊虎沟组(本溪组)代表了前华夏植物群(*Procathaysian Flora*)演替为华夏植物群的关键地质时期。北祁连山东段亦成为前华夏植物群和华夏植物群早期发育、繁盛之地区,在纳谟尔期可能是华夏植物群的起源和早期演化中心。

**关键词:** 华夏植物群;前华夏植物群;起源中心;演化中心;纳谟尔晚期;北祁连山东段

华夏植物群(*Cathaysia Flora*)是石炭纪和二叠纪全球四大主要植物群之一,其它三大植物群分别是欧美植物群、冈瓦纳植物群、安加拉植物群。自1870年李希霍芬(V. Richthofen)发现华夏植物群的首要代表类群——大羽羊齿类植物起(Li Xingxue, 1996),华夏植物群的研究已历一百多年,但其起源问题仍然存在很多疑问。华夏植物群的主要特征分子有8类:东方型鳞木(*oriental Lepidophytes*)、大羽羊齿类(*Gigantopterids*)、瓣轮叶类(*Lobatannularians*)、齿叶类(*Tingiales*)、贝叶属(*Conchophyllum*)、织羊齿类(*Emplectopterids*)、带羊齿类(*Taeniopterids*)和束脉蕨类(*Fascipterids*)(李星学等, 1995)。

研究和讨论华夏植物群的起源、演化、植物地理区的形成及华夏植物群的绝灭时,均可按上述几类

植物的起源、兴衰和绝灭为标准。

## 1 华夏植物地理区的形成

华夏植物群形成的时期,前人已有较多研究(Chaloner et al., 1973; 李星学, 1963, 1997; 张泓, 1988; 李星学等, 1993b, 1995; 孙克勤, 1998; 田宝霖等, 1995, 2000; 吴秀元, 1988; 吴秀元等, 2008; 李守军等, 2014; 苗慧心等, 2018),并存在从纳谟尔晚期(Late Namurian)至斯蒂芬期(Stephanian)等不同主张。最近20余年来,由于李星学等(1993b)、Zhang Shanzhen等(1993)、陈芬等(1995)、田宝霖等(2000)、Laveine等(2003a)、Li Xingxue等(2003)、孙克勤等(2004)以及吴秀元等(2008)一系列资料的公布,大部分学者趋向于华夏植物区系形成于纳谟尔晚期(Namurian B—C期)的红土洼组,由于前

注:本文为国家自然科学基金资助项目(编号:41530101、41802001)、中国科学院战略性先导科技专项(B类)(编号:XDB18000000)、广东省自然科学基金资助项目(编号:2018A030310303)的成果。

收稿日期:2018-08-14; 改回日期:2019-02-21; 责任编辑:刘志强。Doi:10.16509/j.georeview.2019.02.018

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人对红土洼组中的植物化石,特别是最为繁盛且时代可靠的甘肃靖远、景泰地区的红土洼组中植物化石仅开展了较初步的研究工作,其植物化石多样性的认识并不确切。本文基于最近的系统研究(程晨,2016),结合邻近地区宁夏中宁、中卫地区的资料(Zhang Shanzhen et al., 1993; 陈芬等, 1995), 讨论华夏植物地理区系的形成时间。

现代植物地理区系划分的原则,一般以植物分类单元在不同地域的异同程度来区分不同级别的植物地理区系,古植物地理区系的划分原则基本按现代植物地理区系原则划分。根据 Wnuk (1996) 提出的植物地理分区标准,划分大区(Realm)必须以特有的、并在植物群中占有相当数量的科一级的地方性植物分子的丰富程度做标准,而划分出区(Region)一级的植物地理区,则要以在植物群中占有一定比例的、特有的土著属或土著种一级的植物为标准,但 Wnuk (1996) 的方案并未明确具体的比例数。在海相生物的研究中, Kauffman (1973) 曾提出以某区特有的地方性的底栖动物土著分子所占的百分比为标准,提出划分出大区则土著分子必须占 >75%, 而区一级的划分应以土著分子占生物群分异度的 75%~50% 为标准(陈旭, 1993)。

经统计,甘肃靖远、景泰及宁夏中宁、中卫等地(图1)的有动物化石伴生而时代较为确切的属于纳缪尔晚期红土洼组中的植物共计有 33 属 95 种(不包括繁殖器官,种子及鳞木叶部化石)(表1),其中属于华夏植物群典型分子的多种东方型鳞木类包括猫眼鳞木(*Lepidodendron oculus-felis*)、华夏木(*Cathaysiodendron*)、窝木(*Bothrodendron*)及封印木(*Sigillaria*)等;在欧美植物区维斯发期(Westphalian)才繁盛的属种 *Sigillaria brardii*, 在我国华南维宪期梓山组中已有报导(赵修祜和吴秀元, 1982a); 东方型鳞木类早已以先驱者身份见于早石炭世; *Tingia* 和 *Conchophyllum* 等瓢叶类分子也早已发育; *Linopteris* 以及特有的属网延羊齿(*Reticlethopteris*)等在研究区红土洼组相当繁盛(Sze, 1933; 李星学等, 1993a), *Mariopteris* 继续发育(李星学, 1964; 李星学等, 1993b), 且很有可能为大羽羊齿类的祖先; 还有大约 76 个土著分子出现在红土洼组(表1)。按照古植物地理区系划分原则(Wnuk, 1996; Kauffman, 1973), 在甘肃靖远、景泰及宁夏中宁、中卫一带的红土洼组, 植物群中土著分子已经占整个植物群植物分异度的 80% 以上, 其中有相当数量的地方性的科、属、种均是华夏植物群的典

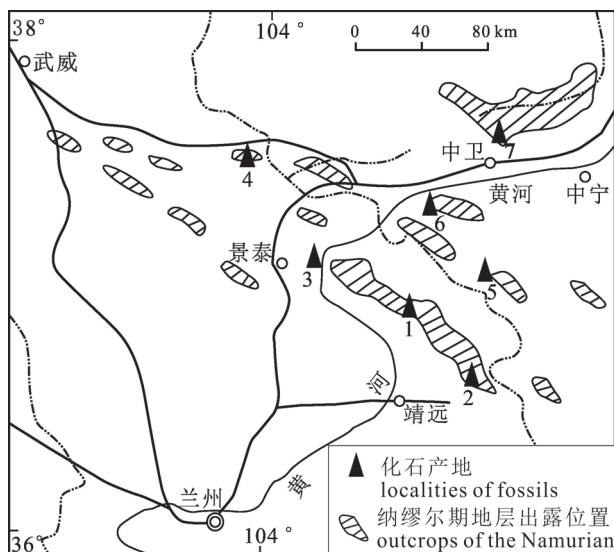


图1 研究区交通图(据自李星学等, 1993b 修改)

Fig. 1 Location map of outcrops

(modified from Li Xingxue et al., 1993b&c)

1—靖远井儿川; 2—靖远磁窑红土洼; 3—景泰响水; 4—景泰洪堡; 5—中卫校育川; 6—中卫下河沿; 7—卫宁北山(刘志才等, 1983; 史美良等, 1987)

1—Jinerchuan; 2—Ciyao; 3—Xiangshui; 4—Hongshuibao; 5—Xiaoyuchuan; 6—Xiaheyan; 7—Beishan (from Liu Zhicai et al., 1983&; Shi Meiliang et al., 1987&)

型分子,表明该地区已经充分满足了建立一个独立的华夏植物地理区系的条件。

因此,我们认为华夏植物地理区系形成于晚石炭世早期的红土洼组,其地理范围大致在北祁连山东段,华北板块西部的贺兰山等地(吴秀元等, 1987a; 陈芬等, 1995)和西北部内蒙古大余太地区(黄本宏, 1987); 另外,东北部辽东半岛(米家榕等, 1990; 金建华, 1995)少数地区可能也包括在内。

## 2 华夏植物群的起源及早期演化

关于华夏植物群的起源存在二种主要观点,其一认为华夏植物群是在早石炭世全球一致性的拟鳞木植物群(*Lepidodendropsis flora*)的基础上分化和发展起来的(Jongmans, 1952, 1954; Chandras et al., 1994; Sun Keqin, 1994; 米家榕等, 1995; 孙克勤, 1998; Sun Keqin et al., 1999; 孙克勤等, 2004), 该观点在上世纪八十年代以前得到较广泛接受; 其二认为华夏植物群起源于前华夏植物群(Procathaysian Flora)(李星学等, 1993b; 李星学, 1997; 田宝霖等, 2000; 吴秀元等, 2008)。本文通过对北祁连山东段纳缪尔晚期植物群的系统性对比研究,同时参考邻

表 1 北祁连山东段纳缪尔晚期红土洼组植物化石地理分布

| Table 1 The Geographic distribution of the upper Namurian (Hongtuwa Formation) flora in the east sector of the North Qilian Mountains |               |                     |          |               |               |               |          |                                                                   |               |                     |          |               |               |               |          |
|---------------------------------------------------------------------------------------------------------------------------------------|---------------|---------------------|----------|---------------|---------------|---------------|----------|-------------------------------------------------------------------|---------------|---------------------|----------|---------------|---------------|---------------|----------|
| 植物属种<br>(Genera and Species)                                                                                                          | 靖远<br>井儿<br>川 | 靖远<br>磁窑<br>红土<br>洼 | 景泰<br>响水 | 景泰<br>红水<br>堡 | 中卫<br>校育<br>川 | 中卫<br>下河<br>沿 | 卫宁<br>北山 | 植物属种<br>(Genera and Species)                                      | 靖远<br>井儿<br>川 | 靖远<br>磁窑<br>红土<br>洼 | 景泰<br>响水 | 景泰<br>红水<br>堡 | 中卫<br>校育<br>川 | 中卫<br>下河<br>沿 | 卫宁<br>北山 |
| 石松类( Lycopsida)                                                                                                                       |               |                     |          |               |               |               |          | <i>R. gutbieri</i> (Ett.)                                         | +             |                     |          |               |               |               |          |
| <i>Lepidodendron aolungpylukense</i> Sze                                                                                              |               | +                   | +        |               |               |               | +        | <i>R. distansum</i> Li et al.                                     |               | +                   |          |               |               |               |          |
| <i>L. ninghsiaense</i> Sze et Lee                                                                                                     |               |                     | +        | +             |               |               |          | <i>Zeilleria aeparsa</i> Li et al.                                |               | +                   | +        |               |               |               |          |
| <i>L. cf. ninghsiaense</i> Sze et Lee                                                                                                 |               |                     |          | +             |               |               |          | <i>Diplotmema</i> cf. <i>stocesianum</i> Goth.                    |               |                     |          |               |               |               | +        |
| <i>L. dichotomum</i> Sternb.                                                                                                          | +             |                     |          | +             |               |               | +        | <i>D. furcate</i> (Brongn.)                                       |               |                     |          |               |               |               | +        |
| <i>L. subrhombicum</i> Gu et Zhi                                                                                                      |               |                     | +        |               |               | +             |          | <i>D. subgeniculata</i> (Stur)                                    |               | +                   |          |               |               |               |          |
| <i>L. cf. subrhombicum</i> Gu et Zhi                                                                                                  |               | +                   |          |               |               |               |          | <i>D. cf. subgeniculata</i> (Stur)                                |               |                     |          |               |               |               | +        |
| <i>L. cf. szeianum</i> Lee                                                                                                            |               |                     | +        |               |               |               | +        | <i>Pecopteris aspera</i> Brongn.                                  | +             |                     | +        |               | +             |               |          |
| <i>L. cf. tripunctatum</i> Stockm. et Math.                                                                                           |               |                     | +        |               |               | +             |          | <i>P. plumosa</i> (Artis) Brongn.                                 | +             |                     |          |               |               |               | +        |
| <i>L. volkmannianum</i> Sternb.                                                                                                       |               | +                   |          |               |               |               |          | <i>P. cf. pennaeformis</i> Brongn.                                |               |                     |          |               |               |               | +        |
| <i>L. cf. volkmannianum</i> Sternb.                                                                                                   |               |                     | +        |               | +             |               |          | <i>Neuropteris tenuifolia</i> (Schloth.)                          |               |                     |          |               |               |               | +        |
| <i>L. cf. worthenii</i> Lesq.                                                                                                         | +             |                     |          |               |               |               | +        | <i>N. acuminatissima</i> ( Brongn.)                               |               |                     | +        | +             |               |               | +        |
| <i>L. cf. ciyaoense</i> Wu et al.                                                                                                     | +             | +                   |          |               |               |               |          | <i>N. macrophylla</i> Brongn.                                     |               |                     | +        |               |               |               |          |
| <i>L. qilianense</i> Cheng                                                                                                            | +             | +                   |          |               |               |               |          | <i>Paripteris gigantea</i> (Sternb.)                              | +             | +                   |          |               | +             |               | +        |
| <i>L. cf. oculus-felis</i> (Abb.) Zeil                                                                                                | +             | +                   | +        |               |               |               |          | <i>P.kaipingiana</i> Sze                                          |               |                     | +        |               | +             |               |          |
| <i>L. gigantea</i> (Brongniart)                                                                                                       | +             |                     | +        | +             |               | +             |          | <i>P. otozamioides</i> (Sze)                                      | +             |                     |          |               | +             | +             | +        |
| <i>Lepidodendron</i> sp.                                                                                                              |               | +                   | +        |               |               |               |          | <i>P. cardiopteroides</i> (Bohlin)                                | +             |                     |          |               | +             |               | +        |
| <i>Cathaysiodendron</i> sp.                                                                                                           | +             |                     |          |               | +             |               |          | <i>P. pseudogigantea</i> (Potonie)                                | +             |                     |          |               | +             |               | +        |
| <i>Bothrodendron circulare</i> Sze                                                                                                    |               | +                   | +        |               |               |               |          | <i>P. abbreviate</i> (Stockm.)                                    |               |                     |          |               |               |               | +        |
| <i>B. ruchengense</i> Zhao et Wu                                                                                                      | +             | +                   | +        |               |               |               |          | <i>P. linguaeifolia</i> (Bertrand)                                |               |                     |          |               |               |               | +        |
| <i>Sigillaria brardii</i> Brongn.                                                                                                     | +             | +                   |          |               |               |               |          | <i>P. longifolia</i> Wu et Deng                                   |               |                     |          |               |               |               | +        |
| <i>Ulodendron</i> sp.                                                                                                                 |               |                     | +        |               |               |               |          | <i>Linopteris</i> cf. <i>neuropteroides</i> (Guth.)               | +             | +                   | +        | +             | +             | +             | +        |
| <i>Stigmara ficoides</i> Brongn.                                                                                                      | +             | +                   | +        | +             |               |               |          | <i>L. neuropteroides</i> (Guth.)                                  | +             |                     | +        | +             |               |               |          |
| <i>S. rugulosa</i> Goth.                                                                                                              | +             |                     |          | +             |               |               |          | <i>L. densissima</i> Gu et Zhi                                    | +             | +                   |          |               | +             |               |          |
| 楔叶类                                                                                                                                   |               |                     |          |               |               |               |          | <i>L. intricata</i> Gu et Zhi                                     | +             | +                   |          |               |               |               | +        |
| <i>Mesocalamites cistiformis</i> Stur                                                                                                 | +             | +                   | +        |               |               |               | +        | <i>L. lepida</i> Gu et Zhi                                        | +             | +                   |          |               |               |               |          |
| <i>M. ramifer</i> Stur                                                                                                                | +             |                     |          |               |               |               | +        | <i>L. cf. lepida</i> Gu et Zhi                                    | +             |                     |          |               |               |               | +        |
| <i>Asterophyllites longifolius</i><br>(Sternb.) Stockm. et Will.                                                                      | +             |                     |          |               |               |               | +        | <i>L. simplex</i> Gu et Zhi                                       | +             | +                   | +        |               |               |               |          |
| <i>A. equisetiformis</i> (Schloth.) Brongn.                                                                                           |               |                     |          |               |               |               | +        | <i>L. cardiopteroides</i> Gu et Zhi                               |               | +                   | +        |               |               |               |          |
| <i>A. tenuifolius</i> (Sternb.)                                                                                                       |               |                     |          | +             | +             |               |          | <i>L. jingyuanensis</i> Li et Wu                                  | +             | +                   | +        |               |               |               |          |
| <i>Sphenophyllum tenerrimum</i> Ett.                                                                                                  |               | +                   |          |               | +             |               | +        | <i>L. brongniarti</i> (Guth.)                                     | +             |                     | +        |               | +             |               | +        |
| <i>S. emarginatum</i> Brongn.                                                                                                         |               |                     | +        | +             |               |               | +        | <i>L. cf. germarii</i> Gieb.                                      | +             |                     |          |               |               |               | +        |
| 真蕨和种子蕨类<br>(Filices and Pteridospermopsida)                                                                                           |               |                     |          |               |               |               |          | <i>L. maxima</i> Shen et al.                                      | +             |                     |          |               |               |               |          |
| <i>Anisopteris</i> sp.                                                                                                                |               |                     | +        |               |               |               |          | <i>Neuraethopteris</i> aff. <i>schlehani</i> (Stur)               | +             | +                   |          |               |               |               |          |
| <i>Cardiopteridium spetsbergense</i> Nath.                                                                                            |               |                     |          |               | +             |               | +        | <i>Reticaethopteris yuanii</i> (Sze)                              |               |                     |          | +             |               | +             |          |
| <i>Adiantites honghuapuenensis</i> Wu et Wang                                                                                         | +             |                     | +        | +             |               |               |          | <i>R. longipinna</i> Cheng                                        |               | +                   |          | +             |               |               |          |
| <i>Rhacopteris</i> sp.                                                                                                                |               |                     |          |               |               |               | +        | <i>Mariopteris</i> sp.                                            |               |                     |          | +             |               |               | +        |
| <i>R. cf. plumosa</i> Li                                                                                                              |               | +                   | +        |               |               |               |          | <i>Mariopteris</i> ( <i>Karinopteris</i> ) <i>acuta</i> (Brongn.) | +             |                     | +        |               |               |               |          |
| <i>Sphenopteris</i> cf. <i>delmeri</i> Stockm. et Will.                                                                               |               |                     |          |               |               |               | +        | <i>Aneimites</i> sp.                                              |               |                     |          |               |               | +             |          |
| <i>S. cf. footneri</i> Mar.                                                                                                           |               |                     |          |               |               |               | +        | <i>Potoniea adiantiformis</i> Zeill.                              |               |                     |          |               |               | +             | +        |
| <i>S. schatzlarensis</i> (Stur)                                                                                                       |               |                     |          |               |               |               | +        | 飘叶类( Noeggerathiales)                                             |               |                     |          |               |               |               |          |
| <i>S. cf. parabaeumleri</i> (Sze)                                                                                                     |               |                     |          |               | +             |               |          | <i>Tingia</i> cf. <i>trilobata</i> Stockm. et Math.               |               |                     |          |               | +             |               | +        |
| <i>Alloiopteris</i> cf. <i>essinghi</i> (Andrae)                                                                                      |               |                     |          |               |               |               | +        | <i>T. gerardii</i> Stockm. et Math.                               |               |                     |          |               | +             |               | +        |
| <i>A. gansuensis</i> Li et Shen                                                                                                       |               | +                   |          |               |               |               |          | <i>T. hamaguchii</i> Kon ’ no                                     |               |                     |          |               | +             |               |          |
| <i>A. cf. plumosaeformis</i> Goth.                                                                                                    |               |                     |          |               |               |               | +        | <i>Conchophyllum parvifolium</i> Bohlin                           |               |                     |          |               | +             |               | +        |
| <i>Eusphenopteris</i> cf. <i>obtusiloba</i> (Brongn.)                                                                                 |               |                     |          | +             |               |               | +        | <i>C. cf. richthofenii</i> Schenk                                 |               |                     |          |               | +             |               | +        |
| <i>E. obtusiloba</i> (Brongn.)                                                                                                        | +             |                     |          |               | +             |               |          | <i>Discinites orientalis</i> Gu et Zhi                            |               |                     |          | +             |               |               | +        |
| <i>Rhodeopteridium</i> ( <i>Zeilleria</i> )<br>cf. <i>parasparsa</i> (Sze)                                                            | +             |                     | +        |               |               |               | +        | 银杏类( Ginkgopsida)                                                 |               |                     |          |               |               |               |          |
| <i>R. sublipoldi</i> Zimm.                                                                                                            |               |                     |          | +             |               |               |          | <i>Dicranophyllum latum</i> Schenk                                | +             |                     |          | +             |               |               |          |
| <i>R. chinghaiense</i> Sze                                                                                                            | +             |                     |          | +             |               |               |          | 科达类                                                               |               |                     |          |               |               |               |          |
| <i>R. cf. tenuis</i> (Goth.)                                                                                                          |               |                     | +        |               |               |               | +        | <i>Cordaites principalis</i> ( Germ.) Gein.                       |               |                     |          |               | +             |               | +        |

区红土洼组的植物记录(表 1),证实华夏植物群起源于中国前晚石炭世的前华夏植物群,其依据如下:

2.1 东方型鳞木类

这类植物与欧美区的鳞木类主要有以下区别:

(1)茎干表面叶痕在叶座内占的面积比较大,有的叶座和叶痕几乎同形等大,如研究区维宪期臭牛沟组中的靖远华夏木(*Cathaysiodendron jingyuanense*)(李星学等,1974;Wu Xiuyuan et al.,1987,1997;王军等,2004;吴秀元等,2005),在中卫校育川的纳缪尔晚期也有类似标本发现(吴秀元等,1987b)。在河南固始维宪期—纳缪尔期的地层中(杨山组)亦有不少具有这种结构的鳞木或华夏木,如固始鳞木(*Cathaysiodendron gushiense*(Wu))、杨山华夏木(*C. yangshanense* Zhang et al.)(吴秀元,1992;陈芬等,1996;张宜等,2006),而在华南的维宪期梓山组产有叶座和叶痕都很大,且叶座和叶痕的几乎同形等大的方鳞木(*Lepidodendron quadratum* Zhao et Wu)(赵修祜等,1982a,1982b;Laveine et al.,1993),需要指出的是,此类鳞木植物在我国的晚石炭世至早—中二叠世的华夏植物群中已很繁盛,如猫眼鳞木(*Lepidodendron oculus-felis*),*Cathaysiodendron* spp.(李星学,1963)。

(2)鳞木的叶座均无下通气道痕。除了西藏昌都类乌齐组中发现的叶座确具有下通气道痕外(邓龙华,1978),华夏植物群中的鳞木属从未发现下通气道痕构造,而欧美植物群的鳞木植物普遍具有下通气道痕。田宝霖等(2000)对欧美和华夏这两类鳞木植物构造的解剖构造研究认为,鳞木早期演化过程中各种特征的产生是随机的,在演化中逐渐保留下成功的特征,这种性状特征成为随机优势并在以后的演化中得到发展,从而成为一种演化的构造基础。

(3)我国石炭—二叠纪鳞木属较为繁盛,自早石炭世维宪期出现之后一直是主要的造煤植物,从无叶痕的、非常繁盛的亚鳞木到具叶痕的始鳞木(*Eolepidodendron*),到具叶痕并有三小点的鳞木之间表现出明显的过渡演化特征。在欧美区很繁盛的封印木属在我国较少发现,包括江西梓山组中(早石炭世维宪期)地球上最早的并一直延续到二叠纪的*Sigillaria brardii*(斯行健,1958),甘肃山丹和内蒙古太原组中的鱼鳞封印木(*Sigillaria ichthyolepis*)(《中国古生代植物》,1974)以及贵州上二叠统煤核中的*Sigillaria* cf. *brardii*(郭英廷和田宝霖,1994)。我国在晚泥盆世至早石炭世的地层中很少找到拟鳞

木,虽然在华南中泥盆世已发现有较多拟鳞木种(Hsü,1946;Schweitzer et al.,1987),比世界任何地方都出现得早,但在此之后并不繁盛,在华南的晚泥盆世仅找到锉拟鳞木(*Lepidodendropsis hirmeri*)一种,它在欧洲产自早石炭世,而我国早石炭世维宪期却很少见到这种植物,这与封印木属植物的萧条可能有关系。

(4)早石炭世有些鳞木的叶痕形态与华夏植物群中的某些鳞木非常相似。鳞木的叶痕特征通常比较固定,其形态、大小和位置是鉴定鳞木种的重要标准,除了螺旋状排列的菱形叶座外,维宪期臭牛沟组的*Lepidodendron gansuense*(吴秀元等,2005),纳缪尔期的靖远组和红土洼组中的鱼鳞木(*Lepidodendron aolungpylukense*)(斯行健,1960;李星学等,1993b;Laveine et al.,2003b)以及斯蒂芬期至早二叠世太原组的斜方鳞木(*Lepidodendron posthumii*)(李星学,1963)都具菱形叶座和大致同形的盔形叶痕(《中国古生代植物》,1974);而华夏植物群中的*Lepidodendron oculus-felis*,其叶痕形态在早石炭世的鳞木中也有类似分子,如臭牛沟组中的靖远鳞木(*Lepidodendron jingyuanense*),其叶痕呈宽的双凸镜形,两侧角对称而尖锐,顶底端宽圆或为宽的U形(图2)。可以看出,早石炭世某些鳞木属形态结构一直延续到华夏植物群中成为形态结构非常特殊的一类鳞木。李星学(1980)称这类华夏植物群中特有的鳞木类植物为东方型(Oriental type)鳞木类植物。

2.2 楔叶类

红土洼组中发现的*Sphenophyllum emarginatum*(图3),在西欧的Westphalian B期才出现,以往在我国仅产于河北开平的开平组和赵各庄群( $C_2^3-P_1$ )(Stockmans et al.,1939,1957),山西太原山西组( $P_1$ )和下石盒子组( $P_2$ )(Halle,1927;《中国古生代植物》,1974),后来发现在靖远和中宁大石头井红土洼组中(Zhang Shanzhen et al.,1993)。该种虽然不是华夏植物群最典型的分子,但它比欧洲出现的要早得多(Abbott,1958;Bell,1938,1944,1962~1966),也如*Paripteris*和*Linopteris*一样,是华夏区的特殊植物。因为这种每轮为大小相近,倒楔形或椭圆形具六枚叶的植物在我国出现非常早,如长江中、下游晚泥盆世五通组中被Gothan和斯行健定名为*Sphenophyllum lungtanense*(Gothan et al.,1933),湖南早石炭世的长沙楔叶?(*Sphenophyllum*?(*Tetrafolia*)*changshaense*)(敖振宽,1963);近三十年

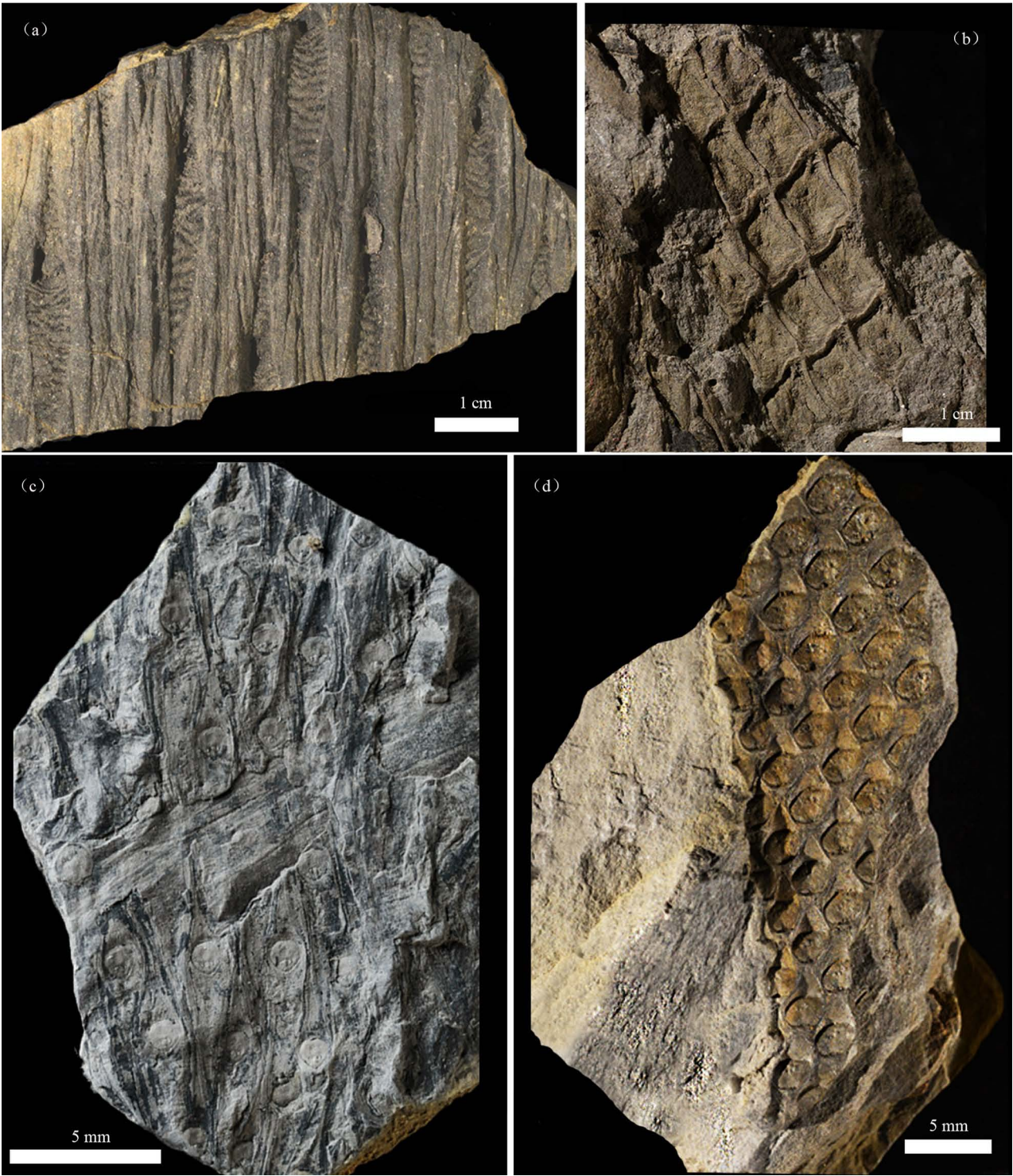


图 2 华夏植物群中典型的鳞木类代表分子

Fig. 2 The typical Lepidodendrids in the Cathaysia Flora

(a) *Lepidodendron aolungpylukense* Sze, 标本编号 PB22842; (b) *Cathaysiodendron* sp., PB22843; (c) *Bothrodendron ruchengense* Zhao et Wu, PB22844; (d) *Sigillaria brardii* Brongn., PB22844; 产地: (a) 景泰响水, (b) 、(c) 、(d) 靖远井儿川; 时代: 纳缪尔晚期红土洼组  
(a) *Lepidodendron aolungpylukense* Sze, Catalogue number PB22842; (b) *Cathaysiodendron* sp., PB22843; (c) *Bothrodendron ruchengense* Zhao et Wu, PB22844; (d) *Sigillaria brardii* Brongn., PB22845; Localities (a) Jingtai Xiangshui, (b) 、(c) 、(d) Jingyuan Jingerchuan; Age: Late Namurian, Hongtuwa Stage

来,华南晚泥盆世地层中已发现多种楔叶化石(陈其奭,1988;王德明等,2008;Huang Pu et al.,2017)以及靖远纳谿尔早期靖远组的 *Sphenophyllum jingyuanense*(李星学等,1993b)都有类似构造,每轮六枚叶的形态非常相似,它们可能是二叠纪瓣轮叶(*Lobatannularia*)的先祖(Asama,1970)。

2.3 齿叶类

(1) *Tingia* 是华夏植物群中重要的标志性植物,也是华夏区晚石炭世至早中二叠世常见的植物,在西北地区的纳谿尔早期已有三裂齿叶(*Tingia? trilobata*)(陈芬等,1995),在景泰洪水堡的红土洼组中有菱齿叶(*Tingia hamaguchii*)及钝齿叶(*Tingia? gerardii*)。它们以往都只在华北的上石炭统太原组及二叠系山西组和石盒子组中出现(Halle,1927;李星学,1963),而在宁夏中宁的大石头井红土洼组中也有 *Tingia? trilobata* 及唐山贝叶比较种(*Conchophyllum cf. richthofenii*)(Zhang Shanzhen et al. 1993)。李星学等(1993b)曾在纳谿尔早期的地层描述了靖远瓢叶(*Noeggerathia jingyuanensis* Li et Wu),该植物可能是 *Tingia* 的祖先(Browne,1933)。

(2) 另一华夏植物群重要分子 *Conchophyllum cf. richthofenii*,小羽贝叶(*C. parvifolium*)也在本区红土洼组和羊虎沟组中找到,以往一直作为晚石炭世本溪组和羊虎沟组的植物群组合代表之一(图3)。

2.4 真蕨、种子蕨类

(1) 偶脉羊齿类的 *Paripteris* 和 *Linopteris* 作为我国华夏植物群的早期代表已经得到共识(吴秀元等,1991;Wu Xiuyuan et al.,1992;Laveine et al.,2000)。*Paripteris* 在华南及西北早石炭世维宪期已经很繁盛(张善桢,1956;冯少南,1977;邓宝,1978;张善桢等,1980;冯少南等,1982;赵修祜等,1982a,1982b,1986;吴秀元,1992;吴秀元等,1981,1986,2000,2004,2005),而 *Linopteris* 则在臭牛沟组中有极少量发现,大量出现于纳谿尔早期,一直延续到晚石炭世中期(吴秀元等,1983,1987a;李星学等,1993;Zhang Shanzhen et al,1993;陈芬等,1995),曾被李星学(1963)作为华夏植物群早期代表,它们之间可能存在偶羽组的羽状脉发展到网状脉的的演化关系,如 *Paripteris* 演化到 *Linopteris*。奇羽组也有类似情况,脉延羊齿(*Neuraethopteris*)曾在浙江叶家塘群及甘肃臭牛沟组中发现(赵修祜等,1986;吴秀元等,2005),而与它对应的 *Reticaethopteris* 在北祁连山东段的红土洼组中多有发现(Sze,1933;李星学等,1993a),它们之间可能存在从羽状脉的

*Neuraethopteris* 发展到网状脉的 *Reticaethopteris* 的演化关系。这些分子被认为是华夏植物群的早期代表(李星学等,1993a)。

(2) *Karinopteris*(*Mariopteris*)一属产于华南维宪期的梓山组( $C_1^1$ )(李星学,1964),内蒙古鄂尔多斯的本溪组( $C_2^2$ ),河北开平的开平组( $C_3^3$ ),赵各庄群( $C_2^3-P_1$ )以及石盒子群( $P_{1-2}$ )(李星学,1964)。由于均具有两歧式分叉的叶架结构,李星学等(1993b)认为早石炭世晚期的 *Karinopteris* 到二叠纪的单网羊齿(*Gigantonoclea*)可能存在如下的演化关系,即早石炭世维宪期和纳谿尔期红土洼组的钝畸羊齿(*Karinopteris*(*Mariopteris*) *acuta*)——>晚石炭世和早二叠世太原群的薄畸羊齿(*Karinopteris*(*Mariopteris*) *halleyi*)——>早二叠世的山西组至下石盒子组的织羊齿(*Emplectopteris*)——>早、中二叠世石盒子群的 *Gigantonoclea*。这种渊源关系如果成立,则华夏植物群中的代表植物大羽羊齿类的远祖及其近亲在前华夏植物群中都有端倪可寻(图4)。

2.5 银杏纲

叉叶(*Dicranophyllum*)虽然不是华夏植物群的典型分子,但它也比欧美区出现得早。土著分子宽叉叶(*Dicranophyllum latum* Schenk)最早发现于河北开平晚石炭世的唐山组( $C_2^2$ )(Stockmans et al.,1939),我们在晚石炭世红土洼组( $C_1^1$ )中亦有发现。

3 结论

综上所述,华夏植物群的一些典型分子,其原始类型在前华夏植物群中都能找到踪迹,特别是东方型鳞木类,它们与前华夏植物群中的鳞木几乎一脉相承,相互演替的痕迹非常明显,位于东亚的华夏植物群应起源于前华夏植物群;早石炭世以拟鳞木(*Lepidodendropsis*)为代表的植物群,包括扇羊齿(*Rhacopteris*)、拟铁线蕨(*Adiantites*)、铲羊齿(*Cardiopteridium*)、三裂羊齿(*Triphyllopteris*)等是当时生长在全球的能适应各种生态环境的植物分子,不应作为植物地理区的标准类群,它们与繁盛于晚石炭世至二叠纪的植物分子如芦木(*Calamites*)、楔羊齿(*Sphenopteris*)和栉羊齿(*Pecopteris*)等性质一样,是遍布各地的广适型植物,也不能作为划分四大植物地理区的典型标准植物分子。

因此我们得出以下结论:

(1) 位于东亚的四大植物群之一的华夏植物群应起源于前华夏植物群;

(2) 华夏植物群的早期植物包括以

*Lepidodendron aolungpylukense* 为代表的东方型鳞木类、以 *Tingia* 和 *Conchophyllum* 为代表的齿叶类植物,以及纳缪尔晚期我国独有的植物如 *Paripteris*、*Linopteris*、*Reticaletopteris* 和每轮具大小相近、形态类似的六枚叶的楔叶植物 *Sphenophyllum emarginatum* 为特征的起源于前华夏植物群的独特

植物群,其最低产出层位为纳缪尔晚期的红土洼组;  
(3)甘肃靖远、景泰及宁夏中卫、中宁等地可能是华夏植物群的起源和早期演化中心。

**致谢:**感谢中国科学院南京地质古生物研究所樊晓羿高级工程师为标本拍照提供帮助、万明礼博士在文章撰写过程中提供的宝贵意见。

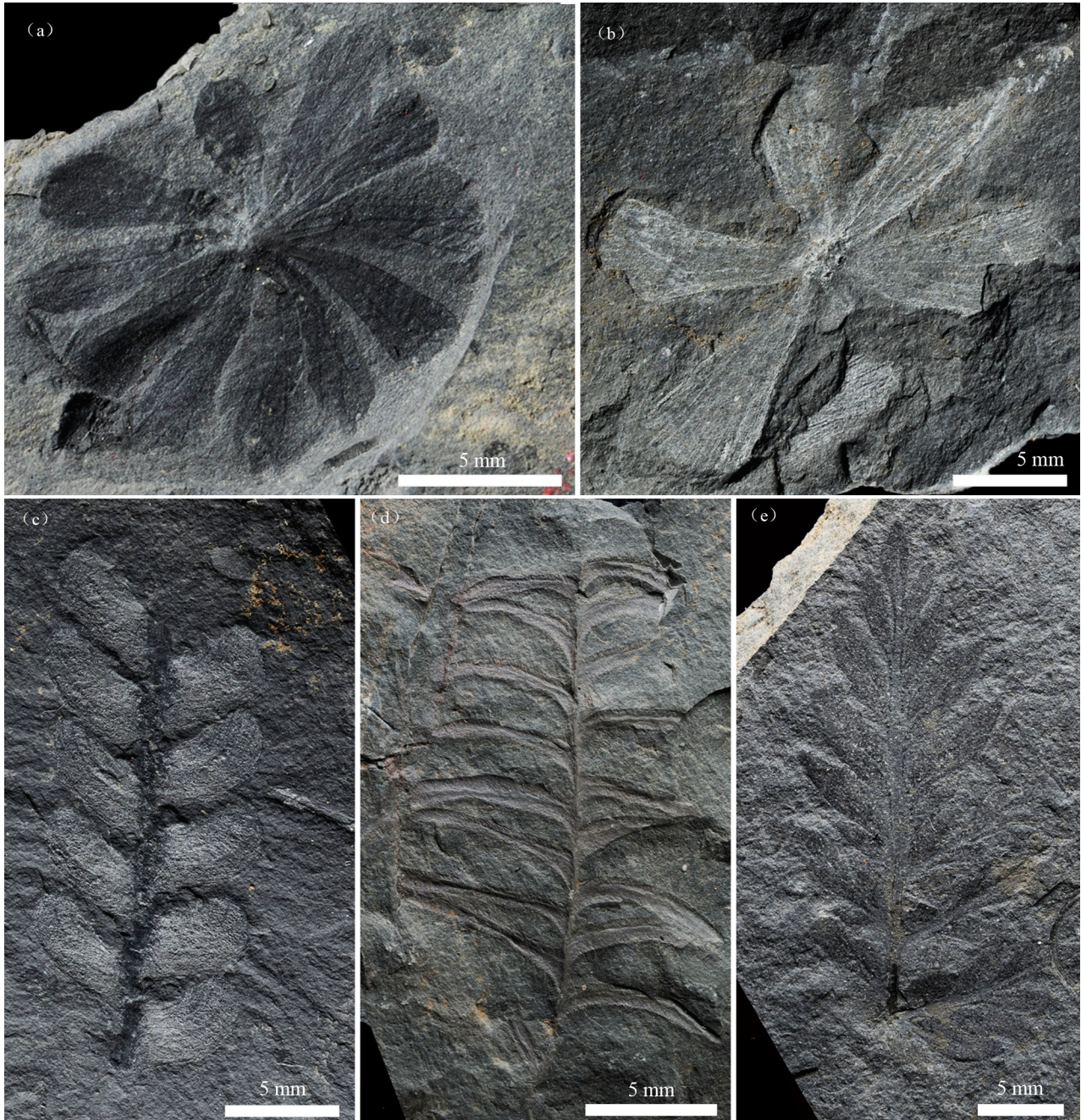


图 3 华夏植物群中典型代表分子

Fig. 3 The typical elements in the Cathaysia Flora.

(a)、(b) *Sphenophyllum emarginatum* Brongn., PB22846、PB22847; (c) *Conchophyllum parvifolium* Bohlin, PB22848; (d) *Reticaletopteris longipinna* Cheng, PB22849; (e) *Mariopteris* sp., PB22850; 产地:景泰红水堡;时代:纳缪尔晚期红土洼组  
(a)、(b) *Sphenophyllum emarginatum* Brongn. , PB22846、PB22847; (c) *Conchophyllum parvifolium* Bohlin, PB22848; (d) *Reticaletopteris longipinna* Cheng, PB22849; (e) *Mariopteris* sp. , PB22850; Locality: Jingtai Hongshuibao; Age: Late Namurian, Hongtuwa Stage

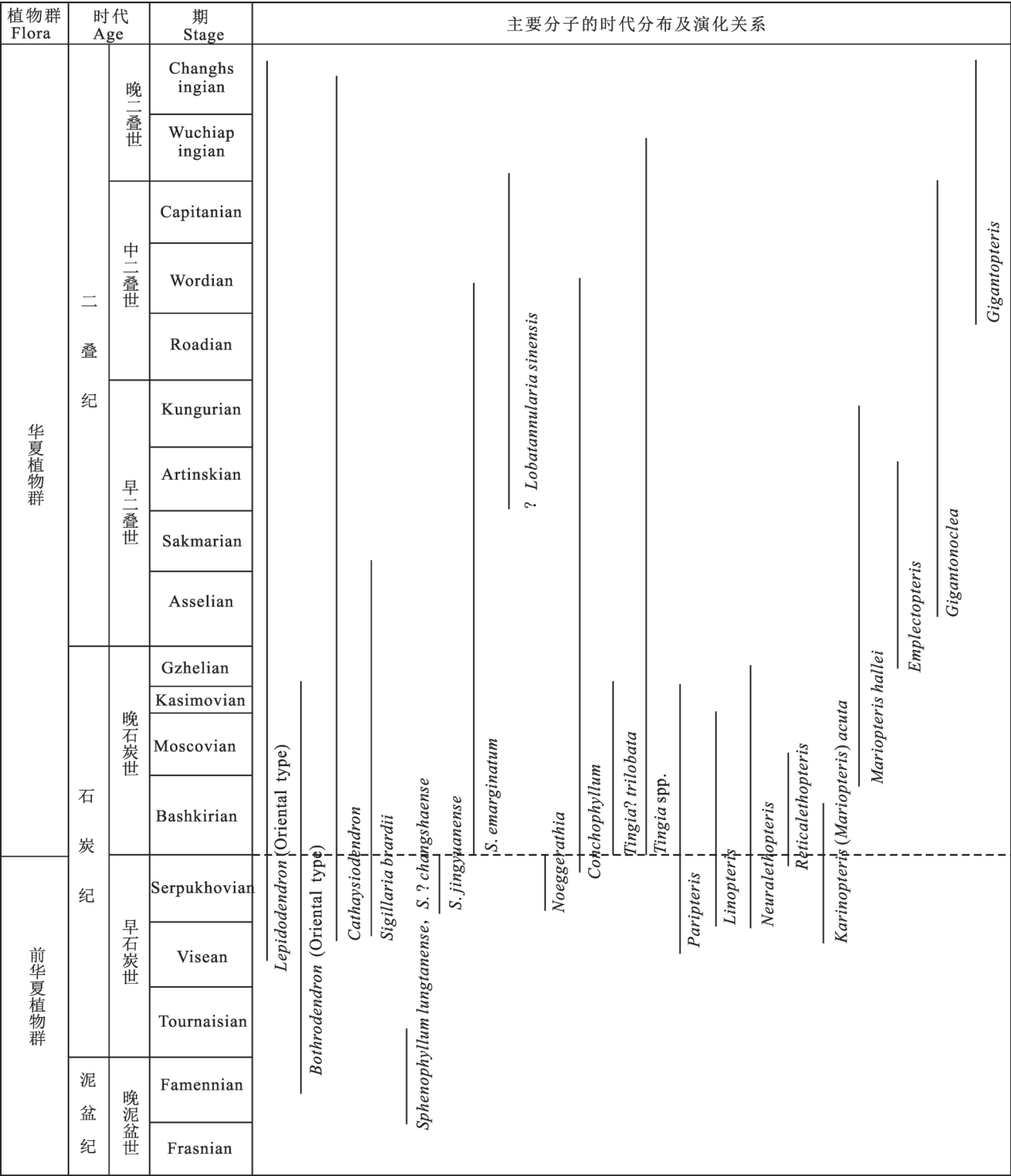


图 4 华夏植物群和前华夏植物群组成分子的大致演化关系图

Fig. 4 Evolutionary relationship between the Cathaysia Flora and the Procatthaysian Flora

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## The Late Carboniferous Flora ( Bashkirian ) in the east sector of north Qilian Mountain: a note on the origin center of the Cathaysia Flora

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**Objectives:** The Cathaysian flora has long been known as one of the four major floras during the Carboniferous and Permian times, but the origin of the flora still remains as yet unsolved.

**Methods:** Based on a systematic study of the Late Namurian ( Bashkirian ) flora in the east sector of North Qilian Mountain, there are 33 genera and 95 species as endemic elements ( genera, species ) accounting for more than 80% of the floral composition.

**Results:** There are many typical elements of Cathaysia Flora, for example, ① Oriental Lepidophytes take up about 25% of the flora, including *Cathaysiodendron* from the Early Carboniferous, various Oriental type of *Lepidodendron*, *Bothrodendron* and *Sigillaria brardii*. ② *Sphenophyllum lungtangense* and *Sphenophyllum* ? ( *Tetrafolia* ) *changshaense*, which appeared since Late Devonian, the Early Carboniferous *Sphenophyllum jingyuanense*, the Late Namurian *Sphenophyllum emarginatum*. All these species with long cuneiform leaf lamina appeared much earlier in Cathaysia than in Euramerica, from which Permian *Lobatannularia* might have evolved. ③ *Tingia* and *Conchophyllum* had long been regarded as typical representatives of the Cathaysia Flora. *Tingia* appeared since late Early Carboniferous, and till to Late Namurian ( Hongtuwa Formation ) three species existed. ④ Many types of *Paripteris* and *Linopteris*, which flourished in middle and late Early Carboniferous, were still very common in early and middle Late Carboniferous. This is the most prominent feature in the early stage of Cathaysia Flora. ⑤ *Mariopteris* ( *Karinopteris* ), which occurred from Early Carboniferous continuously well developed, might be the remote ancestral group of Gigantopterids.

**Conclusions:** This shows the Late Namurian flora in the east sector of North Qilian Mountain was in the early stage of evolution of the Cathaysia Flora, and the Late Devonian Shaliushui Formation, the Early Carboniferous Chouniugou Formation, the Late Carboniferous Tsingyuan and Hongtuwa Formations, together with Yanghugou Formation were the geological period of the evolutionary succession from Procathaysian Flora to the Cathaysia Flora. The east sector of North Qilian Mountain also became an early developed and prosperous area of the Procathaysian Flora and the Cathaysia Flora. It is proved again that the east sector of North Qilian Mountain might be the center of origin and early evolution of the Namurian Cathaysia Flora.

**Keywords:** Cathaysia Flora; Procathaysian Flora; origin center; evolution center; the Late Namurian; the east sector of North Qilian Mountains

**Acknowledgements:** This study was supported by the National Natural Science Foundation of China ( No. 41530101, No. 41802001 ), the Strategic Priority Research Program ( B ) of Chinese Academy of Sciences ( No. XDB18000000 ) and Natural Science Foundation of Guangdong ( No. 2018A030310303 ). We appreciate Mr. FAN Xiaoyi of Nanjing Institute of Geology and Palaeontology ( NIGPAS ) for taking photographs, and Dr. WAN Mingli of NIGPAS for his assistance in this text

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Manuscript received on: 2018-08-14; Accepted on: 2019-02-21; Edited by: LIU Zhiqiang

**Doi:** 10.16509/j.georeview.2019.02.018