

吉林汪清早白垩世似卷柏化石*

徐青^{1,2)} 杨小菊¹⁾

1)中国科学院南京地质古生物研究所, 南京 210008, xjyang@nigpas.ac.cn;

2)中国科学院大学, 北京 100049

摘要 文中描述了发现于吉林汪清下白垩统大拉子组似卷柏化石: 纤细草本, 侧叶和中叶呈四行排列。侧叶互生, 卵形, 全缘, 顶端尖锐, 叶片前端略向内侧弯曲, 叶背呈龙骨状, 基部无柄, 略呈鞘状; 中叶生于两侧叶之间, 形态与侧叶相似, 在茎上密集贴生。该化石与报道自我国辽西下白垩统义县组下部尖山沟层的多产似卷柏 *Selaginellites fausta* (Wu) Sun and Zheng 特征相似, 但由于未保存生殖器官结构, 无法进一步详细对比, 因此将其定为 *Selaginellites cf. fausta* (Wu) Sun and Zheng。这是我国目前为止发现的距今最近的似卷柏化石, 丰富了中国似卷柏的化石记录。

关键词 似卷柏 大拉子组 早白垩世 汪清 吉林

1 前言

石松类植物是演化历史最漫长的陆生维管植物之一, 其最早的化石记录可以追溯到距今约 4.2 亿年的志留纪 Pridoli 世 (Rickards, 2000), 该类植物在晚泥盆世快速分化, 其中的异形孢子类型开始发展。石炭纪时石松类植物最为繁茂, 以鳞木目为主要代表的木本石松类植物是石炭纪森林的主要组成部分 (斯行健等, 1963; 徐洪河、王怿, 2002; 薛进庄等, 2006)。值得关注的是, 木本石松类植物在二叠纪开始逐渐衰落, 至中生代仅有石松目和卷柏目等草本类型。中生代发现的石松类植物化石, 常因为其保存较差、形态描述不清、鉴定混乱等问题, 在古植物学的研究中经常被忽视 (Thomas, 1997)。

似卷柏属 *Selaginellites* Zeiller 和似石松属 *Lycopodites* Brongniart 是草本类石松植物化石的两种重要类型。*Selaginellites* 代表具有异形孢子, 且在茎、叶及分枝形态等特征上与现代卷柏属 *Selaginella* L. 相似的草本石松类化石; *Lycopodites* 代表具同型孢子且形态特征与现生石松属 *Lycopodium* L. 相似的石松类化石 (Zeiller, 1906)。上述两属很难从外部形态上进行区分, 常有古植物学者将未

发现异型孢子、外形接近 *Selaginella* 的化石归入 *Lycopodites*, 所以 *Lycopodites* 是一个笼统的形态属 (斯行健等, 1963; 邓胜徽, 1995; 孙革等, 2001)。

似卷柏属化石是否应该直接归入现生卷柏属这一问题长期以来一直存在争议 (Thomas, 1992; Schweitzer *et al.*, 1997)。Zeiller (1906) 和 Halle (1907) 最初认为 *Selaginella* 和 *Selaginellites* 最大的区别为大孢子囊内所含大孢子数目, 似卷柏属植物的大孢子数目一般多于现生卷柏属的 4 个, 但后来的研究发现少数现生卷柏属植物大孢子囊内也可育出超过 4 枚大孢子 (Thomas, 1992)。因此, 一些学者主张用现生卷柏属 *Selaginella* 表示化石卷柏植物, 弃用 *Selaginellites* 这一属名 (Thomas, 1992, 1997, 2005; Cleal and Wang, 2002)。Thomas (2005) 对德国克森州晚石炭世的卷柏类化石 *Selaginella gutbieri* (Gutbier) Thomas, *Selaginella stachygynandroides* (Gutbier) Thomas, *Selaginella zeilleri* (Halle) Thomas 重新进行了观察, 发现这些标本的营养叶三型、呈六行排列, 一般从小到大分别位于侧面、中间和腹面, 称为侧叶、中叶和腹叶, 由此建立卷柏属亚属 *Selaginella* (*Hexaphyllum*) Thomas, 提出石炭纪之后该属植物存在从三型叶到二型叶过渡的现象。也有很多学者仍沿用

收稿日期: 2017-11-10

* 国家自然科学基金 (41472011, 41688103)、中国科学院战略性先导科技专项 (B 类) (XDB18000000) 联合资助。

Selaginellites 来表示化石卷柏植物,从而与现生卷柏进行区分(郑少林、李杰儒,1978;李星学等,1982;孙革等,2001;Kustatscher *et al.*, 2010)。

目前全球报道的似卷柏化石 20 余种,我国产有 10 种,其中早白垩世仅报道有 1 种,即发现于辽西北票义县组下部尖山沟层的 *Selaginellites fausta* (Wu) Sun and Zheng (吴舜卿, 1999; 孙革等, 2001)。本文是早白垩世晚期大拉子组似卷柏属的首次报道,丰富了似卷柏属的化石记录。

2 地质背景

大拉子组是下白垩统延吉群的组成单元,其标准剖面位于吉林省龙井市智新镇,是中国东北地区早白垩世的典型地层之一(余静贤、苗淑娟,1983)。该组发现有丰富的各门类动植物化石,目前已经报道化石种类包括:双壳类(郝诒纯等,2000)、介形类(勾韵娴,1983;叶得泉,1995;Wang *et al.*, 2012)、叶肢介(陈丕基,2012;Li *et al.*, 2016;Teng and Li, 2017)、鱼类(张弥曼等,1977)、昆虫(Zhang, 1997)、

孢粉(余静贤、苗淑娟,1983;黄嫫、张光富,2002)和植物化石,其中植物化石尤为丰富。已报道包括蕨类植物 9 属 13 种,苏铁类植物 4 属 4 种,银杏类植物 2 属 2 种,松柏类植物 9 属 14 种和早期被子植物 23 属 49 种(张川波,1980;张武等,1980;周志炎等,1980;陶君容、张川波,1990,1992;张光富,2001),其中的松柏类掌鳞杉科植物研究程度最高(Zhou, 1995;Yang and Deng, 2007;Yang, 2008;Yang *et al.*, 2009;Guignard *et al.*, 2017)。根据上述化石门类研究,大拉子组的时代被认为属于早白垩世晚期或 Albian 期(Deng *et al.*, 2012;Sha and Lucas, 2012)。

本文研究的化石采自吉林汪清罗子沟镇小北沟村(N43°45'51", E130°14'36") (插图 1), 这里出露的早白垩世地层相当于智新盆地的大拉子组,其岩性主要为上部粉砂质页岩和粉砂岩、中部油页岩和下部黑色片状页岩,产有丰富的植物、叶肢介和鱼类化石(周志炎等,1980)。本文所研究的似卷柏化石即采自大拉子组上部的粉砂岩层,该层伴生植物还包括大量的松柏类、蕨类和少量苏铁类和被子植物。

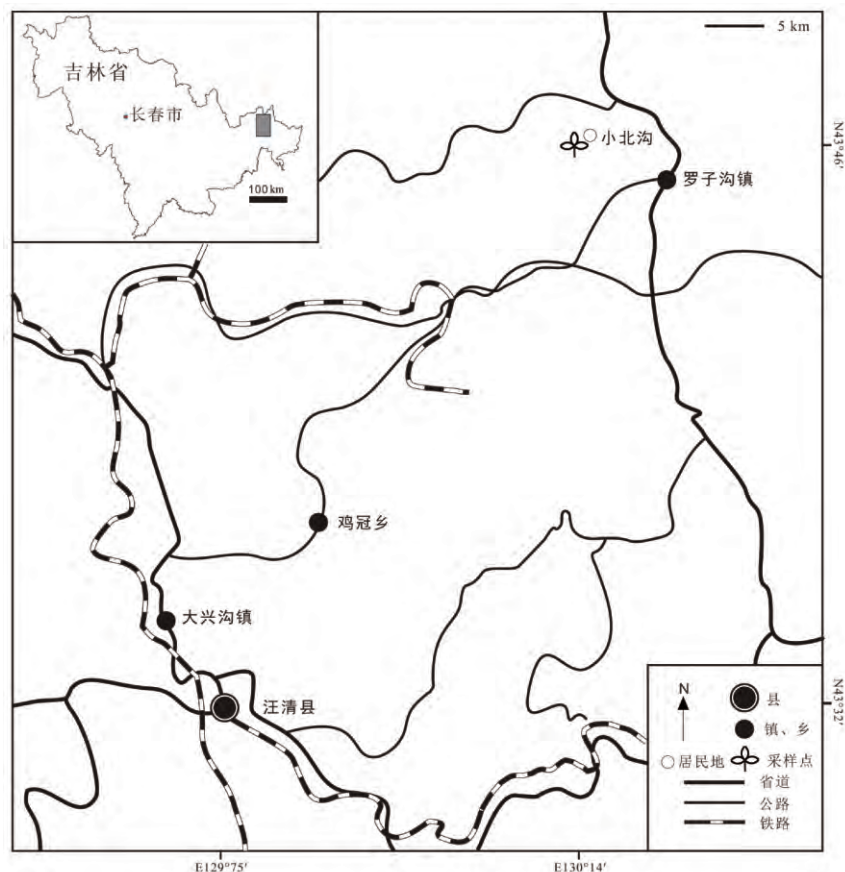


插图 1 化石产地交通位置图

Locality of plant fossil in Jilin Province, China.

3 系统古生物学

卷柏目 Order Selaginellales Prantl, 1874

卷柏科 Family Selaginellaceae Willkomm, 1854

似卷柏属 Genus *Selaginellites* Zeiller, 1906

多产似卷柏 (相似种) *Selaginellites cf. fausta*
(Wu) Sun and Zheng

(插图 2)

描述 植物体小型, 植株高约 3 cm, 仅保存有营养枝。茎细弱, 有的茎弯曲; 多次二叉分枝, 分枝

角度 22° — 45° , 多集中在 30° (插图 2-A)。茎上部着生叶, 紧密排列, 可见互生的两行侧叶 (插图 2-C, D), 与茎成 28° — 60° 角, 自分叉处至枝顶渐大。侧叶 (插图 2-E, F) 长 0.5—1.2 mm, 宽 0.2—0.7 mm, 卵形, 全缘, 叶片前端略向内侧弯曲, 顶端尖锐, 叶背呈龙骨状, 基部渐尖或钝形, 无柄, 略呈鞘状。中叶生于两侧叶之间, 紧贴茎生长, 密集, 相互重叠, 形态与侧叶相似, 长 0.1—0.4 mm (插图 2-E, G, H)。靠近顶部的叶不成四行而呈螺旋状排列。茎下部叶排列稀疏, 仅见两排侧叶以小角度 (近于贴生) 生于茎两侧, 叶背呈明显龙骨状, 长约 0.8—1.1 mm。

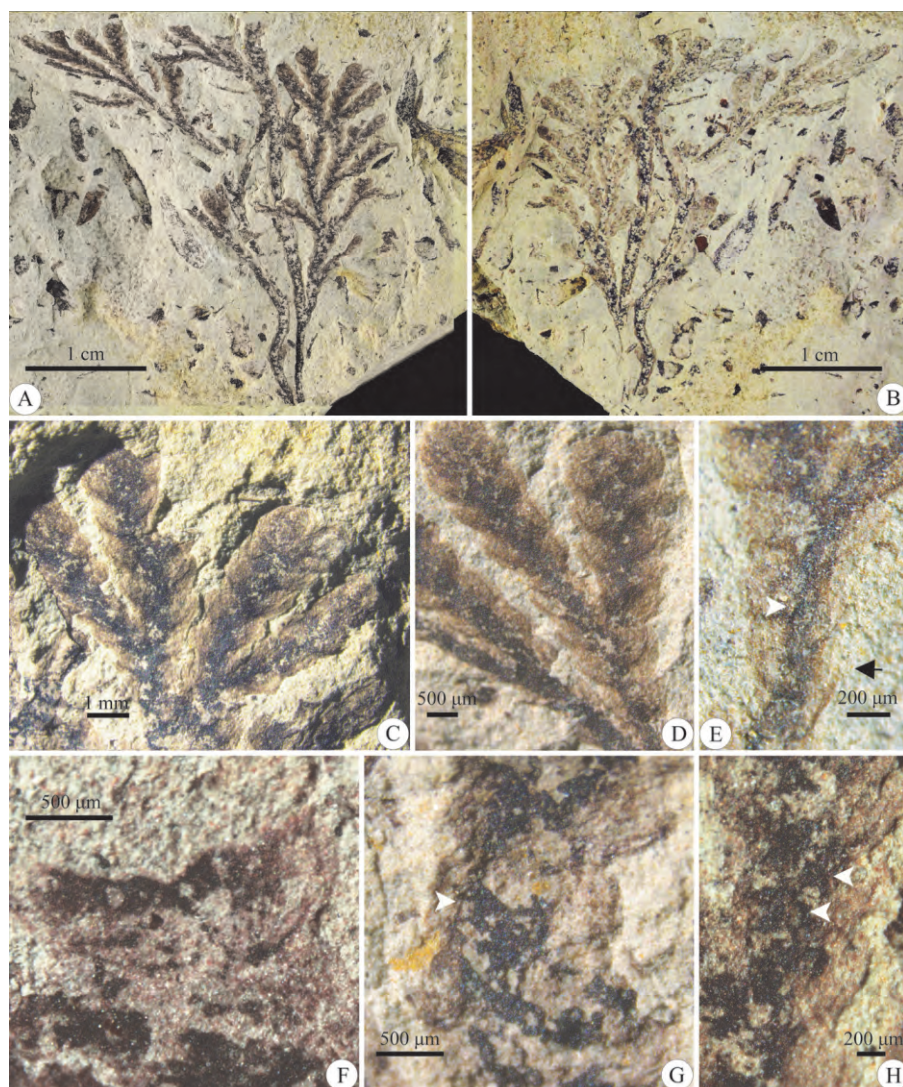


插图 2 吉林汪清下白垩统大拉子组似卷柏化石 *Selaginellites cf. fausta* (Wu) Sun and Zheng

Selaginellites cf. fausta (Wu) Sun and Zheng from the Lower Cretaceous Dalazi Formation of Wangqing, Jilin Province, China.

A, B. 化石正副模, 示整体形态及分枝方式, 登记号: PB22605A, PB22605B。C, D. 示叶背呈龙骨状的两行侧叶形态及着生方式。E. 示侧叶 (黑箭头) 与中叶 (白箭头)。F. 示卵圆形侧叶。G, H. 示中叶 (白箭头) 形态及其着生方式。

A, B. Over view of *Selaginellites cf. fausta* (Wu) Sun and Zheng, part and counterpart, showing the form size, and the dichotomous branching, PB22605A, PB22605B. C, D. Upper part of the specimen, showing dorsally keel-like ribbed and decussate lateral leaves. E. Lateral leaves and median leaves (white arrow showing the median leaves, black arrow indicating the lateral leaves). F. Ovate lateral leaves with mucronate apices. G, H. Median leaves (white arrows).

4 比较与讨论

本化石保存有正副模。植物为纤细草本、分枝方式为二叉分枝;叶小,简单,异型叶,成对生长并排列成四行;侧叶大于中叶,斜上生长,互生,中叶紧贴茎,覆瓦状排列,从整体形态看,当前化石应归入 *Selaginellites* 属。*Selaginellites* 属各种的鉴定主要依据生殖器官和营养枝叶的特征,其中生殖器官的特征包括:孢子叶的形状、大小孢子的表面纹饰等,被认为是该属植物最为重要的鉴定标准,并将具异型孢子的孢子囊穗也归于 *Selaginellites* (Seward, 1913; Lundblad, 1948; Hoskins and Abbott, 1956; Chaloner, 1958; Thomas, 1997; Bek *et al.*, 2001; Kustatscher *et al.*, 2010)。但由于保存的问题,很多化石标本常常仅保存有营养器官,甚至仅有破碎的茎叶体保存而未存有生殖器官。此时营养器官枝叶的形态特征对于属种的鉴定就显得至关重要,甚至有仅凭营养枝碎片定种的可能,如孙稚颖等(2006)通过对中国产 29 种和泰国产 1 种卷柏科植物叶的宏观和微观观察,发现叶外形、叶表皮细胞形态及气孔特征可为种间分类提供重要依据,并根据叶形态特征做出卷柏的分种检索表。近些年,一些似卷柏属营养叶的角质层信息也为该类植物的鉴定提供了很好的证据(Šimůnek and Thomas, 2012)。

目前关于似卷柏属化石记录的报道主要集中于古生代和中生代,根据保存情况将化石分成四种类型(表 I)。

当前化石植株具有侧、中叶,叶呈四行排列,是卷柏类植物中典型的异型叶类型,即表 I 中的类型 III。*Selaginella denticulata* (Goldenberg) Thomas, *Selaginella labutae* Bek, *Selaginella primaeva* (Goldenberg) Thomas 和 *Selaginellites tibeticus* Li and Zhu 产自古生代,与本种相比个体均较大,差距也较明显。产自捷克克拉德诺晚石炭世的 *Selaginella labutae* 侧、中叶较大,侧叶较为狭长,呈镰刀状,边缘具锯齿,基部偏斜,中叶呈倒卵形(Bek *et al.*, 2009),与本化石区别明显。产自德国萨尔州晚石炭世的 *Selaginella denticulata* 与当前化石标本的叶均具有小尖头,但前者叶明显较大(侧叶 12 mm,中叶 5 mm),叶边缘呈锯齿状;同样产地的 *Selaginella primaeva* 侧叶呈披针状,且与茎成较大角度,中叶边缘具锯齿(Thomas, 1997),皆与本化石差别明显。我国西藏晚二叠世的 *Selaginellites*

tibeticus 除侧、中叶略大于本化石外,其侧、中叶的形态、排列方式等特征均较为相似,但其侧叶着生角度明显较大,顶端指向两侧(李星学等, 1982),因而有别于当前化石标本。

中生代异型似卷柏化石共 11 种,本研究将这些中生代似卷柏属化石与当前化石标本进行了细致比较(表 II)。当前化石的侧叶为明显卵圆形,据此特征可将其与 *Selaginellites coburgensis* Van Konijnenburg-van Cittert, *Selaginellites angustus* Lee, *Selaginellites spatulata* Zheng and Lee, *Selaginellites sinensis* Zheng and Lee, *Selaginellites drepanoformis* Zheng and Lee 等进行区分。

产自云南禄丰晚三叠世的 *Selaginellites yunnanensis* Hsü 侧叶为卵形,茎上部排列紧密、下部排列较松的特征,与本化石较为相似,但 *Selaginellites yunnanensis* 侧叶顶端不向内侧弯曲、与茎相交角度较大等特征(李佩娟等, 1976)与本化石不同。产自美国亚利桑那州晚三叠世的 *Selaginella anasazia* Ash 分枝角度较大,侧、中叶皆较大、较长,排列较为疏松,中叶为披针形(Ash, 1972),与当前化石特征不同。产自中国辽宁中侏罗世的 *Selaginellites chaoyangensis* Zheng and Lee 和 *Selaginellites asiatica* Zheng and Lee 的叶较本化石都较大, *Selaginellites chaoyangensis* 为单轴羽状分枝,侧叶为长卵形且与茎成直角; *Selaginellites asiatica* 侧叶与茎之间角度较大(郑少林、李杰儒, 1978),均可与当前标本进行区分。

与当前化石最为相近的是报道于我国早白垩世义县组下部尖山沟层的多产似卷柏 *Selaginellites fausta* (Wu) Sun and Zheng。该种最早由吴舜卿(1999)基于产自辽宁北票下白垩统义县组的化石材料建立,将其描述为:仅发现生殖枝,标本孢子囊穗具梗、叶为线状钻形、孢子囊着生于孢子叶叶腋,并根据这些特征将其定为 *Lycopodites fausta* Wu。此后,孙革等(2001)在同层位发现了更多形态和结构保存良好的标本,这些标本特征稳定且具异型孢子,故将其改归于似卷柏属。*Selaginellites fausta* (Wu) Sun and Zheng 小型纤细草本,二歧分枝,叶二型呈四行排列,侧叶卵圆形至披针形,长约 0.6—0.8 mm,顶端尖且上指,背部具龙骨状突起;中叶贴生于茎上,形状与侧叶相似,长 0.2—0.3 mm,这些特征组合均与当前描述的化石标本茎叶特征吻合。但由于当前化石标本仅保存有营养枝,无法与 *Selaginellites fausta* 的生殖器官结构进一步对比,因此将其

表 I 卷柏类植物化石记录
Fossil records of *Selaginellites* and *Selaginella*

类型	种名	时代	产地	参考文献
I *	<i>Selaginellites leptostachys</i>	晚石炭世	德国萨尔州 斯米亚西部	Thomas, 1997; Bek <i>et al.</i> , 2001
	<i>Selaginellites crassicinctus</i>	晚石炭世	美国堪萨斯州	Hoskins and Abbot, 1956
	<i>Selaginellites canonbiensis</i>	晚石炭世	苏格兰	Chaloner, 1958
	<i>Selaginellites polaris</i>	三叠纪	格陵兰	Lundblad, 1948
	<i>Selaginellites leonardii</i>	中三叠世	意大利	Kustatscher <i>et al.</i> , 2010
	<i>Selaginellites dawsoni</i>	早白垩世	英国威尔登	Seward, 1913
II *	<i>Selaginellites elongatus</i>	晚石炭世	德国萨尔州	Thomas, 1997
	<i>Selaginella fraiponti</i>	晚石炭世	美国堪萨斯州	Schlanker and Leisman, 1969
	<i>Selaginella benxiensis</i>	晚石炭世	中国山西	Cleal and Wang, 2002
	<i>Selaginella harrisiana</i>	晚二叠世	新南威尔士州	Townrow, 1968
	<i>Selaginellites rostratus</i>	中侏罗世	土库曼斯坦	Burakova, 1963
III *	<i>Selaginella labutae</i>	晚石炭世	捷克克拉德诺	Bek <i>et al.</i> , 2009
	<i>Selaginella denticulata</i>	晚石炭世	德国萨尔州	Thomas, 1997
	<i>Selaginella primaeva</i>	晚石炭世	德国萨尔州	Thomas, 1997
	<i>Selaginellites tibeticus</i>	晚二叠世	西藏	李星学等, 1982
	<i>Selaginella anasazia</i>	晚三叠世	美国亚利桑那州	Ash, 1972
	<i>Selaginellites coburgensis</i>	晚三叠世	德国 Wüstenwelsberg	Van Koniunenburg-Van Cittert <i>et al.</i> , 1972
	<i>Selaginellites yunnanensis</i>	晚三叠世	云南禄丰	李佩娟等, 1976
	<i>Selaginellites angustus</i>	早中侏罗世	山西大同	斯行健等, 1963
	<i>Selaginellites asiatica</i>	中侏罗世	中国辽宁	郑少林、李杰儒, 1978
	<i>Selaginellites chaoyangensis</i>	中侏罗世	中国辽宁	郑少林、李杰儒, 1978
	<i>Selaginellites spatulata</i>	中侏罗世	中国辽宁	郑少林、李杰儒, 1978
	<i>Selaginellites sinensis</i>	中侏罗世	中国辽宁	郑少林、李杰儒, 1978
	<i>Selaginellites drepanoformis</i>	中侏罗世	中国辽宁	郑少林、李杰儒, 1978
	<i>Selaginellites fausta</i>	早白垩世	中国辽西	吴舜卿, 1999; 孙革等, 2001
V *	<i>Selaginella gutbieri</i>	晚石炭世	德国萨克森州 波斯基亚西部	Thomas, 1997, 2005
	<i>Selaginella zeillerei</i>	晚石炭世	英国约克; 法国约克; 法国卢瓦尔; 德国萨克森州	Chaloner, 1954 Thomas, 1997, 2005
	<i>Selaginella stachygynandroides</i>	晚石炭世	德国萨克森州	Thomas, 1997, 2005
	<i>Selaginella amasrae</i>	晚石炭世	土耳其	Simunek and Thomas, 2012

* I. 仅保存有孢子囊穗。II—IV. 保存孢子囊穗和营养枝类型, II. 营养枝具同型叶; III. 营养枝具异型叶; IV. 营养枝具三型叶。

定为 *Selaginellites* cf. *fausta* (Wu) Sun and Zheng。

Selaginellites cf. *fausta* 是首次在大拉子组发现的似卷柏化石,也是我国目前发现的距今最近的似卷柏化石,丰富了我国似卷柏属的化石记录。*Selaginellites fausta* 发现于义县组下部尖山沟层,时代为早白垩世早期 (Chen *et al.*, 2005; Zhang and

Sha, 2012; 万晓樵等, 2013), 在早白垩世晚期大拉子组发现了其相似种 *Selaginellites* cf. *fausta*。该相似种的形态、大小与现生圆枝卷柏 *Selaginella sanguinolenta* (L.) Spring 及江南卷柏 *Selaginella moellendorffii* Hieron 较为相似,但也略有不同 (插图 3) (表 III)。*Selaginella sanguinolenta* 侧叶、

中叶形状相同,叶为卵形,鞘状,叶背呈龙骨状,尖端上指,但其侧叶与中叶大小十分相近,长宽皆大于 *Selaginellites cf. fausta* (中国科学院植物研究所, 1972; 张宪春、张丽兵, 2004)。 *Selaginella moellendorffii* 为典型的异叶型,下部主茎稀疏的分布着侧叶,侧叶与中叶形状相似,卵圆形,尖端急尖,上指,但其叶边缘具细齿,叶背不呈或略呈龙骨状(中国科学院植物研究所, 1972; 张宪春、张丽兵, 2004),与 *Selaginellites cf. fausta* 略有区分。这可能暗示

该属在中生代晚期形态就较为稳定。似卷柏一般生活在潮湿环境中,指示较为湿润的气候环境(邓胜徽, 2007),结合汪清罗子沟盆地产出的其他植物类型 *Cupressinocladus*, *Pseudofrenelopsis*, *Brachyphyllum*, *Elatocladus*, *Elatides*, *Ruffordia*, *Gleichenites* 及 *Onychiopsis* 等皆为小叶型,反映早白垩世晚期该区域整体呈现较为干旱气候,期间可能存在间歇性湿润的变化,或者有局部湿润的小环境。

表 II 中生代异型叶似卷柏化石特征比较

Comparisons of *Selaginellites cf. fausta* with Mesozoic heterophyllous *Selaginellites*.

种名	分枝形式	侧叶	中叶	参考文献
<i>Selaginella anasazia</i>	不等二歧分枝	1.5—2.3×0.6—1 mm, 卵形, 尖端急尖或具短尖头, 着生角度 45°	长 1—1.2 mm, 披针形, 不贴生	Ash, 1972
<i>Selaginellites coburgensis</i>	二歧分枝	1×1.5—2 mm, 镰型, 钝尖, 近直角着生于茎上	<1×1.5 mm, 倒卵形	Van Konijnenburg-Van Cittert <i>et al.</i> , 2014
<i>Selaginellites yunnanensis</i>	假二歧至二歧分枝	1×0.5 mm, 卵形, 有时呈镰刀状弯曲, 顶端尖锐并指向枝的两侧, 近直角着生于茎上	很小, 长椭圆形至卵形	李佩娟等, 1976
<i>Selaginellites angustus</i>	二歧分枝	1.5×2 mm, 近三角形至镰刀形, 顶端尖锐	长约 1 mm, 贴生	张武等, 1963
<i>Selaginellites asiatica</i>	不等二歧分枝	0.3×1.5 mm, 大叶卵形, 瓦生, 顶端渐尖或钝圆, 着生角度 60°—70°	小叶卵圆形, 贴生	郑少林、李杰儒, 1978
<i>Selaginellites chaoyangensis</i>	单轴羽状分枝	1.5—2 mm, 长卵形, 尖端渐尖, 指向两侧, 着生角度 80°—90°	长约 0.5 mm, 长卵或宽披针形, 贴生	郑少林、李杰儒, 1978
<i>Selaginellites spatulata</i>	下部单轴分枝, 上部为不等二歧分枝	2×1 mm, 匙形, 钝尖, 尖端指向两侧	卵形	郑少林、李杰儒, 1978
<i>Selaginellites sinensis</i>	单轴式分枝	2.5×1 mm, 匙形, 在分枝中部增大至 10×3 mm, 尖端钝圆指向两侧	长约 1 mm, 卵形, 贴生	郑少林、李杰儒, 1978
<i>Selaginellites drepanoformis</i>	下部为二歧分枝, 上部为不等的二歧分枝	长 3—4 mm, 镰形, 尖端尖锐指向两侧, 以近直角着生于茎上	长约 1 mm, 披针形, 贴生	郑少林、李杰儒, 1978
<i>Selaginellites fausta</i>	二歧分枝	长 0.6—0.8 mm, 卵形, 钝尖, 尖端上指, 叶背呈龙骨状突起, 以宽角着生在茎上	长约 0.2—0.3 mm, 长卵形, 贴生	吴舜卿, 1999; 孙革等, 2001
<i>Selaginellites cf. fausta</i>	二歧分枝	0.5—1.2×0.2—0.7 mm, 卵形, 具小尖端, 叶片前端略向内侧弯曲, 叶背呈龙骨状突起, 着生角度 28°—60°	长约 0.1—0.4 mm, 卵形, 贴生	本文

表 III *Selaginellites cf. fausta*, *Selaginella sanguinolenta* 和 *Selaginella moellendorffii* 特征比较Comparisons among *Selaginella sanguinolenta*, *Selaginella moellendorffii* and *Selaginellites cf. fausta*

种名	分枝形式	叶型	侧叶	中叶	参考文献
<i>Selaginella sanguinolenta</i>	二歧分枝	不明显的异型叶, 近一形	1—2×0.4—0.8 mm, 卵圆形, 近全缘, 具小尖头, 背部呈龙骨状突起	叶形、大小与侧叶相似, 叶尖端与轴平行, 长 0.8—1.5 mm	中国科学院植物研究所, 1972; 张宪春、张丽兵, 2004
<i>Selaginella moellendorffii</i>	羽状分枝	异叶型	1—2.4×0.5—1.8 mm, 卵圆形, 边缘有细齿, 尖端急尖, 背部略呈龙骨状突起	叶形与侧叶相似, 叶尖端与轴平行或尖端交叉, 长 0.6—1.8 mm	中国科学院植物研究所, 1972; 张宪春、张丽兵, 2004
<i>Selaginellites cf. fausta</i>	二歧分枝	异叶型	0.5—1.2×0.2—0.7 mm, 卵圆形, 全缘, 具小尖头, 背部呈龙骨状突起	叶形与侧叶相似, 叶尖端与轴平行或略交叉, 长 0.1—0.4 mm	本文

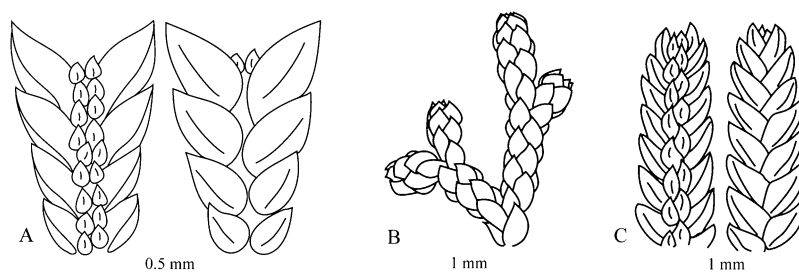


插图 3 *Selaginellites cf. fausta*(A)与现生卷柏 *Selaginella sanguinolenta*(B)和 *Selaginella moellendorffii*(C)

营养枝形态示意图。B,C 仿中国科学院植物研究所,1972。

Comparison of the vegetative shoots of *Selaginellites cf. fausta* (A), *Selaginella sanguinolenta* (B) and *Selaginella moellendorffii* (C).

B and C is after Institute of Botany, the Chinese Academy of Sciences, 1972.

致谢 野外工作得到中国科学院南京地质古生物研究所梅盛吴高级工程师的帮助,标本照相工作得到樊晓羿的帮助,评审专家提出宝贵意见,在此一并致谢。

参 考 文 献 (References)

- Ash S D, 1972. Late Triassic plants from the Chinle Formation in North-Eastern Arizona. *Palaeontology*, **15**: 598—618.
- Bek J, Libertín M, Drábková J, 2009. *Selaginella labutae* sp. nov., a new compression herbaceous lycopod and its spores from the Kladno-Rakovník Basin, Bohemian of the Czech Republic. *Review of Palaeobotany and Palynology*, **155** (3-4): 101—115.
- Bek J, Opluštil S, Drábková J, 2001. Two species of *Selaginella* cones and their spores from the Bohemian Carboniferous continental basins of the Czech Republic. *Review of Palaeobotany and Palynology*, **114**(1): 57—81.
- Burakova A T, 1963. Flora of the Jurassic deposits of Tuarkya. *Problema Neftajazonosti Sredney Asii*, **13**: 117—232 (in Russian).
- Chaloner W G, 1954. Notes on the spores of two British Carboniferous lycopods. *Annals and Magazine of Natural History*, **7**(74): 81—91.
- Chaloner W G, 1958. A carboniferous *Selaginellites* with densosporites microspores. *Palaeontology*, **1**(3): 245—253.
- Chen Pi-ji (陈丕基), 2012. Cretaceous Conchostracan biostatigraphy of China. *Journal of Stratigraphy (地层学杂志)*, **36**(2): 300—313 (in English with Chinese abstract).
- Chen Pi-ji, Wang Qi-fei, Zhang Hai-chun, Cao Mei-zhen, Li Wen-ben, Wu Shun-qing, Shen Yan-bin, 2005. Jianshangou Bed of the Yixian Formation in West Liaoning, China. *Science in China, Series D, Earth Sciences*, **48**(3): 298—298.
- Cleal C J, Wang Z Q, 2002. A new and diverse plant fossil assemblage from the upper Westphalian Benxi Formation, Shanxi, China, and its palaeofloristic significance. *Geological Magazine*, **139**(2): 107—130.
- Deng Sheng-hui (邓胜徽), 1995. Early Cretaceous flora of Huolinghe Basin, Inner Mongollia, Northeast China. Beijing: Geological Publishing House. 1—173 (in Chinese with English abstract).
- Deng Sheng-hui (邓胜徽), 2007. Palaeoclimatic implications of main fossil plants of Mesozoic. *Journal of Palaeogeography (古地理学报)*, **9**(6): 59—74 (in Chinese with English abstract).
- Deng Sheng-hui, Lu Yuan-zheng, Fan Ru, Li Xin, Fang Lin-hao, Liu Lu, 2012. Cretaceous floras and biostratigraphy of China. *Journal of Stratigraphy (地层学杂志)*, **36**(2): 241—265 (in English with Chinese abstract).
- Gou Yun-xian (勾韵娴), 1983. Cretaceous Ostracods from the Yanbian area, Jilin Province. *Acta Palaeontologica Sinica (古生物学报)*, **22**(1): 42—55 (in Chinese with English abstract).
- Guignard G, Yang Xiao-ju, Wang Yong-dong, 2017. Cuticle ultrastructure of *Pseudofrenelopsis gansuensis*: Further taxonomical implications for Cheirolepidiaceae. *Cretaceous Research*, **71**: 24—39.
- Halle T G, 1907. Einige krautartige Lycopodiaceen paläozoischen und mesozoischen Alters. *Kungliga Svenska Vetenskapsakademins Handlingar*, **7**(5): 1—17.
- Hao Yi-chun (郝诒纯), Su De-ying (苏德英), Yu Jing-xian (余静贤), Li You-gui (李友桂), Zhang Wang-ping (张望平), Liu Gui-fang (刘桂芳), 2000. *Stratigraphy Lexicon of China, Cretaceous System*. Beijing: Geological Publishing House. 1—124 (in Chinese).
- Hoskins J H, Abbott M L, 1956. *Selaginellites crassincinctus*, a new species from the Desmoinesian Series of Kansas. *American Journal of Botany*, **43**(1): 36—46.
- Huang Pin (黄 嫔), Zhang Guang-fu (张光富), 2002. Sporopollen assemblage from the Dalazi Formation of the Zhixin Basin, Jilin. *Acta Micropalaeontologica Sinica (微体古生物学报)*, **19** (3): 263—275 (in Chinese with English abstract).
- Institute of Botany, the Chinese Academy of Sciences (中国科学院植物研究所), 1972. *Pictorial Yearbook of Chinese Advanced Plants, Tome 1*. Beijing: Science Press. 1—865 (in Chinese).
- Kustatscher E, Wachtler M, Van Konijnenburg-Van Cittert J H A, 2010. Lycophytes from the Middle Triassic (Anisian) Locality Kühwiesenkopf (Monteprà Della Vacca) in the Dolomites (Northern Italy). *Palaeontology*, **53**(3): 595—626.
- Li Gang, Ohta T, Batten D J, Sakai T, Kozai T, 2016. Morphology and phylogenetic origin of the spinicaudatan *Neodiestheria* from

- the Lower Cretaceous Dalazi Formation, Yanji Basin, north-eastern China. *Cretaceous Research*, **62**: 183—193.
- Li Pei-juan (李佩娟), Tsao Cheng-yao (曹正尧), Wu Shun-qing (吴舜卿), 1976. The Mesozoic plants of Yunnan. *In*: Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), The Mesozoic Fossils of Yunnan, Part 1. Beijing: Science Press. 87—160 (in Chinese).
- Li Xing-xue (李星学), Yao Zhao-qi (姚兆奇), Zhu Jia-nan (朱家楠), Duan Shu-ying (段淑英), Hu Yu-fan (胡雨帆) 1982. Late Permian plants from northern Xizang. *In*: Comprehensive Scientific Expedition of Tibet Plateau, Chinese Academy of Sciences (eds.), Palaeontology of Xizang, Part 5. Beijing: Science Press. 1—16 (in Chinese with English abstract).
- Lundblad A B, 1948. Selaginelloid Strobilus from East Greenland (Triassic). *Meddelelser fra Dansk Geologisk Forening*, **11**: 351—363.
- Rickards J D, 2000. The age of the earliest club mosses: The Silurian Baragwanathia flora in Victoria, Australia. *Geological Magazine*, **137**: 207—209.
- Schlanker C M, Leisman G A, 1969. The herbaceous Carboniferous Lycopod *Selaginella fraiponti* comb. nov. *Botanical Gazette*, **130**(1): 35—41.
- Schweitzer H J, Van Konijnenburg-Van Cittert J H A, Vander Burgh J, 1997. The Rhaeto—Jurassic flora of Iran and Afghanistan. 10. Bryophyta, Lycophyta, Sphenophyta, Pterophyta-Eusporangiateae and Protoleptosporangiateae. *Palaeontographica*, **243**: 103—192.
- Seward A C, 1913. A British fossil *Selaginella*. *The New Phytologist*, **7**: 85—89.
- Sha Jin-geng, Lucas S G, 2012. Non-marine Cretaceous chronology and correlation. *Journal of Stratigraphy (地层学杂志)*, **36**(2): 137—152 (in English with Chinese abstract).
- Šimůnek Z, Thomas B A, 2012. A new species of *Selaginella* (Selaginellaceae) from the Bolsovian (Carboniferous Period) of the Zonguldak-Amasra Coal Basin, north-western Turkey. *Geologia Croatia*, **65**(3): 345—350.
- Sun Ge (孙革), Zheng Shao-lin (郑少林), David L, Wang Yong-dong (王永栋), Mei Sheng-wu (梅盛吴), 2001. Early Angiosperms and Their Associated Plants from Western Liaoning. Shanghai: Shanghai Scientific Technical & Publishers. 1—227 (in Chinese with English summary).
- Sun Zhi-ying (孙稚颖), Zhang Xian-chun (张宪春), Cui Shao-mei (崔绍梅), Zhou Feng-qing (周凤琴), 2006. Leaf morphology of 29 Chinese and one Thailand species of the Selaginellaceae and its taxonomic significance. *Acta Phytotaxonomica Sinica (植物分类学报)*, **44**(2): 148—160 (in Chinese with English abstract).
- Sze H C (斯行健), Li H H (李星学) *et al.*, 1963. The Fossil Plants in China, Part 2: The Mesozoic Plants in China. Beijing: Science Press. 1—429 (in Chinese).
- Tao Jun-rong (陶君容), Zhang Chuan-bo (张川波), 1990. Early Cretaceous angiosperms of the Yanji basin, Jilin Province. *Acta Botanica Sinica (植物学报)*, **32**(3): 220—229 (in Chinese with English abstract).
- Tao Jun-rong (陶君容), Zhang Chuan-bo (张川波), 1992. Two angiosperm reproductive organs from the early Cretaceous China. *Acta Phytotaxonomica Sinica (植物分类学报)*, **30**(5): 423—427 (in Chinese with English abstract).
- Teng Xiao, Li Gang, 2017. Clam shrimp genus *Ordosestheria* from the Lower Cretaceous Dalazi Formation in Jilin Province, north-eastern China. *Cretaceous Research*, **78**: 196—205.
- Thomas B A, 1992. Paleozoic herbaceous lycopsids and the beginnings of extant *Lycopodium* sens. lat. and *Selaginella* sens. lat. *Annals of the Missouri Botanical Garden*, **79**: 624—631.
- Thomas B A, 1997. Upper Carboniferous herbaceous lycopsids. Review of Palaeobotany and Palynology, **95**(1—4): 129—153.
- Thomas B A, 2005. A reinvestigation of *Selaginella* species from the Asturian (Westphalian D) of the Zwickau coalfield, Germany and their assignment to the new sub-genus *Hexaphyllum*. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften*, **156**: 403—414.
- Townrow J A, 1968. A fossil *Selaginella* from the Permian of New South Wales. *Botanical Journal of the Linnean Society*, **61**: 13—23.
- Van Konijnenburg-Van Cittert J H A, Kustatscher E, Bauer K, Pott C, Schmeißner S, Dütsch G, Krings M, 2014. A *Selaginellites* from the Rhaetian of Wüstenwelsberg (Upper Franconia, Germany). *Neues Jahrbuch für Geologie und Paläontologie*, **272**: 115—127.
- Wan Xiao-qiao (万晓樵), Li Gang (李罡), Huang Qing-hua (黄清华), Xi Dang-peng (席党鹏), Chen Pi-ji (陈丕基), 2013. Division and correlation of terrestrial Cretaceous stages in China. *Journal of Stratigraphy (地层学杂志)*, **37**(4): 457—471 (in Chinese with English abstract).
- Wang Ya-qiong, Sha Jin-geng, Pan Yan-hong, Zhang Xiao-lin, Rao Xin, 2012. Non-marine Cretaceous ostracod assemblages in China: A preliminary review. *Journal of Stratigraphy (地层学杂志)*, **36**(2): 289—299 (in English with Chinese abstract).
- Wu Shun-qing (吴舜卿), 1999. A preliminary study of the Jehol Flora from Western Liaoning. *Palaeoworld*, **11**: 7—57 (in Chinese with English abstract).
- Xu Hong-he (徐洪河), Wang Yi (王悻), 2002. A new lycopsid cone from the Upper Devonian of western Junggar basin, Xinjiang, China. *Acta Palaeontologica Sinica (古生物学报)*, **41**(2): 251—258 (in Chinese with English abstract).
- Xue Jin-zhuang (薛进庄), Hao Shou-gang (郝守刚), Wang De-ming (王德明), 2006. A review of the middle-late Devonian Lycopsids. *Acta Scientiarum Naturalium Universitatis Pekinensis (北京大学学报, 自然科学版)*, **42**(6): 808—816 (in Chinese with English abstract).
- Yang Xiao-ju, 2008. A male cone of *Pseudofrenelopsis dalatzensis* with *in situ* pollen grains from the Lower Cretaceous of North-east China. *Geobios*, **41**: 689—698.
- Yang Xiao-ju, Deng Sheng-hui, 2007. Discovery of *Pseud-*

- ofrenelopsis gansuensis* from the Lower Cretaceous of Wangqing, Jilin Province, and its significance in correlation of Cretaceous red beds in China. *Acta Geologica Sinica*, **81**(6): 905—911.
- Yang Xiao-ju, Guignard G, Thévenard F, Wang Yong-dong, Barale G, 2009. Leaf cuticle ultrastructure of *Pseudofrenelopsis dalatzensis* (Chow et Tsao) Cao ex Zhou (Cheirolepidiaceae) from the Lower Cretaceous Dalazi Formation of Jilin, China. *Review of Palaeobotany and Palynology*, **153**(1): 8—18.
- Ye De-quan (叶得泉), 1995. Ostracode fossil of Cretaceous in Yanji Basin and its significance. *Petroleum Geology & Oilfield Development in Daqing (大庆石油地质与开发)*, **14**(2): 1—10 (in Chinese with English abstract).
- Yu Jing-xian (余静贤), Miao Shu-juan (苗淑娟), 1983. Early Cretaceous spores and pollen assemblage of Yanbian district. *Bulletin of the Tianjing Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences (中国地质科学院天津地质矿产研究所所刊)*, **8**: 55—79 (in Chinese with English abstract).
- Zeiller R, 1906. Bassin Houiller et Permien de Blanzay et du Creusot, Flore Fossile. *Études Gêles Minérales de la France*. Paris: Ministère des Travaux Publics. 1—265.
- Zhang Chuan-bo (张川波), 1980. Discussion on stratigraphic division and times of Late Mesozoic in Yanji Basin. *Journal of Jilin University (Earth Science Edition) (吉林大学学报, 地球科学版)*, **10**(1): 51—56 (in Chinese with English abstract).
- Zhang Guang-fu (张光富), 2001. Early Angiosperms from the Dalazi Formation of Yanbian Area, Jilin, China. *Nanjing: Nanjing Institute of Geology and Palaeontology, Chinese Academy of Science*. 1—109 (in Chinese with English abstract).
- Zhang Hai-chun, 1997. Early Cretaceous insects from Dalazi Formation of the Zhixin Basin, Jilin Province, China. *Palaeoworld*, **7**(8): 75—104.
- Zhang Mi-man (张弥漫), Zhou Jia-jian (周家健), Liu Zhi-cheng (刘智成), 1977. The age of the Cretaceous fish-bearing strata from Northeast China and their sedimentary environment. *Vertebrata Palasiatica (古脊椎动物与古人类学报)*, **15**(1): 194—198 (in Chinese).
- Zhang Wu (张 武), Zhang Zhi-cheng (张志诚), Zheng Shao-lin (郑少林), 1980. Fossil plants part. In: *Shenyang Institute of Geology and Mineral Resources (ed.), Palaeontological Atlas of Northeast China, Part 2: Mesozoic and Cenozoic Volume*. Beijing: Geological Publishing House. 221—372 (in Chinese).
- Zhang Xiao-lin, Sha Jin-geng, 2012. Sedimentary laminations in the lacustrine Jianshangou Bed of the Yixian Formation at Sihetun, western Liaoning, China. *Cretaceous Research*, **36**(2): 96—105.
- Zhang Xian-chun (张宪春), Zhang Li-bing (张丽兵), 2004. *Flora Reipublicae Popularis Sinicae, Tomes 6(3)*. Beijing: Science Press. 1—303 (in Chinese).
- Zheng Shao-lin (郑少林), Li Jie-ru (李杰儒), 1978. Several new species of Jurassic *Selaginellites* from Western Liaoning. *Symposium of Stratigraphical Paleontology (地层古生物论文集)*, **1**: 146—151 (in Chinese with English summary).
- Zhou Zhi-yan (周志炎), Chen Pi-ji (陈丕基), Li Bao-xian (厉宝贤), Wen Shi-xuan (文世宣), Li Wen-ben (黎文本), Zhang Lu-jin (张璐瑾), Ye Mei-na (叶美娜), Liu Zhao-sheng (刘兆生), Li Zai-ping (李再平), Yang Xue-lin (杨学林), 1980. Younger Mesozoic non-marine deposits of the Yanbian area, Eastern Jilin. *Bulletin of Nanjing Institute of Geology and Palaeontology, Academia Sinica (中国科学院南京地质古生物研究所所刊)*, **1**: 1—21 (in Chinese).
- Zhou Zhi-yan, 1995. On some Cretaceous pseudofrenelopsids with a brief review of cheirolepidiaceous conifers in China. *Review of Palaeobotany & Palynology*, **84**: 419—438.

***SELAGINELLITES* CF. *FAUSTA* FROM THE LOWER CRETACEOUS OF WANGQING, JILIN PROVINCE**

XU Qing^{1, 2)} and YANG Xiao-ju¹⁾

1) *Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing 210008, China, xjyang@nigpas.ac.cn;*

2) *University of the Chinese Academy of Sciences, Beijing 100049, China*

Key words *Selaginellites*, Dalazi Formation, Early Cretaceous, Wangqing, Jilin

Abstract

A fossil plant attributed to *Selaginellites* from the Lower Cretaceous Dalazi Formation in Wangqing County, Jilin Province is described in this paper. The fossil is tenuous herbaceous, small, stem thin, leaves heterophyllous, decussate, arranged in four rows (two lateral rows and two median rows). Lateral leaves larger, ovate, entire, dorsally keel-like ribbed, apices top and the front of the blade is slightly curved inward, attached to the stem with an amplexicaul

base without petiole. Median leaves small, adpressed to the stem densely and parallel with stem, much similar with lateral leaves in shape. This specimen resembles closely *Selaginellites fausta* (Wu) Sun and Zheng from the Jianshangou bed of the lower part of the Lower Cretaceous Yixian Formation. It is hard for further comparison due to no reproductive organ have been found, the present fossil is attributed to *Selaginellites* cf. *fausta* (Wu) Sun and Zheng. It represents the latest fossil record of *Selaginellites* in China so far, and enriches the *Selaginellites* fossil record in China.