

# 山西柳林孙家沟组孢粉植物群<sup>\*</sup>

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**提要** 记述山西晚二叠世晚期孙家沟组的丰富孢粉植物群, 计有 57 属 109 种(包括相似种和未定种), 讨论孢粉植物群的性质; 以西欧镁灰岩组分子为主体, 并有相当数量的安加拉-亚安加拉(如新疆北部)成分参与, 还有少量华夏植物群的残留分子。

**关键词** 孢粉植物群 孙家沟组 山西

## 前言

石千峰群主要由砖红到紫红色的砂岩、砂质泥岩与砂质页岩组成, 厚度数百米至 1 000 m 以上, 广泛分布于华北地区。由于层型剖面命名地点的石千峰群出露不全, 1959 年中国科学院山西地层队根据宁武剖面将石千峰群由下而上划分为孙家沟组、刘家沟组与和尚沟组, 其时代归为早三叠世(刘鸿允、刘宪亭, 1984)。在 60 年代, 对石千峰群(系)的时代曾进行了讨论(李星学, 1963); 70—80 年代地质学家主要根据山西古植物、孢粉、介形虫以及古脊椎动物等化石研究, 提出了孙家沟组划为晚二叠世, 刘家沟组、和尚沟组归为早三叠世, 这为石千峰群时代讨论向前迈进了一步, 与此同时(1975—1978), 山西区测队以及山西地层断代总结中王自强等(1987, 1989)对石千峰群古植物化石又进行了一系列研究, 包括对孙家沟组古植物的研究, 并补充讨论了古植代-中植代界线的过渡问题。在孢子花粉方面的研究, 此期间同样获得很大进展, 最早由曲立范(1980, 1982)研究陕甘宁盆地石千峰群的孢粉, 为石千峰群二叠—三叠纪地层的划分提供了充分的化石依据, 其后欧阳舒、王仁农(1985)对豫西平顶山砂岩, 吴建庄(1995)对河南淮阳, 王蓉(1987)对安徽界首等地的孙家沟组孢粉分别进行了研究。本文作者在开展“中国石炭纪—二叠纪孢粉植物群及植物地理区系

划分”项目中, 于 1997 年又前往山西怀仁、宁武、太原西山、垣曲、长治等地考察石炭—二叠纪地层剖面, 并采集了孢粉样品。同时还利用了 80 年代, 由王立新提供的山西柳林、沁水、河南济源、陕西乡宁、韩城<sup>\*\*</sup>等地孙家沟组部分样品。前后共浸解分析了 33 个孙家沟组的孢粉样品。

本文所涉及孙家沟组材料均属山西柳林县军渡、大凤山、赫家津等地区, 其中在 6 个样品中获得保存完美, 含量丰富的孢粉。

在野外工作中, 得到山西省地质矿产局副总工程师苗培森以及山西区调队的领导大力协助, 王绍鑫同志与作者共同进行野外工作。标本分析由郭金玉、刘登舟、张保平同志完成。本文作者对上述单位和同志给予的协助谨致衷心的感谢。

## 地层简述

山西柳林地区孙家沟组, 底部为杂色含砾长石砂岩。下部为暗紫红色、灰紫红色砂质泥岩、粉砂岩、细砂岩、泥岩, 并含有钙质结核和灰岩质砾岩凸镜体, 砂岩交错层理发育, 中部为灰绿色、紫红色厚层状细粒长石砂岩, 板状砂质泥岩夹深灰色、紫红色泥岩和薄层砾岩凸镜体, 上部为紫红色砂质泥岩与细粒长石砂岩互层, 顶部夹灰色钙质凸镜体。下部含有脊椎动物化石 *Shansisaurus xuecunensis* Cheng, Tapinocephalidae, Pareiasauridae; 中上部在

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绿色层中含有丰富的植物化石,主要分子有 *Ullmannia bronnii* Goep., *Pseudovoltzia liebeana* (Geinitz), *Callipteris martinsii* (Kurtze), *Quadrocladus solmsii* (Goth. et Nag.), *Taeniopteris taiyuanensis* Halle, *Tatarina* cf. *sinuosa* Gom., *Peltaspermum dafengshanense* Wang et Wang。在中上部深灰色泥岩中含有丰富的孢粉。厚约 179m (地层剖面详见王自强、王立新,1987)。

孢粉植物群特征

山西柳林地区晚二叠世晚期石千峰组所见孢粉 57 属 109 种 (其中包括未定种), 名单如下:

- Leiotriletes adnatus* (Kosanke) Potonié et Kremp
- L.* sp.
- Dictyophyllidites* sp.
- Calamospora microrugosa* (Ibrahim) Schopf, Wilson et Bentall
- C. pallida* (Loose) Schopf, Wilson et Bentall
- C.* cf. *pallida* (Loose) Schopf, Wilson et Bentall
- C. tener* (Leschik) Madler
- Punctatisporites minutus* Kosanke
- P. obliquus* Kosanke
- Granulatisporites granulatus* Ibrahim
- Cyclogranisporites aureus* (Loose) Potonié et Kremp
- C. micaceus* (Imgrund) Imgrund
- C.* cf. *minutus* Bharadwaj
- C.* sp.
- Apiculatisporis parvispinosus* (Leschik) Qu
- Ap. variocorneus* Sullivan
- Ap.* sp.
- Lophotriletes* sp.
- Apiculatasporites perirugosus* (Ouyang et Li) Ouyang
- Ap.* sp.
- Acanthotriletes castanea* Butterworth et Williams
- Ac.* sp. A, B
- Anapiculatisporites* sp.
- Verrucosisporites microtuberosus* (Loose) Smith et Butterworth
- V. sinensis* Imgrund
- Neoraistrickia* cf. *irregularis* Ouyang et Li
- Raistrickia* sp.
- Convolutispora* sp.
- Camptotriletes?* sp.
- Triquitrites* sp.
- Lycospora* sp.
- Densosporites* sp.

- Kraeuselisporites* sp.
- Crassispora* sp.
- Polycingulatisporites* sp.
- Discisporites psilatus* de Jersey
- Lundbladispora* sp.
- Endosporites* sp.
- Punctatisporites minutus* Ibrahim
- Tuberculatisporites* cf. *medius* Zhou
- Cordaitina* sp.
- Florinites antiquus* Schopf
- F.* cf. *diversiformis* Kosanke
- Potonieisporites novicus* Bharadwaj
- P.* sp.
- Vesicaspora wilsonii* (Schemel) Wilson et Venkatachala
- Protopinus asymmetricus* Ouyang
- Alisporites* cf. *auritus* Ouyang et Li
- A. parvus* de Jersey
- A. tenuicarpus* Balme
- A.* sp.
- Klausipollenites schaubergeri* (Potonié et Klaus) Jansonius
- K.* sp.
- Falcisporites* cf. *nuthallensis* (Clarke) Balme
- F. zapfei* (Potonié et Klaus) Leschik
- Vitreisporites cryptocarpus* Ouyang et Li
- V. pallidus* (Reissinger) Nilsson
- Pteruchipollenites reticarpus* Ouyang et Li
- P.* sp.
- Platysaccus papilionis* Potonié et Kremp
- P. radialis* (Leschik) Clarke
- P.* cf. *undulatus* Ouyang et Li
- Pityosporites* sp.
- Sulcatisporites* cf. *ovatus* (Balme et Hennelly) Madler
- Corisaccites quadratoideus* Zhou
- C.* sp.
- Schulzospora?* sp.
- Limitisporites minor* Zhou
- L. monstruosus* (Luber et Waltz) Hart
- L. rhombicarpus* Zhou
- L.* cf. *rhombicarpus* Zhou
- Vestigisporites* sp.
- Gardenasporites heisseli* Klaus
- G.* sp. 1 (= 欧阳舒、王仁农, 1985 的 *G.* sp. (sp. nov.))
- G.* sp. 2
- Jugasporites schaubergeroides* Klaus
- J. tectus* Leschik
- J.* sp.
- Chordasporites* cf. *orientalis* Ouyang et Li

*C. parvus* Wang  
*C. sp.* (Cf. *Sahnites thomasi* Pant )  
*Lueckisporites virkkiae* Potonié et Klaus  
*L. sp.*  
*Scutasporites xinjiangensis* (Hou et Wang) Ouyang  
*Taeniaesporites albertae* Jansonius  
*T. noviaulensis* Leschik  
*T. novimundi* Jansonius  
*T. watangensis* Qu  
*Protohaploxylinus dvinensis* (Sedova) Hart  
*Protohaploxylinus microcorpus* (Schaarschmidt) Clarke  
*P. ovalicarpus* Zhou  
*P. proluxus* (Luber) Samoilovich  
*P. samoilovichiae* (Jansonius) Hart  
*P. suchonensis* (Sedova) Hart  
*P. cf. verus* (Efremova) Hou et Wang  
*P. sp.*  
*Striatopodocarpites divaricata* (Wilson) Hart  
*S. sp.*  
*Striatoabieites brickii* Sedova  
*S. duivenii* (Jansonius) Hart  
*S. cf. multistriatus* (Balme et Hennelly) Hart  
*Crustasporites globosus* Leschik  
*C. cf. globosus* Leschik  
*Vittatina striata* (Luber) Samoilovich  
*V. vittifera* (Luber) Samoilovich  
*Cycadopites caperatus* (Luber) Hart  
*C. cf. glaber* (Luber) Hart  
*Ephedripites sp.*

孢粉组合中裸子植物(包括种子蕨)花粉占整个组合的 84.3%—89%, 蕨类植物孢子仅占 8.3%—14%, 并偶见极个别的疑源类。

蕨类植物孢子属种贫乏, 含量颇低, 主要为无环三缝孢亚类, 约 16 属 30 种, 其中 *Apiculatisporis* 占 0.2%—2.9%, 有 *A. parvispinosus*, *A. vario-corneus*, *Cyclogranisporites* 占 0.3%—1.1%, 有 *C. aureus*, *C. micaceus*, *C. cf. minutus*, 其次为 *Leiotriletes adnatus*, *Calamospora microrugosa*, *C. cf. pallida*, *C. pallida*, *C. tener*, *Punctatisporites minutus*, *P. obliquus*, *Granulatisporites granulatus*, *Acanthotriletes castanea*, *Verrucosiporites microtuberosus*, *V. sinensis*, 还有个别的 *Dictyophyllidites*, *Raistrickia*, *Neo-raistrickia cf. irregularis*, *Anapiculatisporites*, *Convolutispora*, *Camptotriletes*。具环三缝孢及腔状三缝孢出现较少, 仅见 9 属, 有 *Discisporites psilatus* 占 0.4%—2.2%, 另有少量 *Kraeuselisporites*,

*Lundbladisporea*, *Endosporites*, *Polycingulatisporites*, 在赫家津地区尚见有个别的 *Lycospora*, *Crassispora*, *Densosporites*, 在军渡偶见 *Triquitrites*。单缝孢有 *Punctatosporites*, *Tuberculatosporites*。

裸子植物花粉以种子蕨类和松柏类花粉为主要组成分子, 本体具肋条和裂缝二气囊粉占有相当优势, 约占 43.6%—60.1%, 有 15 属 41 种, 本体不具肋条与裂缝的二气囊粉占 23%—40.5%, 有 10 属 19 种。其中: 具有肋纹二气囊粉 *Lueckisporites* 占 9.8%—21%, 有 *L. sp.*, *L. virkkiae*; *Protohaploxylinus* 占 1.9%—7.1%, 有 *P. dvinensis*, *P. microcorpus*, *P. ovalicarpus*, *P. proluxus*, *P. samoilovichiae*, *P. cf. verus*; *Striatopodocarpites* 占 0.2%—4.7%, 有 *S. divaricata*; 其他尚有少量的 *Striatoabieites*, 有 *S. brickii*, *S. duivenii*, *S. cf. multistriatus*; *Chordasporites cf. orientalis*, *C. parvus* 以及个别的 *Vittatina striata*, *V. vittifera*, *Crustasporites globosus* 和 *Scutasporites xinjiangensis* 等。具裂缝二气囊花粉有 *Jugasporites* 约占 4.8%—18%, 有 *J. schaubergeroides*; *Limitisporites* 占 1.4%—5.2%, 有 *L. minor*, *L. monstruosus*, *L. rhombicarpus*, *L. cf. rhombicarpus*; *Gardenasporites* 占 3.8%—10.8%, 有 *G. heisseli*。本体不具肋条二气囊花粉的 *Alisporites* 在军渡地区其相对含量较高, 约占 10%, 其它地区一般为 2.2%—3.6%, 有 *A. cf. auritus*, *A. parvus*, *A. tenuicarpus*; 较为常见的有 *Pteruchipollenites reticarpus* 约占 2.2%—9.2%, *Klausipollenites schaubergeri* 约占 0.4%—1.5%, *Platysaccus* 占 1.2%—2%, 有 *P. papilionis*, *P. radialis*, *P. cf. undulatus*, *Falcisporites* 占 0.5%—2.9% 有 *F. zapfei*, *F. cf. nuthallensis* 以及含量较少的 *Vitreisporites cryptocarpus*, *V. pallidus*, *Protopinus*, *Vesicaspora*, *Sulcatiporites* 等分子, 也出现了少量的单沟粉 *Cycadopites* 和多沟粉 *Ephedripites*。裸子植物花粉中单气囊粉较少, 仅占 0.4%—3.1%, 主要有 *Florinites*, *Potonieisporites*, *Cordaitina* 等。

从上述山西柳林地区孙家沟孢粉组合特征看, 无论在孢粉属种的数量上以及属种百分含量上与华北晚二叠世早期的孢粉植物群相比已经历了“突变事件”, 其中蕨类植物孢子与种子蕨类孢子已大大衰退, 而先进种子蕨类(多肋纹花粉)与松柏类(少肋二

气囊花粉与无肋纹二气囊花粉)占绝对优势。这又从孢粉植物群证实了姚兆奇、欧阳舒(1980)、欧阳舒(Ouyang, 1991)、王自强等(1989)所指出的,古植代-中植代过渡界线在华北是在上石盒子组与孙家沟组之间,换言之,孙家沟组已为中植代陆生高地裸子植物繁盛时期。在孢子组成上值得注意的是古植代石松类(包括鳞木类)孢子的子遗,即 *Lycospora*, *Densosporites* 和 *Crassispora* 仍有个别存在,另一方面,也出现了形态上更近中植代成分的少量代表如 *Dictyophyllidites*, *Lundbladispota*, *Kraeuselisporites* 和 *Discisporites*。此期孢粉组合被称为 *Lueckisporites virkkiae*-*Jugasporites schaubergeroides* 组合(欧阳舒等, 1999)。

孢粉组合与国内外对比及其孢粉植物群讨论

本区孙家沟组的孢粉组合特征与山西离石、豫西平顶山、安徽界首、河南淮阳的孙家沟组孢粉组合颇为相似,均呈现出蕨类植物孢子稀少,含量较低,裸子植物花粉含量都较丰富,在这些地区都出现了 *Lueckisporites virkkiae*, *Jugasporites*, *Protohaploxypinus*, *Striatopodocarpites*, *Alisporites*, *Pteruchipollenites*, *Klausipollenites* 等分子,但在不同地区其孢粉组成和含量上尚有一定差异。在山西离石、安徽界首裸子植物花粉分别达到 85% 与 60%—77%, 并都以本体具肋条与裂缝二气囊花粉为主;山西离石具肋条二气囊花粉可达 50%, 具裂缝二气囊花粉达到 17%—30%, 不具肋纹二囊粉为 23%—40%, 在安徽界首具肋纹与裂缝二囊粉为 17%—30%, 不具肋纹的为 32%。另外在豫西平顶山、河南淮阳、安徽界首等地分别出现的 *Punctatisporites palmipedites*, *Gulisporites cochlearius*, *Waltzispota*, *Knoxisporites cf. instarrotulae*, *Patellisporites cf. meishanensis*, *Tripartites cristatus* 以及 *Balteusispota textura* 等, 这些属种在柳林地区则未发现。在柳林地区所见的 *Polycingulatisporites*, *Discisporites*, *Crustaesporites globosus* 在河南、安徽等地未见报道(见表 I)。

在垂直分布上,柳林地区孙家沟的孢粉组合与其上下地层的孢粉组合有明显的差异。在华北地区

的上石盒子组(高联达, 1984; 周和仪, 1987; 廖克光, 1987), 华南地区的龙潭组(欧阳舒, 1962; 侯静鹏等, 1995)以及云南地区宣威组(欧阳舒, 1986)的孢粉组合中蕨类植物孢子无论在种属数量上还是其含量上都很丰富, 普遍均含有丰富的华夏孢粉植物群分子如 *Macrotorispora*, *Patellisporites meishanensis*, *Anticapipollis* 等。孙家沟组上覆中生代地层刘家沟组富含 *Lundbladispota*, *Aratrisporites* 等分子(曲立范, 1982)。这些组合特征都易与孙家沟组合相区别。

有趣的是, 本文组合还与新疆北部(亚安加拉区)的上二叠统, 特别是其顶部的锅底坑组中下部的孢粉组合(侯静鹏、王智, 1986; 欧阳舒等\*, 1999)有一定的相似性, 锅底坑组合中也存在见于本组合的一些种, 如 *Lueckisporites virkkiae*, *Scutasporites xinjiangensis*, *Taeniaesporites cf. novimundi*, *Protohaploxypinus cf. samoilovichiae*, *P. cf. verus*, *Striatoabieites multistriatus*, *Vittatina vittifera*, *Klausipollenites schaubergeri*, *Falcisporites zapfei*, *Alisporites parvus*, *Cycadopites caperatus*, 共有的属除蕨类植物一些光面、粒面、刺面、瘤面孢子形态属之外, 还有 *Dictyophyllidites*, *Lycospora*, *Densosporites*, *Tuberculatosporites*, *Cordaitina*, *Florinites*, *Platysaccas* 和 *Ephedripites* 等。但二者之间区别还是很明显的, 特别在种的组成上锅底坑组合分异度更高(已知近 80 属, 150 种), 上列共有或很近似的种( $\geq 10$  种), 仅占锅底坑组合的一小部分(略 1/15); 而且锅底坑组合中一些重要的属, 如 *Limatulasporites*, “*Remysporites*”, *Samoilovichisaccites*, *Striatolebachites*, *Hamiapollenites*, *Welwitschipollenites* 及 *Tympanicysta* 等, 皆未见于柳林地区的孢粉组合。尽管如此, 上述共有分子的出现, 表明在华北晚二叠世晚期植被中, 确有一些安加拉-亚安加拉植物混生。因为具肋纹, 特别是多肋纹花粉的最早记录是见于亚安加拉区(巴什基尔早期), 这些属种子蕨(如盾籽目 *Peltaspermales*)的多肋花粉也是西乌拉尔石炭纪一二叠纪最重要组分。而且被认为其母体植物伴随欧亚板块的北移而发生南迁(欧阳舒等, 1994), 这类花粉在华夏植物群中直到早二叠世(山西组)才出现, 它们在欧美区出现也较晚(维斯发 B 期)。又如 *Scutasporites xinjiangensis* 与亚安加拉区松柏类 *Quadracladus*(生殖器官 *Sashinia*)的原

\* 新疆石油管理局克拉玛依研究院、中国科学院南京地质古生物研究所、新疆北部石炭纪-二叠纪孢子花粉系统研究。  
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表 I 华北地区孙家沟组重要孢粉属种比较

Correlation chart of main miospores from Sunjiagou Formation in N. China

孢粉属种名称	本 文	山西离石 曲立范 1980	安徽界首 王 蓉 1987	河南平顶山 欧阳舒、王仁农 1985	河南淮阳 吴建庄 1995
<i>Leiotriletes</i>	+		+	+	+
<i>Punctatisporites</i>	+	+		+	
<i>P. palmipedites</i>			+	+	
<i>Dictyophyllidites</i>	+		+		
<i>Calamospora</i>				+	+
<i>C. microrugosa</i>	+		+		
<i>Gulisporites</i>				+	+
<i>Granulatisporites</i>	+			+	+
<i>G. granulatus</i>	+	+			
<i>Cyclogranisporites</i>	+	+	+	+	+
<i>Apiculatisporis</i>	+	+	+		+
<i>Acanthotriletes</i>	+		+	+	+
<i>Verrucosisporites</i>	+		+		+
<i>Knoxisporites</i>				+	+
<i>Balteusispora</i>				+	
<i>Lycospora</i>	+	+	+	+	+
<i>Densosporites</i>	+		+		+
<i>Crassispora</i>	+		+		+
<i>Patellisporites</i> cf. <i>meishanensis</i>				+	+
<i>Polycinulatisporites</i>	+				
<i>Kraeuselisporites</i>	+	+	+	+	
<i>Lundbladispora</i>	+			+	+
<i>Tripartites cristatus</i>					+
<i>Tuberculatosporites</i>	+		+	+	+
<i>Florinites</i>	+		+	+	+
<i>Cordaitina</i>	+	+			+
<i>Potonieisporites</i>	+	+	+	+	+
<i>Alisporites</i>	+	+	+	+	+
<i>A. parvus</i>	+		+	cf.	
<i>Vitreisporites</i>	+	+	+	+	+
<i>V. pallidus</i>	+		+		+
<i>Klausipollenites</i>	+		+	+	+
<i>Pteruchipollenites reticorpus</i>	+		+		sp.
<i>Platysaccus</i>	+		+	+	+
<i>Sulcatisporites</i>	+		+		+
<i>Cedripites</i>			+	+	
<i>Limitisporites</i>	+		+		+
<i>Gardenasporites</i>	+		+	+	+
<i>Chordasporites</i> sp.	+	+	+	+	+
<i>Scutasporites xinjianqensis</i>	+				
<i>Juqasporites schaubergeroides</i>	+	+	+	sp.	sp.
<i>J. tectus</i>	+		+		
<i>Illinites</i>		+	+	+	+
<i>Lueckisporites virkkiae</i>	+	+	+	+	+
<i>Protohaploxypinus</i> cf. <i>suchonensis</i>	+			+	
<i>P. microcorpus</i>	+			+	+
<i>P. samoilovichiae</i>	+		+		
<i>Striatopodocarpites</i>	+		+	+	+
<i>Striatoabieites</i>	+		+	+	+
<i>Striatites</i>		+	+		+
<i>Taeniaesporites</i>	+	+	+	+	+
<i>Crustaesporites globosus</i>	+				
<i>Vittatina</i>	+	+	+	+	+

表 II 山西和西欧晚二叠世晚期孢粉对比表  
Correlation of the late Late Permian miospore of Shanxi and W. Europe

山西柳林 本文	英国(British) Clarke 1965	德国(Germany) Leschik 1956	爱尔兰(Ireland) Visscher 1971
<i>Potonieisporites novicus</i>	+	<i>Nuskoisporites dulhuntyi</i>	<i>Nuskoisporites dulhuntyi</i>
<i>Florinites</i> cf. <i>florini</i>	<i>Nuskoisporites dulhuntyi</i>		
<i>Alisporites parvas</i>			“ <i>Perisaccus granulatus</i> ” +
<i>Klausipollenites schaubergeri</i>	+		
<i>Falcisporites zapfei</i>	+	+	
<i>F. nuthallensis</i>	+		
<i>Vitreisporites pallidus</i>			
<i>Pteruchipollenites reticorpus</i>			
<i>Platysaccus radialis</i>	+		
<i>P. papilionis</i>		<i>Limtisporites rectus</i>	“ <i>Limitisporites</i> ” <i>moersenss</i>
<i>Limitisporites monstruosus</i>		<i>L. latus</i>	
<i>Jugasporites schaubergeroides</i>	<i>Jugasporites delasaucei</i>	<i>J. delasaucei</i>	<i>J. delasaucei</i>
<i>J. cf. tectus</i>	+	+	<i>Lueckisporites virkkiae</i>
<i>Lueckisporites virkkiae</i>	+	+	<i>L. virkkiae</i> (Aa–Bb)
<i>Protolahploxypinus microcorpus</i>	+		<i>Guttulapollenites</i>
	+		<i>Stellapollenites</i>
<i>P. cf. samoilovichiae</i>			Multi-taeniate pollen
<i>Taeniaesporites noviaulensis</i>		+	<i>Striatissaccus</i> spp.
<i>T. novimundi</i>	+		“ <i>Rhizomaspota</i> ” sp.
<i>T. albertae</i>	+		
<i>T. watangensis</i>			
<i>Striatopodocarpites</i> sp.	<i>S. cancellatus</i>		
<i>S. divaricata</i>	<i>S. fusus</i>		
<i>Striatoabieites brickii</i>	+	+	
<i>Crustaesporites globous</i>	+	+	
<i>Vittatina</i>	+		+
			<i>Acritarcha</i>

位花粉 (Meyen, 1987) 可以比较, 且此种花粉亦见于俄罗斯地台和新疆北部。出自松柏类的 *Lueckisporites* (Balme, 1995), 华北的标本与亚安加拉区的同属花粉形态更为接近。还有 *Cordaitina* 也是安加拉-亚安加拉的特征分子。所以从孢粉组合得出的结论, 与植物大化石研究结果(王自强等, 1987, 1989)基本上是一致的, 在柳林孙家沟组也产安加拉-亚安加拉区一些植物化石, 如 *Tatarina* cf. *sinuosa*, *Phylladoderma* (*Aequistomia*) cf. *aequalis*, *Gaussia*?, *Quadracladus* 和 *Peltaspermum*, 后两属虽不限于安加拉-亚安加拉区, 但从花粉记录判断, 少肋和多肋花粉(包括 *Vittatina*)至少部分是出自安加拉-亚安加拉区的植物。

柳林组合与西欧的镁灰岩组(Zechstein)的组合更为接近(表 II), 两者共有的种达 13 种以上。考虑到西欧此期组合, 在种的组成上一般要贫乏得多, 所以这种相似性仍给人留下深刻印象。然而, 西欧此期的典型代表之一 *Nuskoisporites dulhuntyi*, 在孙家沟组尚未发现过。另一方面, 华北晚二叠世晚期孢粉组合的分异度要高得多, 特别是蕨类植物孢子

(包括古植代石松纲)分异度较高, 蕨类植物孢子种数约占整个组合 $\geq 1/3$ , 表明华北当时(或至少是产植物、孢粉地层堆积时期)的气候, 远不如西欧那么干旱, 可能反映一种亚干旱气候。

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## PALYNOFLORA FROM THE SUNJIAGOU FORMATION IN LIULIN COUNTY, SHANXI PROVINCE

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**Key words:** Palynoflora, Sunjiagou Formation, Late Permian, Shanxi Province

### Abstract

The Shihchienfeng Group with a maximum thickness more than 1 000 m dominated by “barren” red beds of basically terrestrial origin is widely crop-

ping out in North China and consists of three formations, namely the Sunjiagou, Liujiagou and Heshang-gou formations in ascending order (Liu and Liu, 1984). The age of this group had been a subject in much dispute before seventies (Li, 1963). Mainly

based on palaeobotanical and palynological studies made in seventies to eighties, Chinese geologists have generally been in agreement with the opinion that the Sunjiagou Formation is late Late Permian and the Liujiagou and Heshangou formations are Early Triassic (Induan and Olenic) in age, and the former Shihchienfeng "Series" (or Formation s.s.) with the stratotype at Xishan of Taiyuan in Shanxi is largely equivalent to the Sunjiagou Formation. In addition to the important discoveries of macrofossil plants from the Lower Triassic published in a series of papers from 1978 to 1990 by Wang Zhi-qian and his co-workers, marked progress has also been made in regard to macrofossil plants from the Sunjiagou Formation by Wang Zhi-qian and Wang Li-xin (1987). The spore-pollen assemblage of the Sunjiagou Formation was first reported from the locality Lishi, Shanxi by Qu Li-fan (1980) who dated it as late Late Permian. This conclusion was strengthened subsequently from palynological studies made by Ouyang Shu and Wang Rennong (1985), Wu Jian-zhuan (1995), and Wang Rong (1987) from the same formation in Henan and Anhui provinces.

In this study, 33 samples collected from the Sunjiagou Formation in different localities of Shanxi Province were selected for maceration and it has proven that only 6 samples from the Liulin County are palyniferous. Well-preserved and highly diverse spores and pollen are mainly found in dark grey mudstones of the middle-upper part of the Sunjiagou Formation, a section exposed from Liulin in Shanxi to Zhangjiayang in Shaanxi with a thickness of 197 m (see Wang and Wang, 1987). Totally about 109 species referred to 57 genera have been identified (see that listed in Chinese) and partly illustrated (pl. I—III).

The spore-pollen assemblage is characterized by the low percentage (8.3%—14% of the total) of pteridophytic spores such as *Calamospora pallida*, *Cyclogranisporites micaceus*, *Apiculatisporis parvispinosus*, *Apiculatasporites perirugosus*, *Verrucosisporites sinensis*, *Neoraistrickia* cf. *irregularis*, *Polycingulatisporites* sp. and *Punctatosporites minutus*, and by the dominance of gymnospermous pollen (about 84.3%—89% of the total), with high percentages of bisaccate and non-saccate *Striatiti-*

(43.6%—60.1%) including a number of stratigraphically important species such as *Lueckisporites virkkiae*, *Scutasporites xinjiangensis*, *Protohaploxypinus microcorpus*, *P. dvinensis*, *P. samoilovichiae*, *Striatoabieites brickii*, *S. duivenii*, *Vittatina striata*, *V. vittifera*, *Crustaesporites globosus*, and bisaccate non-*Striatiti* (23%—40.5%) such as *Gardenasporites heisseli*, *Falcisporites zapfei*, *Jugasporites schaubergeroides*, *Klausipollenites schaubergeri*, *Platysaccus papilionis*, *P. radialis*, and *Alisporites parvus*. Monosaccites are only represented by a few species of *Potonieisporites*, *Florinites* and *Cordaitina*. It deserves of mention that among the spores, individuals of Paleophytic lycopods (including lepidophytes), viz. *Lycospora*, *Densosporites* and *Crassisporea* occur as relics; and on the other hand, a few morphologically with an aspect of the Mesophyte appeared (*Dictyophyllidites*, *Lundbladisporea*, *Kraeuselisporites* and *Discisporites*).

The characteristics of the assemblage are quite comparable to those known from the Sunjiagou Formation s.s. in Henan and Anhui provinces (see Table I in Chinese text). However, in the latter assemblages occur such species as *Punctatisporites palmipedites*, *Gulisporites* cf. *cochlearius*, *Waltzisporea* sp., *Knoxisporites* cf. *instarrotulae*, *Patellisporites* cf. *meishanensis*, *Tripartites cristatus* and *Balteusisporea textura* which are not present in the assemblage found from Liulin; on the other hand, *Polycingulatisporites*, *Discisporites* and *Crustaesporites globosus* have not been recorded from Henan and Anhui.

It is interesting to note that the present assemblage also bears some similarity with those from the uppermost Permian Guodikeng Formation in North Xinjiang (Hou and Wang, 1986; Ouyang, 1998, pers. comm.) where belonged to the Subangara Area. In the Guodikeng assemblage also occur such species as *Lueckisporites virkkiae*, *Scutasporites xinjiangensis*, *Taeniaesporites* cf. *novimundi*, *Protohaploxypinus* cf. *samoilovichiae*, *Striatoabieites multistriatus*, *Vittatina vittifera*, *Klausipollenites schaubergeri*, *Falcisporites* cf. *zapfei*, *Alisporites parvus* and *Cycadopites caperatus* in addition to a number of common genera, such as *Dictyophyllidites*, *Lycospora*, *Densosporites*, *Tubercu-*



*latosporites*, *Cordaitina*, *Florinites*, *Platysaccus* and *Ephedripites*, etc. But the difference is also remarkable, especially in specific composition; the above-listed identical species only occupy a minor part of the Guodikeng assemblage which is more diverse in generic and specific composition (more than 150 species of nearly 80 genera); and some important taxa in the Guodikeng assemblage, such as *Limatulusporites*, “*Remysporites*”, *Samoilovitchisaccites*, *Striatolebachiiites*, *Hamiapollenites*, *Welwitschiapollenites*, and *Tympanicysta* are not present in the assemblage found from Liulin. Because the striate, and particularly multi-striate pollen have the earliest records (Early Bashkirian) in the Subangara Area and were assumed to have had a southward migration of their parent plants (for *Raristriatiti*, conifers; for *Multistriatiti*, mostly pteridosperms, e.g. *peltaspermaleans*) (Ouyang *et al.*, 1994), and in the Cathaysian flora they did not appear until Early Permian, so the presence of *L. virkkiae* (this species in N. China is morphologically closer to those known from Subangara), *Scutasporites xinjiangensis*, most of the multistriate taxa including *Vittatina*, and *Cordaitina* etc. in the Liulin assemblage shows somewhat Subangaran affinity of the parent flora, just as some macrofossil plants with an aspect of the Subangara Area have also been found, namely *Tatarina* cf. *sinuosa*, *phylladoderma* (*Aequistomia*) cf. *aequalis*, *Gaussia*?, *Quadracladus* and *Peltaspermum*, etc. in association with the dominating Euramerican plants (Wang and Wang, 1986).

The present assemblage shows a closer relationship with those recorded from Zechstein in Western Europe (see Table II in Chinese text), both share the same species more than 13 in number. Considering the fact that the Western European assemblages are generally low in specific composition, the similarity is impressive. However, *Nuskoisporites* has not been found in the Sunjiagou Formation. Judging from the much higher diversity of miospores, especially pteridophytic spores including a few relics of Paleophytic lycopods, the climate prevailed during the late Late Permian (or at least within the time the relevant plants and miospores-bearing beds accumulated) in North China was possibly semi-arid, i.e. not so severe arid as in W. Europe.

## 图版说明 (EXPLANATION OF PLATES)

所有图像均放大 500 倍, 玻片保存于中国地质科学院地质研究所。标本产地: Ipso (50—51) 山西柳林县赫家津, Ipso (52—53) 山西柳林县大凤山, Ip (306—307) 山西柳林县军渡, Ip (3082) 山西。

### 图 版 I

1. 灰白芦木孢 (比较种) *Calamospora* cf. *pallida* Schopf, Wilson *et* Bentall, 1944 Ipso (50-4)
2. 小圆形粒面孢 (比较种) *Cyclogranisporites* cf. *minutus* Bharadwaj, 1957 Ip (307-2)s
3. 背锥刺孢 (未定种) *Anapiculatisporites* sp. Ip (3802-1)
4. 三角刺面孢 (未定种 A) *Acanthotriletes* sp. A Ip (307-2)
5. 栗刺三角刺面孢 *Acanthotriletes castanea* Butterworth *et* Williams, 1958 Ip (307-2)s
- 6, 7. 杂饰圆形锥瘤孢 *Apiculatisporis variocorneus* Sullivan, 1964  
6. Ip (307-2)s; 7. Ip (3802-4)
8. 圆形刺面孢 (未定种) *Apiculatasporites* sp. Ip (307-1)s
- 9, 10. 细刺圆形锥刺孢 *Apiculatisporis parvispinosus* (Leschik) Qu, 1980 Ip (307-2)s
11. 冠脊孢? (未定种) *Camptotriletes*? sp. Ip (3802-1)s
12. 不规则新叉瘤孢 (比较种) *Neoraistrickia* cf. *irregularis* Ouyang *et* Li, 1980 Ip (3802-1)s
- 13, 14. 光面盘形孢 *Discisporites psilatus* de Jersey, 1964 13. Ip (306-2); 14. Ip (3802-5)
15. 古老弗氏粉 *Florinites antiquus* Schopf, 1944 Ipso (52-3)
16. 新单缝周囊粉 *Potonieisporites novicus* Bharadwaj, 1954 Ip (306-1)
17. 环囊孢 (未定种) *Endosporites* sp. Ip (3802-1)
18. 查氏镰囊粉 *Falcisporites zapfei* (Potonié *et* Klaus) Leschik, 1956 Ip (307-1)s
19. 努萨尔镰囊粉 (比较种) *Falcisporites* cf. *nuthallensis* (Clarke) Balme, 1970 Ip (306-3)
20. 幅射蝶囊粉 *Platysaccus radialis* (Leschik) Clarke, 1965 Ip (307-1)
21. 异形弗氏粉 (比较种) *Florinites* cf. *diversiformis* Kosanke, 1950 Ip (3802-1)
22. 绍伯格克氏粉 *Klausipollenites schaubergeri* (Potonié *et* Klaus) Jansonius, 1962 Ip (307-2)s
23. 中大刺面单缝孢 (比较种) *Tuberculatosporites* cf. *medius* Zhou, 1980 Ip (3802-1)
24. 三角刺面孢 (未定种 B) *Acanthotriletes* sp. B Ip (3802-1)

### 图 版 II

1. 单脊粉 (未定种) *Chordasporites* sp. (cf. *Sahnites thomasi* Pant, 1955) Ip (307-1).
2. 革囊粉? (未定种) *Corisaccites*? sp. Ip (3802-1)
3. 单缝周囊粉 (未定种) *Potonieisporites* sp. Ipso (50-2)
4. 拟绍伯格折缝粉 (比较种) *Jugasporites* cf. *schaubergeroides* Klaus, 1963 Ipso (50-4)

5. 舒尔茨孢? (未定种) *Schulzospora?* sp. Ip(306-4)

6. 小体阿里粉 *Alisporites tenuicarpus* Balme, 1970 Ip(306-3)

7. 小单缝双囊粉 *Limitisporites minor* Zhou, 1980 Ip(307-2)s

8. 绍伯格折缝粉 *Jugasporites schaubergeroides* Klaus, 1963 Ip(3802-1)

9. 覆盖折缝粉 *Jugasporites tectus* Leschik, 1956 Ip(3802-1)

10. 真实单束多肋粉 (比较种) *Protohaploxypinus* cf. *verus* (Efremova) Hou et Wang, 1990 Ip(307-1)s

11. 卵体单束多肋粉 *Protohaploxypinus ovalicarpus* Zhou, 1980 Ip(307-2)s

12. 13. 舒展单束多肋粉 *Protohaploxypinus proluxus* (Luber) Samoilovich, 1953 12. Ip(306-1); 13. Ip(3802-2)

14. 罗汉松型多肋粉 (未定种) *Striatopodocarpites* sp. Ip(307-1)

15. 单束多肋粉 (未定种) *Protohaploxypinus* sp. Ip(3802-1)

16. 菱体单缝双囊粉 *Limitisporites rhombicarpus* Zhou, 1980 Ip(306-4)

17. 诺氏四肋粉 *Taeniaesporites novimundi* Jansonius, 1962 Ipso(51-5)

18. 萨氏单束多肋粉 *Protohaploxypinus samoilovichiae* (Jansonius) Hart, 1964 Ip(3802-1)

19. 阿尔伯达四肋粉 *Taeniaesporites albertae* Jansonius, 1962 Ipso(51-5)

20. 瓦塘四肋粉 *Taeniaesporites watangensis* Qu, 1984 Ip(307-2)

21. 四方形革囊粉 *Corisaccites quadratoides* Zhou, 1980 Ipso(52-1)

22. 细纹叉肋粉 *Vittatina vittifera* (Luber) Samoilovich, 1953 Ip(307-1)s

23. 条纹叉肋粉 *Vittatina striata* (Luber) Samoilovich, 1953 Ip(307-3)

24. 科达粉 (未定种) *Cordaitina* sp. Ip(307-1)s

25. 灰白开通粉 *Vitreisporites pallidus* (Reissinger) Nilsson, 1958 Ip(306-1)

图 版 III

1, 13. 小体单束多肋粉 *Protohaploxypinus microcarpus* (Schaarschmidt) Clarke, 1965 1. Ip(307-1)s; 13. Ip(307-2)s

2, 3. 杜氏冷杉型多肋粉 *Striatoabieites duivenii* (Jansonius) Hart, 1964 2. Ip(307-2)s; 3. Ip(307-1)s

4. 德维纳单束多肋粉 *Protohaploxypinus dvinensis* (Sedova) Hart, 1964 Ip(307-3)s

5. 多肋冷杉型多肋粉 (比较种) *Striatoabieites* cf. *multistriatus* (Balme et Hennelly) Hart, 1964 Ip(3802-1)

6. 海氏假二肋粉 *Gardenasporites heisseli* Klaus, 1963 Ip(306-4)

7, 8. 维氏二肋粉 *Lueckisporites virkkiae* Potonié et Klaus, 1954 7. Ip(306-1); 8. Ip(307-2)s

9. 革囊粉 (未定种) *Corisaccites* sp. Ipso(52-1)

10. 球形贝壳粉 (比较种) *Crustaesporites* cf. *globosus* Leschik, 1956 Ip(307-2)s

11. 球形贝壳粉 *Crustaesporites globosus* Leschik, 1956 Ipso(52-1)

12. 布氏冷杉型多肋粉 *Striatoabieites brickii* Sedova, 1956 Ip(3802-2)

14. 褶皱拟苏铁粉 *Cycadopites caperatus* (Luber) Hart, 1965 Ip(307-1)s

15. 光面拟苏铁粉 (比较种) *Cycadopites* cf. *glaber* (Luber) Hart, 1965 Ip(307-2)s

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