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吉林省龙井市葆园屯田营组孢粉化石的发现及其意义*

尚玉珂[1,2)**]　程金辉[3)]

1)中国科学院南京地质古生物研究所,南京 210008,yukeshang555@163.com;
2)沈阳师范大学古生物学院,沈阳 110034;
3)中国科学院南京地质古生物研究所和生物演化与环境卓越创新中心,资源地层学与古地理学重点实验室,南京 210008

提要　屯田营组为延吉盆地一套中性火山岩夹火山碎屑沉积岩,地质时代长期归于晚侏罗世或中侏罗世,前人对安图县明月镇该组孢粉分析,认为属早白垩世 Berriasian 期。本文经对龙井市葆园该组孢粉研究,认为以 *Cicatricosisporites-Pilosisporites-Aequitriradites* 为代表的孢粉组合时代为 Berriasian 期—Valanginian 期。从而提出葆园屯田营组应为上部,安图县明月镇该组应为下部的意见。孢粉组合指示龙井县葆园地区这一时期有着繁盛的植被,包括真蕨纲、石松纲的蕨类植物,松柏纲、苏铁纲的裸子植物及少数苔藓类的藓纲植物,推测属温暖湿润的亚热带气候。

关键词　孢粉组合　屯田营组　Berriasian 期—Valanginian 期　早白垩世　葆园　龙井　吉林

1　引　言

屯田营组为 1959 年杨学林创建,指延吉盆地长财组之下发育的一套中性火山岩夹火山碎屑沉积岩,主要由灰褐色、灰紫色集块岩和少量玄武安山岩夹多层火山碎屑岩及正常碎屑岩组成,一般不整合在古生代地层和华力西期花岗岩之上。该组主要分布在安图县明月镇、龙井市老头沟、天宝山、屯田营、十里堡和汪清县等地。由于对火山活动研究不够,缺少足够生物地层资料,因此对屯田营组的涵义、时代归属与层序划分存在争议。关于这套地层的时代围绕中、晚侏罗世几经变更,旬义贵、张川波等(吉林省地质矿产局,1988;赵衍华、张普林,1991)先后在该组发现植物化石,时代置于中或晚侏罗世。黎文本(2001)对安图县明月镇屯田营组孢粉化石进行研究,将该组孢粉组合时代划归早白垩世 Berriasian 期。本文研究的是龙井市葆园(在安图县明月镇东南约 30 km)屯田营组孢粉组合。通过研究,旨在进一步探讨屯田营组的时代归属及划分对比,从而为延吉盆地内、外中生代火山岩层的正确划分对比提供依据。

2　材料来源

本文研究样品采自吉林省龙井市葆园火车站—老头沟煤矿剖面(下简称葆园剖面,GPS 坐标:N42°55′37″,E129°7′54″,插图 1,2),为 1980 年张川波实测(赵衍华、张普林,1991,31 页)。该剖面层序为:

上覆地层　长财组

————平行不整合————

12. 杂色安山质集块岩,上部为灰白色酸性火山岩,层凝灰岩。　65 m

11. 暗紫色集块岩夹薄层暗紫色凝灰质粉砂岩和灰白色泥岩。　155 m

10. 灰紫色集块岩夹深红色层凝灰岩,单层薄,10—20 cm,具水平层理。　125 m

9. 黄绿色安山岩,深灰色玄武质安山岩夹暗紫色粉砂质泥岩。　38 m

8. 杂色安山质集块岩,上部为安山质角砾岩。　65 m

7. 灰紫色安山岩,上部为玄武质安山岩(局部具角闪石巨晶)及正常沉积岩。　125 m

6. 灰紫色、杂色熔岩角砾岩。　105 m

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** 通讯作者:尚玉珂,研究员,主要从事中生代孢粉地层学研究。

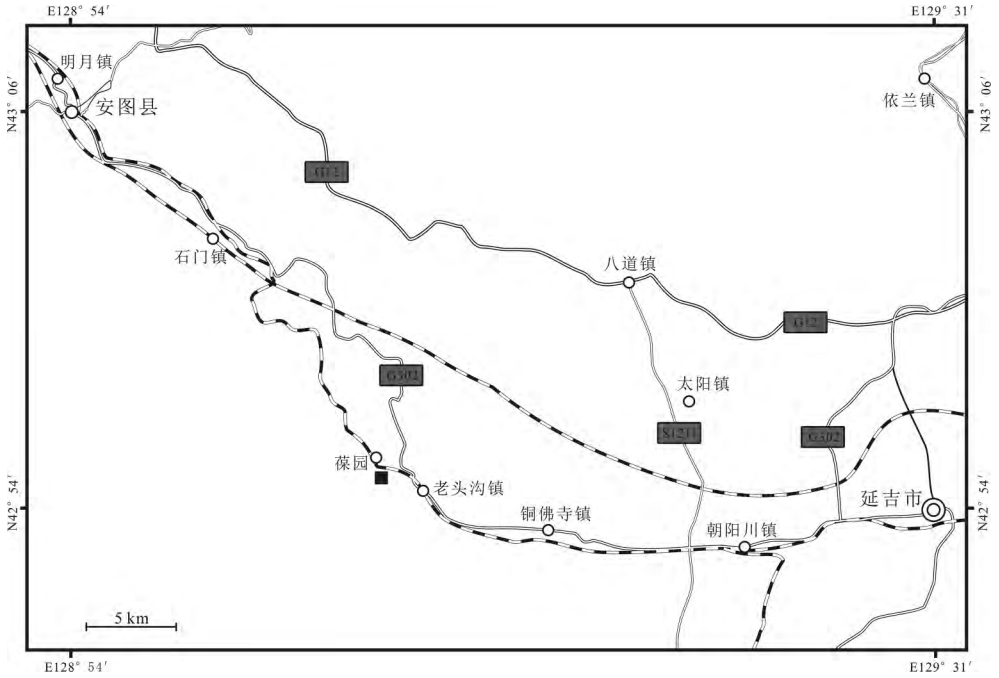

插图 1　吉林省龙井市葆园火车站—老头沟煤矿剖面地理位置图(图中黑色方框指示剖面位置)

Location of the cross section from Baoyuan Railway Station to Laotougou Coalmine in Longjing City, Jilin Province (indicated by the black rectangles).

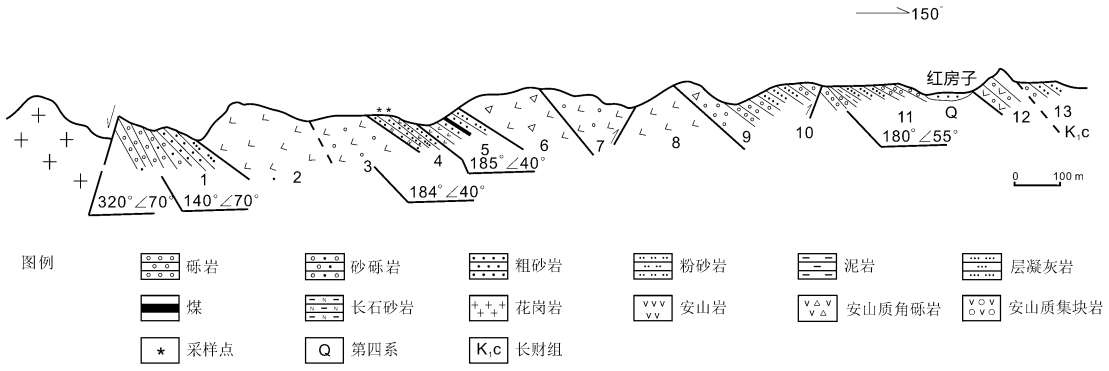

插图 2　吉林省龙井市葆园火车站—老头沟煤矿剖面图(据赵衍华、张普林,1991)

Cross section from Baoyuan Railway Station to Laotougou Coalmine in Longjing City, Jilin Province (after Zhao and Zhang, 1991).

5. 杂色集块岩夹正常沉积碎屑岩,深灰色页岩,劣质煤层,产 *Taeniopteris* sp.。　80 m

4. 灰褐色层凝灰岩,黄褐色花岗质碎屑岩,见植物碎片,上部夹暗紫色粉砂岩。由花岗质含砾粗砂岩-细砂岩-粉砂质泥岩构成半韵律,在第二韵律的泥质岩中产植物化石:*Acanthopteris gothani*, *Cetenis uwatokoi*, *Cladophlebi* sp.。　30 m

3. 深灰色安山质集块岩。　100 m

2. 深灰色玄武质安山岩。　150 m

1. 灰褐色花岗质巨砾岩,有安山质砾岩,上部为深灰色熔岩、集块岩、角砾岩、凝灰质粗砂岩、层凝灰岩,在凝灰质粉砂岩及层凝灰岩中产:*Equisetites* sp., *Coniopteris* cf. *burejensis*, *Elatites* sp.。　120 m

～～～～角度不整合～～～～

下伏地层　华力西期花岗岩。

孢粉样品采自剖面第 4 层,自下而上为 YB1 和 YB2,均为凝灰质粉砂岩夹层,两块样品相距 20 m。

3　孢粉组合特征

葆园剖面屯田营组孢粉组合相当丰富(表Ⅰ),共有孢粉 31 属 51 种,包括蕨类植物孢子 16 属 26 种,裸子植物花粉 15 属 25 种(插图 3—6)。组合中裸子植物花粉多于蕨类植物孢子,前者含量为 58.57%,后者为 41.43%,裸子植物花粉中,以两气囊花粉为主,占组合 32.83%,其中松科、罗汉松科的双囊花粉多于较原始的本体与气囊分化不完善的松柏目双囊花粉,还有一定含量的苏铁科或银杏科

单沟花粉(5.01%)及掌鳞杉科环沟花粉(2.61%),裸子植物花粉中分类位置不明的单囊花粉 *Callialasporites* 占 2.59%,其余花粉除 *Psophosphaera* 含量较高外,均在 2%以下。

蕨类植物孢子中,以光面三缝孢 *Leiotriletes* 最多,占 11.23%,其次为海金沙科孢子,占 10.24%,其中又以 *Cicatricosisporites* 最多,占 7.03%,组合中重要的蕨类植物孢子还有含量在 2%左右的 *Pilosisporites*,*Aequitriradites*,*Lygodiumsporites* 等,组合中还包括桫椤科、紫萁科、石松科、蚌壳蕨科和分类位置不明的其它真蕨类孢子及水蕨科孢子等,除桫椤科的 *Cyathidites* 较多外,其余较少。这一孢粉组合可称为 *Cicatricosisporites-Pilosisporites-Aequitriradites* 组合。

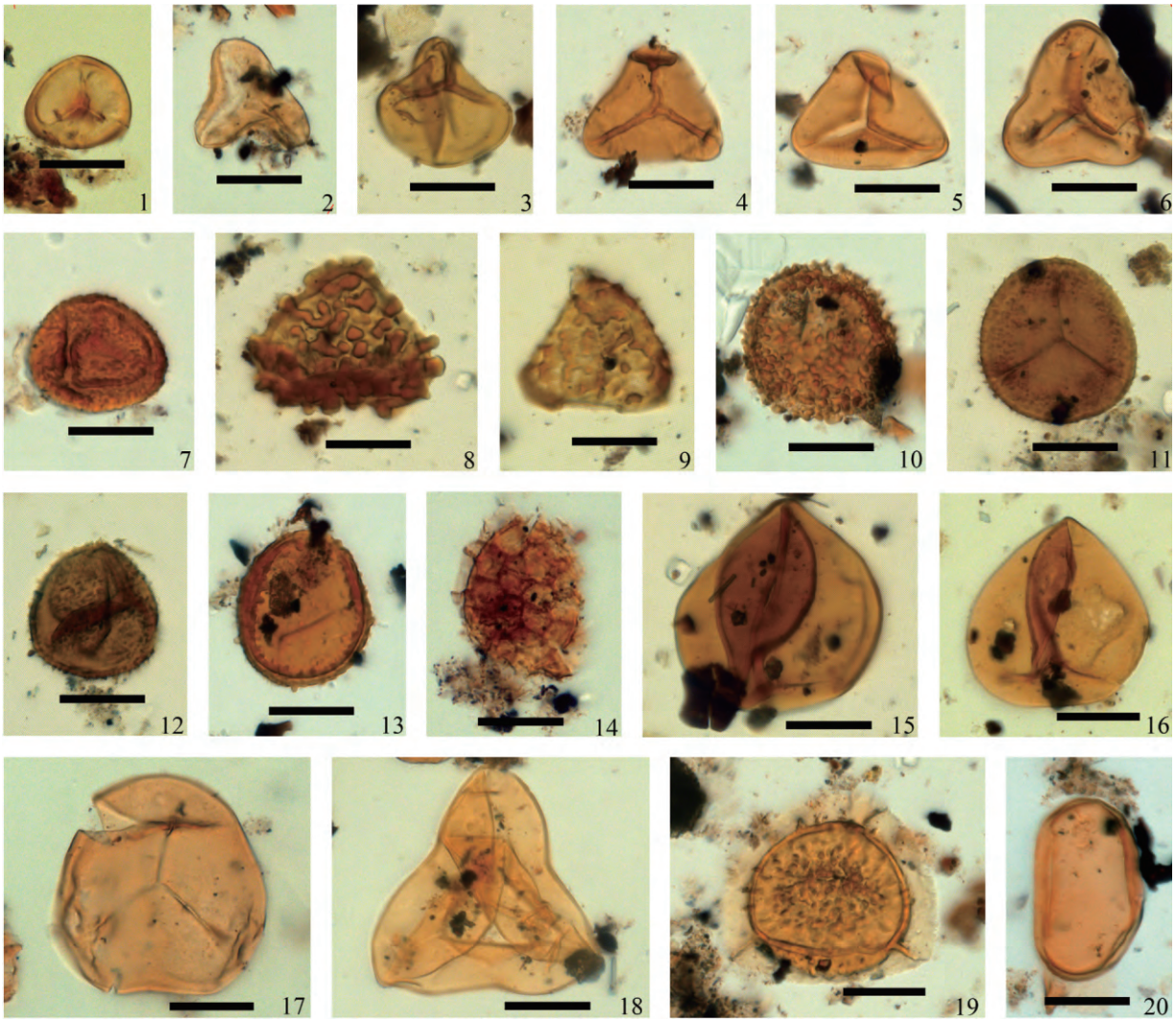

插图 3　葆园剖面下白垩统屯田营组孢子花粉

Pollen and spores from the Tuntianying Formation (Lower Cretaceous) of the Baoyuan section.

1. *Sphagnumsporites steroides* (Potonié and Venitz) Raatz, 1937, YLB1-109; 2. *Cyathidites minor* Couper, 1953, YLB2-277; 3. *Leiotriletes gleicheniaeformis* Bolkhovitina, 1959, YLB2-263; 4. *Cibotiumspora* sp., YLB1-187; 5, 6. *Leiotriletes toroiformis* Hua, 2000, 5. YLB1-64, 6. YLB1-58; 7. *Osmundacidites parvus* De Jersey, 1962, YLB2-350; 8. *Neoraistrickia robusta* Brenner, 1963, YLB1-126; 9. *Converrucosisporites venitus* Batten, 1973, YLB1-48; 10. *Verrucosisporites obscurus* (Bolkhovitina) Sun and Li, 1976, YLB1-130; 11. *Osmundacidites wellmanii* Couper, 1953, YLB2-259; 12. *Pilosisporites delicatus* Norris, 1969, YLB1-77; 13. *Apiculaisporis globosus* (Leschik) Playford and Dettmann, 1965, YLB1-82; 14. *Lycopodiumsporites nodosus* Dettmann, 1963, YLB2-281; 15, 16. *Leiotriletes tenuis* (Maljavkina) Bolkhovitina, 1953, 15. YLB1-52, 16. YLB1-77; 17. *Leiotriletes minuterugosus* (Ibrahim) Naumova, 1953, YLB2-311; 18. *Cyathidites australis* Couper, 1953, YLB2-346; 19. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann 1961, YLB2-308; 20. *Laevigatosporites ovatus* Wilson and Webster, 1946, YLB1-117。**图中比例尺均表示** 20 μm(Scale bars indicate 20 μm)。**全部标本产自龙井市葆园屯田营组**(All specimens are from the Tuntianying Formation of Baoyuan in Longjing City),**保存在中国科学院南京地质古生物研究所**(All specimens are preserved in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences)。

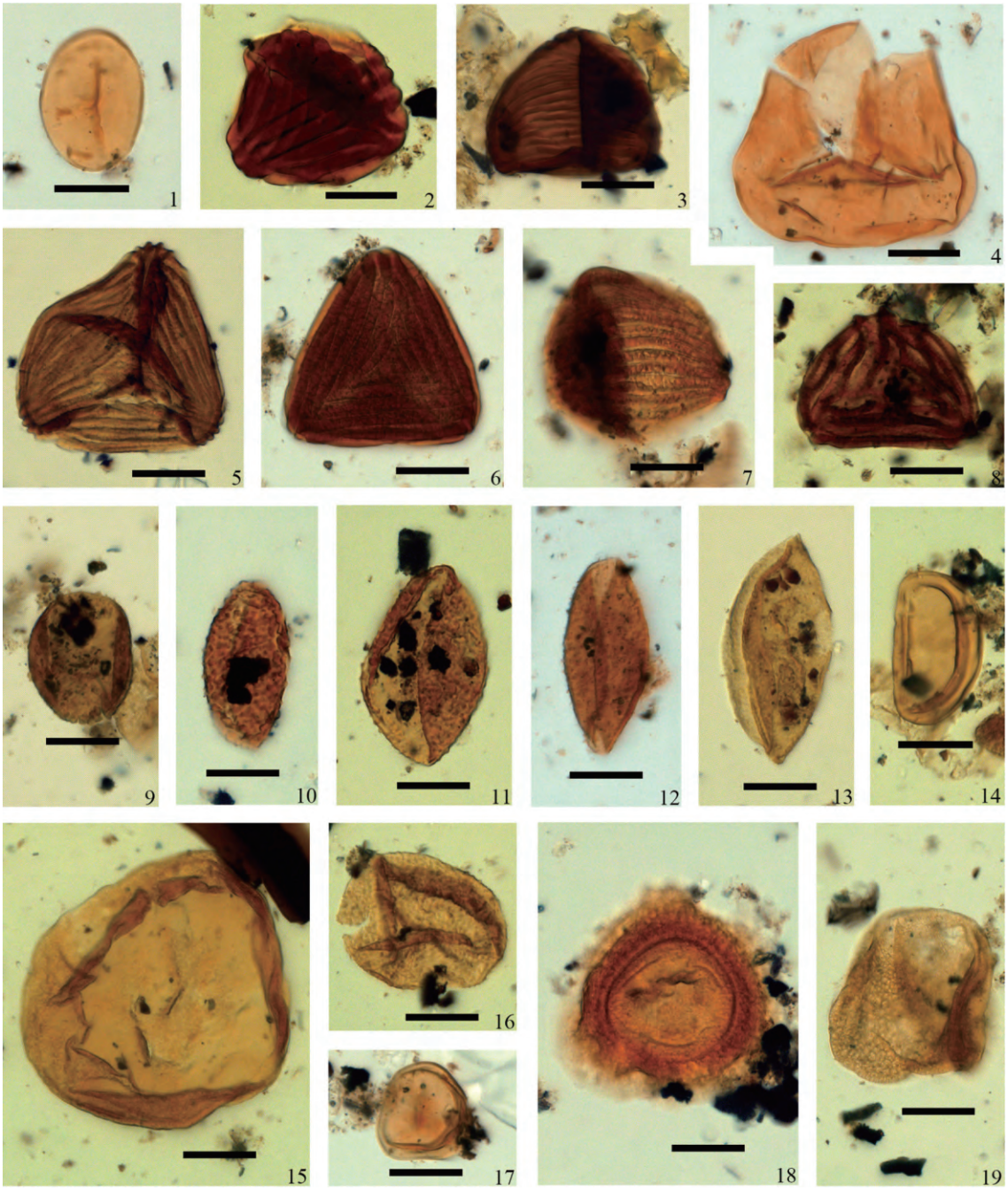

插图 4 葆园剖面下白垩统屯田营组孢子花粉(续 1)

Pollen and spores from the Tuntianying Formation (Lower Cretaceous) of the Baoyuan section (continued 1).

1. *Laevigatosporites ovatus* Wilson and Webster, 1946, YLB1-178; 2. *Cicatricosisporites stoveri* Pocock, 1964, YLB1-189; 3. *Cicatricosisporites* sp., YLB2-416; 4. *Lygodiumsporites pseudomaximus* (Thomson and Pflug) Song and Zheng, 1981, YLB1-208; 5. *Cicatricosisporites australiensis* (Cookson) Potonié, 1956, YLB2-260; 6. *Cicatricosisporites bellus* Zhang, 1965, YLB1-32; 7. *Cicatricosisporites subrotundus* Brenner, 1963, YLB1-92; 8. *Cicatricosisporites corlylensis* Pocock, 1962, YLB1-51; 9. *Monosulcites enormis* Jain, 1968, YLB2-375; 10. *Verrumonocolpites shanbeiensis* Qian and Wu, 1987, YLB1-91; 11. *Granamegamonocolpites monoformis* Qian and Wu, 1987, YLB1-144; 12. *Cycadopites granulatus* (De Jersey) De Jersey, 1964, YLB1-25; 13. *Cycadopites percarinatus* (Bolkhovitina) Pu and Wu, 1985, YLB2-451; 14. *Classopollis* sp., YLB1-16; 15. *Callialasporites* sp., YLB1-134; 16. *Callialasporites priacus* Zhang, 1989, YLB1-84; 17. *Classopollis annulatus* (Verbitzkaja) Li, 1974, YLB2-304; 18. *Densoisporites perinatus* Couper, 1958, YLB1-104; 19. *Quadraeculina limbata* Maljavkina, 1949, YLB1-158。**图中比例尺均表示** 20 μm(Scale bars indicate 20 μm)。**全部标本产自龙井市葆园屯田营组**(All specimens are from the Tuntianying Formation of Baoyuan, Longjing City),**保存在中国科学院南京地质古生物研究所**(All specimens are preserved in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences)。

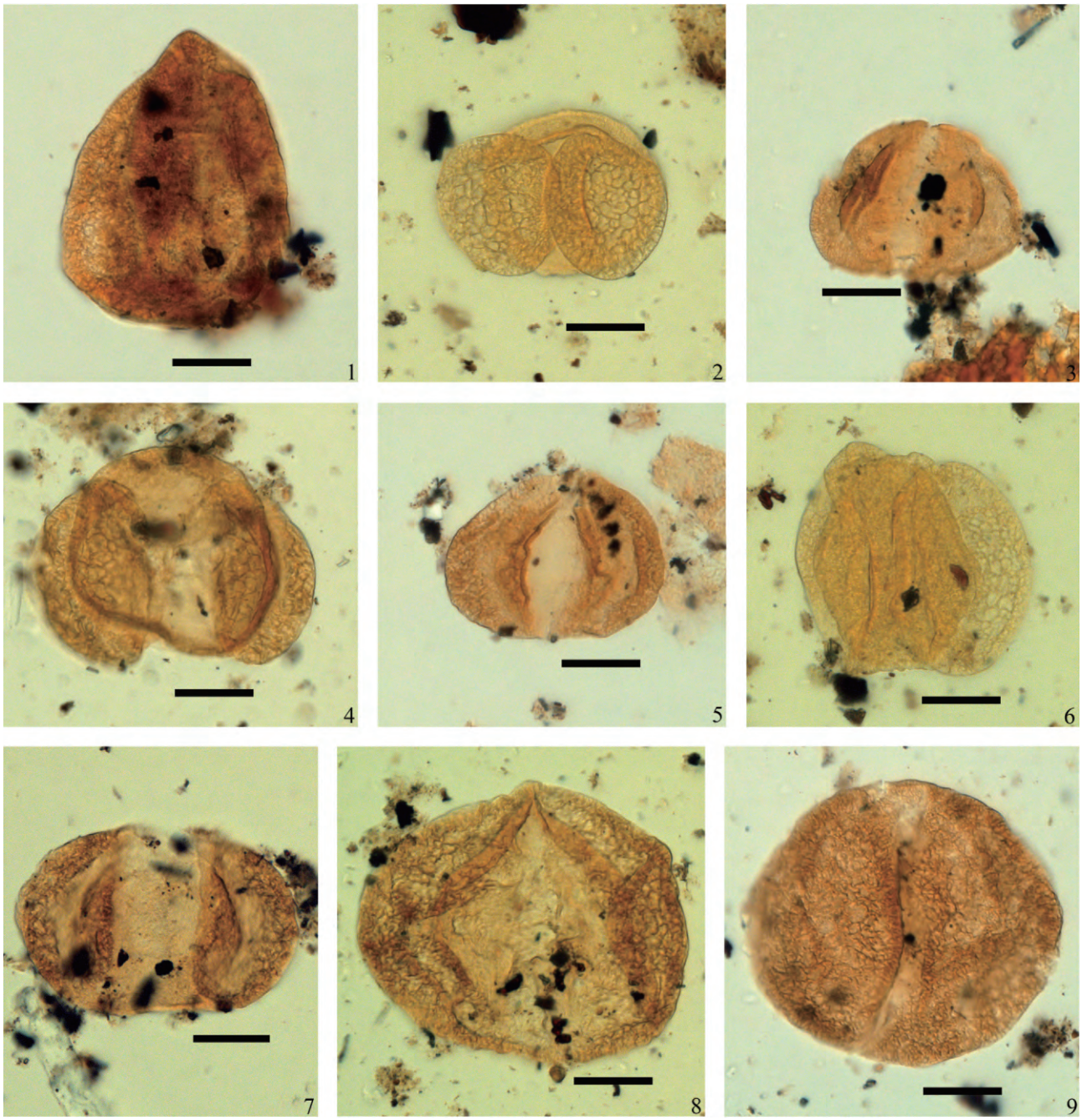

插图 5　葆园剖面下白垩统屯田营组孢子花粉(续 2)

Pollen and spores from the Tuntianying Formation (Lower Cretaceous) of the Baoyuan section (continued 2).

1. *Quadraeculina anellaeforims* Maljavkina, 1949, YLB1-172; 2. *Pinuspollenites pernobilis* (Bolkhovitina) Xu and Zhang, 1980, YLB2-288; 3. *Protoconiferus funarius* (Naumova) Bolkhovitina, 1956, YLB2-421; 4. *Pinuspollenites insignis* (Naumova) Pu and Wu, 1982, YLB1-231; 5. *Piceites enodes* Bolkhovitina, 1956, YLB1-105; 6. *Pinuspollenites stinctus* (Bolkhovitina) Shang, 1981, YLB1-37; 7. *Piceites arxanensis* (Hua) Song, 2000, YLB1-240; 8. *Abietineaepollenites dividuus* (Bolkhovitina) Song, 2000, YLB2-332; 9. *Piceites lateus* Bolkhovitina, 1956, YLB2-265。**图中比例尺均表示** 20 μm(Scale bars indicate 20 μm)。**全部标本产自龙井市葆园屯田营组**(All specimens are from the Tuntianying Formation of Baoyuan, Longjing City),**保存在中国科学院南京地质古生物研究所**(All specimens are preserved in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences)。

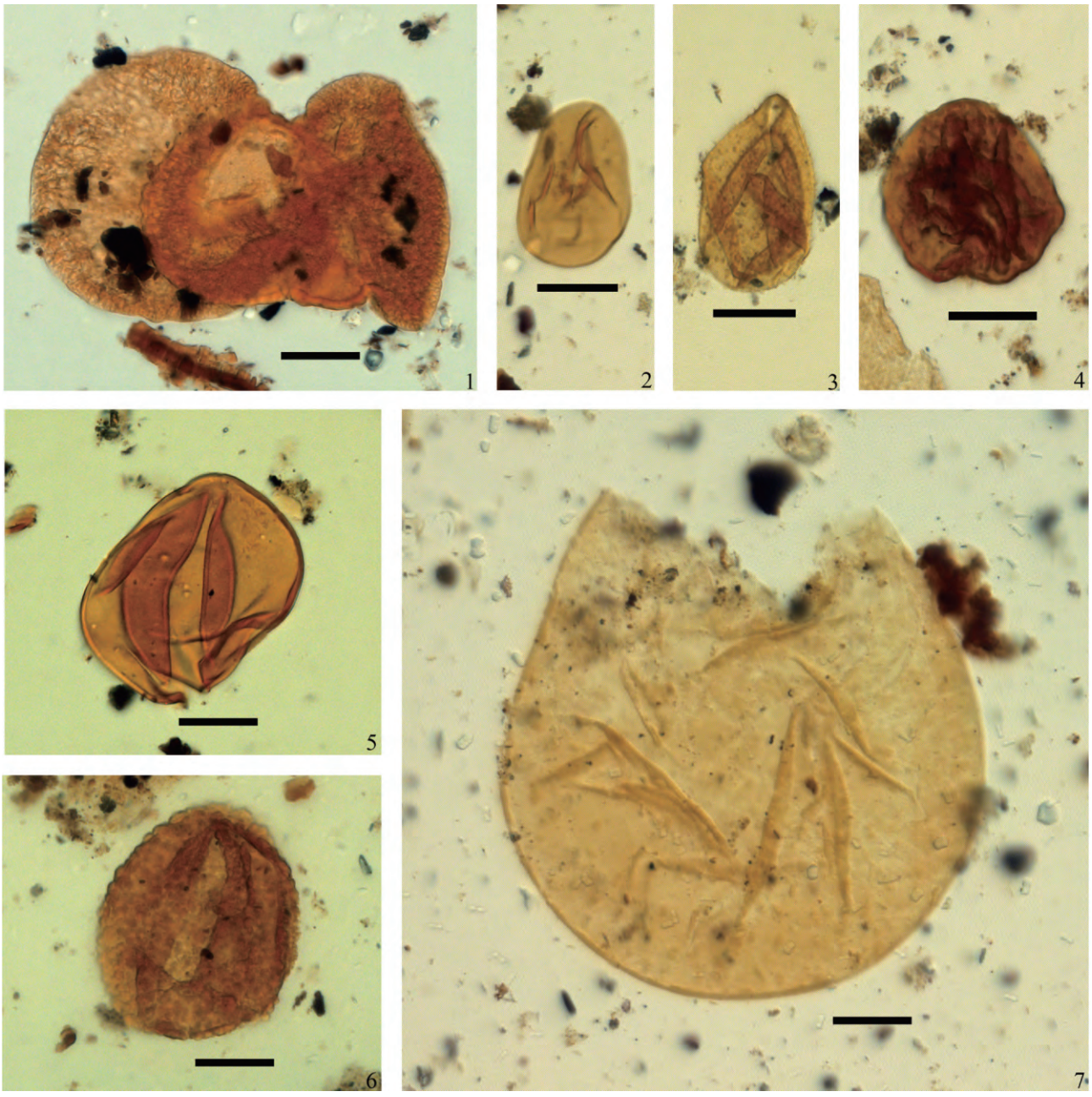

插图 6 葆园剖面下白垩统屯田营组孢子花粉(续 3)

Pollen and spores from the Tuntianying Formation (Lower Cretaceous) of the Baoyuan section (continued 3).

1. *Podocarpidites unicus* (Bolkhovitina) Pocock, 1970, YLB1-73; 2, 3. *Psophosphaera cognatus* (Bolkhovitina) Sun and Li, 1976, 2. YLB2-381, 3. YLB1-196; 4. *Inaperturopollenites dubius* (Potonie and Venitz) Thomson and Pflug, 1953, YLB1-69; 5. *Psophosphaera* sp., YLB2-264; 6. *Cerebropollenites findlaterensis* Pocock, 1970, YLB2-322; 7. *Psophosphaera grandis* Bolkhovitina, 1956, YLB1-78。**图中比例尺均表示** 20 μm (Scale bars indicate 20 μm)。**全部标本产自龙井市葆园屯田营组**(All specimens are from the Tuntianying Formation of Baoyuan, Longjing City),**保存在中国科学院南京地质古生物研究所**(All specimens are preserved in Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences)。

表 I　葆园剖面屯田营组孢子花粉属种及其含量分布*

Distribution and amount of palynomorphs in the Tuntianying Formation of Baoyuan section.

孢粉属种 (Genera and species of palynomorphs)	样品(Samples) YB1	YB2	平均 (Average)
Pteridophyta			
Sphagnaceae			
Sphagnumsporites steroids	0.79/2		0.40/1
Lycopodiaceae			
Lycopodiumsporites nodosus	1.57/4	2.23/5	1.80/4.5
Densoisporites perinatus	0.79/2		0.40/1
Selaginellaceae			
Apiculatisporis globosus	1.57/4	1.64/4	1.61/4
Neoraistrickia robusta	1.97/5		0.99/2.5
Aequitriradites spinulosus	1.97/5	2.85/7	2.41/6
Osmundaceae			
Osmundacidites wellmanii	1.57/4	1.22/3	1.41/3.5
O. parvus		0.81/2	0.41/1
Lygodiaceae			
Cicatricosisporites stoveri	1.18/3	1.63/4	1.41/3.5
C. autstraliensis	1.57/4	2.44/6	2.01/5
C. corlylensis	1.97/5	0.81/2	1.39/3.5
C. subrotundus	0.39/1		0.20/0.5
C. bellus	1.18/3	1.22/3	1.20/3
C. sp.	1.63/4		0.82/2
Lygodiumsporites pseudomaximus	0.79/2	2.03/5	1.41/3.5
Pilosisporites delicatus	1.57/4	2.03/5	1.80/4.5
Dicksoniaceae			
Cibotiumspora sp.	1.57/4	1.22/3	1.42/3.5
Cyatheaceae			
Cyathidites minor	2.36/6	1.22/3	1.79/4.5
C. australis	1.97/5	2.03/5	2.00/5
Filicales Incertae Sedis			
Leiotriletes toroi formis	3.54/9	2.44/6	2.99/7.5
L. minuterugosus	2.76/7	3.25/8	3.01/7.5
L. tenuis	1.18/3	0.81/2	1.00/2.5
L. gleicheniaeformis	2.76/7	5.69/14	4.23/10.5
Verrucosisporites obscurus	1.57/4	2.03/5	1.80/4.5
Converrucosisporites venitus	0.79/2	1.22/3	1.01/2.5
Laevigatosporites ovatus	2.36/6	2.85/7	2.61/6.5
Gymnospermophyta			
Ginkgoaceae or Cycadaceae			
Cycadopites granulatus	2.36/6	3.25/8	2.81/7
C. percarinatus	2.76/7	1.63/4	2.20/5.5
Cheirolepidiaceae			
Classopollis annulatus	1.97/5	1.63/4	1.80/4.5
C. sp.	0.39/1	1.22/3	0.81/2

续 1

Continued 1

孢粉属种 (Genera and species of palynomorphs)	样品(Samples) YB1	YB2	平均 (Average)
Podocarpaceae			
Podocarpidites unicus	1.97/5	2.03/5	2.00/5
Pinaceae			
Pinuspollenites pernobilis	4.72/12	2.03/5	3.38/8.5
P. insignis	1.57/4	6.91/17	4.24/10.5
P. stinctus	4.33/11	4.47/11	4.40/11
Abietineaepollenites dividuus	3.15/8	5.28/13	4.22/10.5
Coniferales Incertae Sedis			
Protoconiferus funarius	3.54/9	2.85/7	3.20/8
Piceites enodes	2.76/7	3.25/8	3.01/7.5
P. arxanensis	5.90/15	2.44/6	4.17/10.5
P. lateus	3.94/10	4.47/11	4.21/10.5
Gymnospermae Incertae Sedis			
Callialasporites priscus	1.18/3		0.59/1.5
C. sp.	1.97/5	2.03/5	2.00/5
Cerebropollenites findlaterensis	1.57/4	1.22/3	1.40/3.5
Quadraeculina limbata	2.36/6		1.18/3
Q. anellaeformis	1.97/5	1.63/4	1.80/4.5
Monosulcites enormis	1.97/5	0.41/1	1.19/3
Verrumonocolpites shanbeiensis	1.57/4	1.63/4	1.60/4
Granamegamonocolpites monoformis	0.79/2		0.40/1
Inaperturopollenites dubius	1.57/4		0.79/2
Psophosphaera cognatus	3.15/8	2.03/5	2.59/6.5
P. grandis	2.76/7	4.47/11	3.62/9
P. sp.	2.03/5		1.01/2.5
蕨类植物孢子 Pteridophyta spores	39.76/101	43.09/106	41.43/103.5
裸子植物花粉 Gymnospermophyta pollen grains	60.24/153	56.91/140	58.57/146.5
统计粒数 Palynomorph amount of statistics	254	246	

*表中斜线前为百分含量,斜线后为粒数。

4 时代讨论及对比

葆园剖面屯田营组孢粉 *Cicatricosisporites-Pilosisporites-Aequitriradites* 组合中,分化完善的两气囊花粉略多于分化不完善的两气囊花粉,蕨类孢子中,海金沙科孢子达 3 属 8 种,含量大于 10%,在组合中占有重要位置,组合中还见有早白垩世较典型分子 *Aequitriradites*, *Pilosisporites* 等,组合呈现出早白垩世特色。

海金沙科孢子 *Cicatricosisporites* 为早白垩世较特征属,它的出现与含量多寡常用来判断是否进入早白垩世及处于何阶段的主要因素之一。在日本(Umetsu and Sato, 2007)、俄罗斯(Bolkhovitina, 1953, 1956)、蒙古(Wang *et al.*, 2014)、英国(Couper, 1958; Norris, 1969; Kemp, 1970)、德国(Döring, 1965)、荷兰(Burger, 1966)、美国(Brenner, 1963; Bebout, 1981)、加拿大(Pocock, 1962; Williams, 1975)、澳大利亚(Cookson and Dettmann, 1958; Dettmann, 1963; Wagstaff *et al.*, 2012)等世界各地,早白垩世均有记录。在我国南北方地区,早已成为早白垩世的特征分子。该属 5 个

种中,有 4 个种仅见于早白垩世。其中 *C. stoveri* 为 Pocock(1964)所建立,模式种全型产自加拿大 Saskatchewan 地区下白垩统,后来在美国 Louisiana 州下白垩统(Phillips and Felix,1971)也有出现,在我国见于内蒙古新巴尔虎右旗、伊敏大磨拐河组、伊敏组(蒲荣干、吴洪章,1985)、吉林蛟河乌林组(黎文本,1984)和吉林汪清大拉子组(尚玉珂,1991)。*C. subrotundus* 为 Brenner(1963)研究美国 Maryland 州 Potomac 群时发现,后来又见于加拿大 Alberta 省(Norris,1967)、美国 Oklahoma 州(Hedlund and Norris,1968),是这些地区早白垩世关键分子,在我国产自吉林延边大拉子组(余静贤、苗淑娟,1983;黄嫔、张光富,2002)、内蒙古阿巴嘎旗巴彦花群、北京房山大灰场组(苗淑娟等,1984)、辽西沙海组(余静贤等,1986)、甘肃酒泉下新民堡群(徐仁等,1974)等。*C. bellus* 为张春彬(1965)所创,全型产自黑龙江鸡西穆棱组,后来在我国北方下白垩统多有出现,如辽西沙海组、吉林延边大拉子组。*C. corylensis* 最初见于加拿大西部下白垩统(Pocock,1962),在我国产自四川三台蓬莱镇组(白云洪等,1983)、江西临川和弋阳冷水坞组(余静贤等,1985),本研究是该种在我国北方的首次记录。*C. australiensis* 是 *Cicatricosisporites* 属中唯一在晚侏罗世出现过的种,除在英国南部 Perbeck 地区上侏罗统顶部 Tithonian 阶发现(Norris,1969)及在其它少数地区出现外,此种更多地在世界各地下白垩统出现,如在英国(Norris,1970)、美国(Bebout,1981)、加拿大(Pocock,1962;Norris,1967)和澳大利亚(Cookson and Dettmann,1958)等地。据 Dörhöfer 和 Norris(1975)报道,在英国 Perbeck 地区,*C. australiensis* 也出现在上 Berriassian 阶—下 Valanginian 阶(Suite C);在我国东北地区下白垩统,该种分布更是广泛,如吉林延边大拉子组;吉林蛟河奶子山组、乌林组;吉林九台营城组(尚玉珂、王淑英,1991);黑龙江东部石河北组上部、城子河组、穆棱组(蒲荣干、吴洪章,1982);黑龙江鹤岗石头河子组(尚玉珂,1994);内蒙古武川固阳组、内蒙古固阳李三沟组(苗淑娟等,1984);兴安岭地区九峰山组、大磨拐河组、伊敏组;辽西九佛堂组、沙海组、阜新组;辽宁北票义县组(黎文本、刘兆生,1999),几乎遍及东北地区下白垩统。

Cicatricosisporites 属一般在早白垩世早期含量较低,至中期繁盛,并达顶点,该属最晚时代为古近纪。如在黑龙江省东部早白垩世早期(Berriasian 期)的石河北组上部,该属含量为 6.6%,含 5 种;近中期(Valanginian?期—Barremian 期)的城子河组为 11.7%,含 14 种。吉林蛟河早白垩世偏早期的奶子山组(Berriasian 期—Valanginian 期)包括 *Cicatricosisporites* 的海金沙科孢子含量为 3%,该属 4 种;近中期的乌林组(Hauterivian 期—Barremian 期)海金沙科孢子为 22.2%,该属达 13 种以上。在葆园屯田营组孢粉组合中,该属含量为 7.03%,含 5 种,应处于早白垩世较早期阶段。

该组合中海金沙科另一个属 *Pilosisporites*,最初为 Delcourt 和 Sprumont(1955)所建立,后来主要出现在早白垩世,如在英国(Couper,1953;Kemp,1970)、德国(Dörhöfer and Norris,1975)、美国(Hedlund and Norris,1968;Bebout,1981;Srivastava,1981)、加拿大(Pocock,1962;Singh,1971;Williams,1975)以及澳大利亚(Cookson and Dettmann,1958;Wagstaff *et al.*,2012)等地的下白垩统均有产出。该属在我国吉林延边、蛟河、九台,黑龙江东部及辽西下白垩统均有记录,在我国南方极少见到。该属一般在 Berriasian 期零星出现,至 Valanginian 期较少,在 Hauterivian 期—Barremian 期较多并渐趋繁盛,在晚白垩世很少出现。Bebout(1981)对美国东部中大西洋外大陆架的上、下白垩统孢粉组合分带进行了细致研究,发现 *Pilosisporites* 的所有 4 个种均仅出现在下白垩统。此属在本组合中仅一种,含量为 1.80%,应与早白垩世较早期情形接近。值得提及的是,本组合所含 *Pilosisporites delicatus* 在英国即出现在上 Berriasian 阶—下 Valanginian 阶(Suite C)中。

本组合所含海金沙科的 *Lygodiumsporites* 是早白垩世较常见属,最早见于晚侏罗世,消失在古近纪。该属在我国主要见于下白垩统。

组合中另一个主要见于早白垩世的属为石松科的 *Aequitriradites*,该属中 *A. spinulosus* 产自英国 Valanginian 期(Couper,1958;Dörhöfer and Norris,1975)、俄罗斯 Hauterivian 期—Cenomanian 期(Bolkhovitina,1959,1961)、加拿大 Valanginian 期—Albian 期(Pocock,1962;Singh,1971)、蒙古 Hauterivian 期—Barremian 期(Wang *et al.*,2014)、澳大利亚 Berriasian 期—Albian 期(Cookson and Dettmann,1958)。在我国该种主要产自早白垩世地层,在东北地区下白垩统为分布十分广泛的种,如黑龙江东部石河北组上部、城子河组、穆棱组;兴安岭九峰山组、大磨拐河组、伊敏组;吉林延边长财

组;吉林蛟河奶子山组、乌林组;吉林九台营城组及辽西九佛堂组、沙海组、阜新组均有产出。该种也是英国上 Berriasian 阶—下 Valanginian 阶(Suite C)中的主要成员。

组合中还有含量 2.61%的 *Classopollis* 花粉,该属花粉在世界各地普遍繁盛于晚侏罗世,在我国南方早白垩世也十分发育,但在我国北方尤其东北早白垩世,分布零星或仅有较低含量,在早白垩世早期即是,如在吉林蛟河奶子山组为 1%—2%,内蒙古满洲里大磨拐河组为 3.04%(程金辉、尚玉珂,2015),辽西九佛堂组为 2%—3%,黑龙江鹤岗石头河子组为 1.2%,黑龙江东部绥滨、鸡西、双鸭山、宝清城子河组,*Classopollis* 的含量均小于 1%。唯黑龙江绥滨石河北组上部此属含量略高,为 7.2%,此与该地层为海相有较大关系,因为掌鳞杉科植物的生长习性之一是偏好海滨高坡地,在那里此类植物会有较大发展。

在葆园剖面屯田营组孢粉组合中,大量出现的是双气囊花粉,其中松科、罗汉松科等本体与气囊分化较好的花粉已明显超过本体与气囊分化不好的松柏目花粉,这也是早白垩世孢粉组合的特征之一,在早白垩世早期多数组合中即已显露。该组合中其它分子如,*Cerebropollenites*, *Quadraeculina*, *Callialasporites*, *Cyathidites*, *Cibotiumspora* 等,它们经常出现在侏罗纪与白垩纪,但它们的繁盛期多在侏罗纪,进入白垩纪已渐减少,本组合中这些类型的含量不多,已不构成优势属种,这与早白垩世孢粉组合的情形相似。

根据上述分析,葆园剖面屯田营组孢粉组合中出现较多的早白垩世重要类型,如 *Cicatricosisporites*, *Pilosisporites*, *Aequitriradites*, *Lygodiumsporites* 等,这些属种的含量均与早期接近,其它属种为侏罗纪与白垩纪常见类型,本体与气囊分化完善的双囊花粉略多于分化不完善的双囊花粉,结合各方面因素,葆园剖面屯田营组孢粉组合时代归于早白垩世 Berriasian 期—Valanginian 期)较适宜。

安图县屯田营组孢粉组合(黎文本,2001)以含大量松柏类两气囊花粉、伴以少量 *Schizaeoisporites*, *Fixisporites*, *Cicatricosisporites* 等属孢子为特征,葆园屯田营组与其有一定相似性,均见到一些早白垩世的特征属,两组合也都有其它各自的早白垩世重要类型,前者有 *Schizaeoisporites*, *Fixisporites*, *Jiaohepollis*,本组合有 *Pilosisporites*, *Aequitriradites*, *Lygodiumsporites*,但两者明显区别在于,本组合中 *Cicatricosisporites* 含量更多,占组合 7.03%,而前者蕨类植物孢子总量为 5%,该属含量明显甚少,本组合还有 2%左右的 *Pilosisporites*, *Aequitriradites*, *Lygodiumsporites*,因此,两组合虽同为早白垩世早期组合,本组合的时代可能更新些,所在层位也应高些。虽同为屯田营组,葆园地区屯田营组应为偏上部,安图明月镇屯田营组应为偏下部。

张川波于 1978 年在葆园屯田营火山碎屑岩夹层中获得丰富的生物地层资料,其中发现大量的植物化石:"*Elatides*" sp., *Coniopteris* cf. *burejensis*, *Equisetum* sp., *Schizolepis* sp., *Acanthopteris gothanni*, *Cladophlebis argutula*, *C.* sp., *Ruphaelia* sp., *Ctenis nwatokoi* 等。上述植物化石组合特征,显示的时代比传统的屯田营组更新(吉林省地质矿产局,1988,202 页)。这一意见与本研究孢粉组合是一致的。

5 古植被、古气候探讨

根据葆园地区屯田营组孢粉组合的构成以及孢粉属种已知亲缘关系,可以初步推测,早白垩世 Berriasian 期—Valanginian 期,延吉盆地葆园地区有着较茂盛的植被,包括真蕨纲的海金沙科、紫萁科、桫椤科、蚌壳蕨科和石松纲的石松科、卷柏科等蕨类植物,以及松柏纲的松科、罗汉松科、掌鳞杉科,苏铁纲的苏铁科或银杏科等裸子植物,植被中还包括苔藓门藓纲的水藓科植物。整个植被中以松科、罗汉松科裸子植物较多,蕨类植物中,海金沙科植物渐渐兴起,其它多种植物同时繁衍并杂于其间。

可以推测,早白垩世 Berriasian 期—Valanginian 期,在距火山喷发中心较远的该地区河、湖岸边或山间盆地旁的高坡地,生长有松科、罗汉松科、苏铁科的高大树木及桫椤科树蕨、海金沙科植物,在下层阴暗地带和河谷、湖沼地洼潮湿地区生长有紫萁科、卷柏科、石松科等草本植物和苔藓类,在一些向阳或干旱地带,生长有掌鳞杉科植物。

松柏类为现存最多的裸子植物,其中松科植物适应性较强,为全球分布,罗汉松科植物分布于热带、亚热带湿润地区、苏铁科植物为热带、亚热带树种,银杏科分布于温带,桫椤科植物是现今仍生长于热带潮湿地区及南半球的温带和亚热带植物,紫萁科现存于温带、亚热带和热带,大多数卷柏科植物现分布于热带、亚热带,个别见于温带,海金沙科、蚌壳

蕨科等大部分蕨类植物性喜潮湿,石松科为耐旱植物。各气候带均有分布。综上所述,早白垩世早期,延吉盆地葆园地区很可能属温暖湿润的亚热带气候。考虑到火山活动的影响,也可能会有较为干旱的间歇。

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DISCOVERY OF PALYNOMORPHS AND THEIR SIGNIFICANCE IN THE TUNTIANYING FORMATION OF BAOYUAN, LONGJING CITY, JILIN PROVINCE

SHANG Yu-ke[1, 2] and CHENG Jin-hui[3]

1) *Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, Nanjing* 210008, *China, yukeshang555@163.com*;

2) *College of Palaeontology, Shenyang Normal University, Shenyang* 110034, *China*;

3) *Key Laboratory of Economic Stratigraphic and Palaeogeography, Nanjing Institute of Geology and Palaeontology and Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, Nanjing* 210008, *China*

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Abstract

The Tuntianying Formation, named in 1959, is a series of volcanic rocks intercalated with volcaniclastic rocks under neath the Changcai Formation in the Yanji Basin. It distributes mainly in Mingyue Town of Antu County, Laotougou, Tianbaoshan, Shilipu and Wangqing areas in Longjing City. Because of the insufficiency of study on volcanic movements and deficiency of biostratigraphic data, the definition, geological age and subdivision of the Tuntianying Formation remain debatable. The geological age of the Tuntianying Formation has been regarded as the Middle or Late Jurassic for a long period before Li (2001) assigned it to Berriasian of the Early Cretaceous based on palynomorphs in the Tuntianying Formation of Mingyue Town, Antu County. We studied palynomorphs in the Tuntianying Formation of Baoyuan, Longjing City to discuss the geological age and subdivision of the Tuntianying Formation further, and to provide more evidence for subdivision and correlation of Mesozoic volcanic strata inside and outside the Yanji Basin. The 2 samples were collected from Bed 4 in the section from Baoyuan railway station to the Laotougou coal mine which was first measured by Zhang Chuan-bo in 1980.

There are 31 genera and 51 species in the palynomorph assemblage, including 16 genera and 26 species of spores of Pteridophyta and 15 genera and 25 species of pollens of Gymnospermae. Pollens of Gynmospermae are more than spores of Pteridophyta in proportion, the former accounting for 58.64% and the latter 41.36%. The main components of pollens of Gymnospermae are dissacate pollens of conifers accounting for 32.81% of the total number, among which developed bisaccate pollens of Pinaceae and Podocarpaceae are more than undeveloped bisaccate pollens of Coniferales. There are a certain amount of monocolpate pollens of Ginkgoaceae or Cycadaceae (5%) and ring-grooved pollens of Cheirolepidiaceae (2.61%). Among the pollens of Gymnospermae incertae sedis, monosaccate *Callialasporites* accounts for 2.59%. The rest palynomorphs account for less than 2% except *Psophosphaera*.

Among spores of Pteridophyta, *Leiotriletes* is the most numerous, accounting for 11.21% of the assemblage. The second are the spores of Lygodiaceae accounting for 10.24%, among which *Cicatricosisporites* accounting for 7.03% is the most numerous. There are some important spores of Pteridophyta accounting for about 2% such as *Pilosisporites*, *Aequitriradites* and *Lygodiumsporites*. This palynomorph assemblage can be named as

Cicatricosisporites-Pilosisporites-Aequitriradites Assemblage.

Among the *Cicatricosisporites-Pilosisporites-Aequitriradites* Assemblage, developed bisaccate pollens are slightly more than undeveloped bisaccate pollens. Spores of Lygodiaceae reach 3 genera and 8 species and account for more than 10% of the total number, which makes them important in the assemblage. In addition, with some typical Early Cretaceous taxa such as *Aequitriradites* and *Pilosisporites*, the assemblage shows a feature of the Early Cretaceous.

In the current palynomorph assemblage occurredsome important Early Cretaceous palynomorphs such as *Cicatricosisporites*, *Pilosisporites*, *Lygodiumsporites* and *Aequitriradites* whose proportions are close to those in early Early Cretaceous. The other taxa are common in the Jurassic and Cretaceous, and developed bisaccate pollens are more than undeveloped bisaccate pollens, which is also a feature of the Early Cretaceous. Hence, the geological age of the palynomorph assemblage in the Tuntianying Formation of Baoyuan should be Berriasian—Valanginian of the Early Cretaceous.

The palynomorph assemblage in the Tuntianying Formation of Antu County (Li, 2001) is characterized with numerous bisaccate pollens of conifers and fewer *Schizaeoisporites*, *Fixisporites*, *Cicatricosisporites*. The current assemblage is similar in a certain content with that in Antu County. However, their difference is obvious. For example, there are more *Cicatricosisporites* accounting for 7.03% of the current assemblage, while spores of Pteridophyta accounts for 5% with *Cicatricosisporites* decreases greatly in the assemblage of Antu County. Furthermore, *Pilosisporites*, *Aequitriradites* and *Lygodiumsporites* account for about 2% in the current assemblage. Therefore, the current assemblage should be younger than that in the Tuntianying Formation of Antu County.

According to the feature of the palynomorph assemblage in the Tuntianying Formation of Baoyuan, we can infer that during Berriasian—Valanginian of the Early Cretaceous, plants of Pinaceae, Podocarpaceae and Cycadaceae with tall trunks and pteridophytes of Cyatheaceae and Lygodiaceae stood on the river or lake banks or the high lands beside intermountain basins, herbs of Osmundaceae, Selaginellaceae and Lycopodiaceae and bryophytes grew in the shady areas of low lands and humid areas of river valleys and lake depressions, and plants of Cheireolepidiaceae grew in some areas with a sunny exposure or arid zone.

During early Early Cretaceous, the palaeoclimate in Baoyuan area of the Yanji Basin was probably warm and humid subtropical, a drier interval might also have existed because of volcanic movement.