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中国煤岩学图鉴

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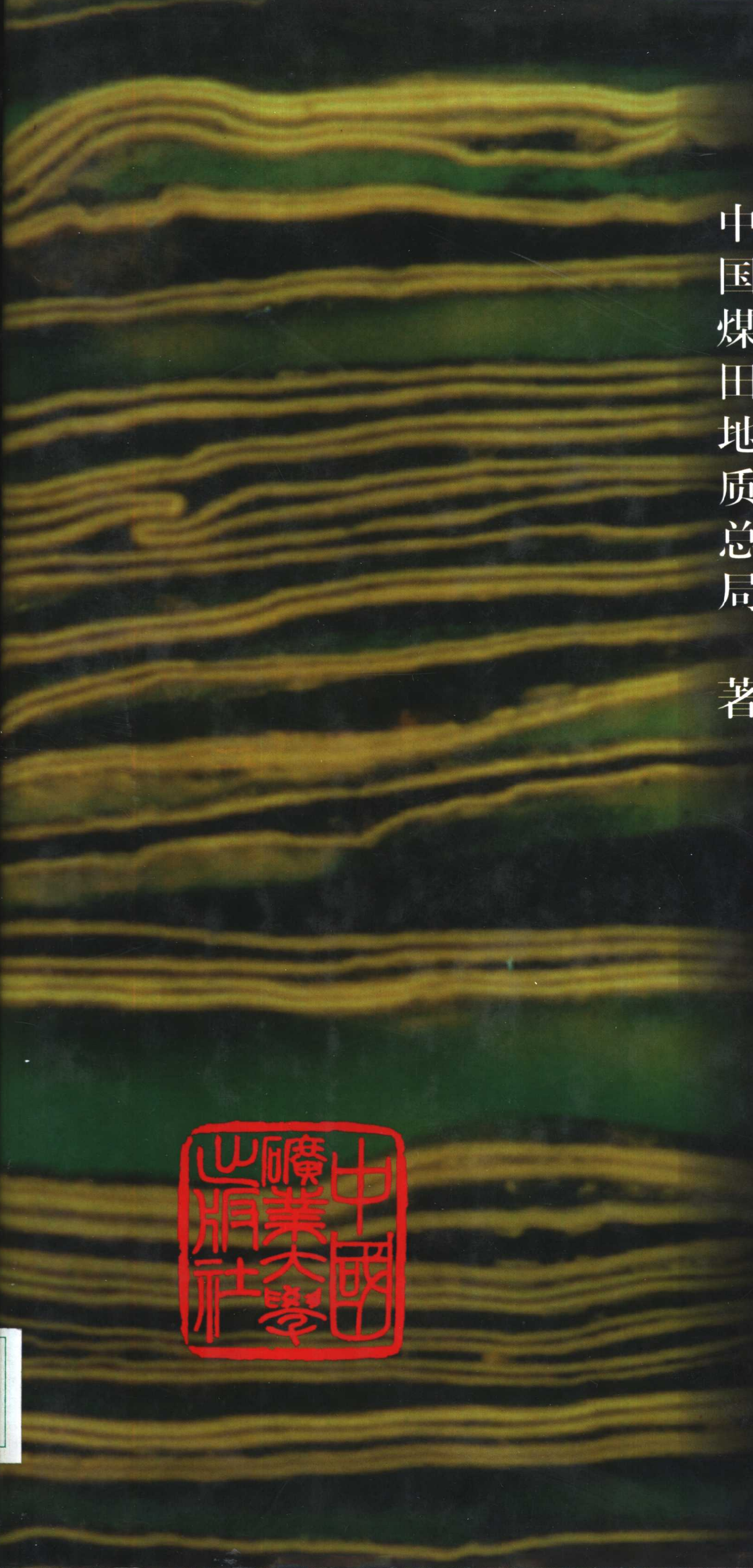

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ATLAS FOR COAL PETROGRAPHY OF CHINA

中国煤田地质总局 著
CHINA NATIONAL ADMINISTRATION OF COAL GEOLOGY

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前　言

我国的煤岩工作者在新中国成立以来的40多年间，以艰苦卓绝的劳动，积累了十分丰富的资料和理论水平较高的各种科研成果。其中有大量独具特色的标本，有制作精美具有代表性的煤岩图版和无法计数的测试数据，其范围包括了我国所有成煤时代的各煤田、各矿区。这批丰硕成果不仅是中国煤岩学也是世界煤岩学的宝贵财富。为了总结、保存和方便应用，国内外历来都很重视煤岩图鉴的整理、编撰工作，我国曾出版过某单个煤田、省区的煤岩图册，有关专著中也附有为数不多的图版，但还未出版过能充分展示我国煤炭资源特色的煤岩图鉴。为此，中国煤田地质总局以煤炭部Ⅰ类科研项目组织编撰《中国煤岩学图鉴》（以下简称《图鉴》），自1993年起，至1996年4月完成。《图鉴》的出版将为加强煤岩学与相关学科的交流和渗透创造更好的条件，为我国提高煤炭资源综合利用水平，发展洁净煤技术，改善燃煤环境质量做出更大的贡献，同时，也将促进煤岩学自身的提高、深化和发展。

《图鉴》汇集了几代煤岩工作者辛勤劳动的成果，虽然参加编制的仅是他们中的一部分，有的因各种情况未能亲自参与，但他们的成果都得到了充分的体现和尊重。因此，《图鉴》是全体煤岩工作者集体智慧的结晶，《图鉴》的出版实现了我国几代煤岩工作者的心愿，达到了承前启后，继往开来的目的。

《图鉴》以煤炭系统40多年煤田地质勘探和科研资料为基础，在广泛收集国内有关单位和个人研究成果的基础上，又增加了新的研究内容，补采了200余个矿点的煤样，力争全面、系统地反映出我国煤岩学研究水平和研究成果的概貌，并突出特色。根据中国煤田地质总局的统一部署，由下而上，先进行省（区）和大片区的汇总，再集中筛选，选出图版精品提高制作质量。先后制作煤岩图片2万余张，最终选定图版111幅，图片973张，文字论述20万字，并附有中、英文图版说明。

《图鉴》以图版为主，文字为辅，图文结合的方式，在整体高度概括的前提下，对具有典型意义的局部进行了详细解剖阐述。图版制作力求精美，色彩、形象真实。以微观照片为主，宏观照片为辅；以显微镜下透射光、反射光和荧光显微镜下的煤岩图片为主，配以少数扫描电镜和透射电镜下的图片。文字力求精炼、准确，所采用的名词、术语不论原出处如何称谓，皆纳入我国现行标准的范畴，使《图鉴》更趋完美和统一，也为今后煤岩学的全面规范化创造条件。

《图鉴》课题组组成人员：组长杨永宽，副组长邹韧、史仲武，成员有姜尧发、许兴华、荣希麟、王文化、任玉梅、张瑞琪、叶瑞丰、张华明、周国庆、张正喜、马玉兰等14人。参加阶段性工作的有王超、郑希民、李永钊、高峰、秦云虎、刘景文、王红冬等7人。毛玉华、柳滨、徐杏芬、盛建海、徐晓琴、傅雪海、程善国、于华冬、曹培忠、王彦君、张桂先、曾雁、刘辉、石磊、刘明雷等15人为《图鉴》做了大量的工作。

《图鉴》编撰分工：第一章，袁三畏、杨永宽；第二章，姜尧发执笔（许兴华负责无烟煤的煤岩资料，荣希麟负责褐煤的煤岩资料）；第三章，杨永宽、史仲武；第四章，姜尧发执笔（周国庆负责禄劝角质残植煤的煤岩资料，张瑞琪、邹韧负责湘中早石炭世煤的煤岩资料，许兴华、徐杏芬负责东南地区中二叠世煤的煤岩资料，张瑞琪、叶瑞丰、邹韧负责西南地区晚二叠世煤的煤岩资料）；第五章，姜尧发执笔（任玉梅负责河西走廊地区煤的煤岩资料，马玉兰负责内蒙古地区煤的煤岩资料，张正喜、王红冬负责山西地区煤的煤岩资料，李永钊、盛建海负责河南地区煤的煤岩资料）；第六章，杨永宽、史仲武执笔（张华明负责西南地区晚三叠世煤的煤岩资料，姜尧发、徐杏芬负责东南地区晚三叠世煤的煤岩资料，任玉梅负责西北地区晚三叠世煤的煤岩资料，史仲武、任玉梅负责西北地区早、中侏罗世煤的煤岩资料，王文化、柳滨负责内蒙古和东北地区早白垩世煤的煤岩资料）；第七章，杨永宽、荣希麟执笔（荣希麟负责西南地区煤的煤岩资料，王文化负责东北地区煤的煤岩资料，杨永宽、姜尧发负责山东、台湾、海南、广东、广西等省（区）煤的煤岩资料）。全书由杨永宽、姜尧发统稿，经中国煤田地质总局组织专家审定。

《图鉴》的编撰过程中得到了煤田地质学界许多专家、学者的热情关怀和真诚的协助。杨起、韩德馨两位院士对《图鉴》的编撰出版工作十分关注。韩德馨院士还提供了有关样品和资料。中国煤田地质总局聘请的中国矿业大学北京研究生部任德贻、中国地质大学潘治贵、煤炭科学研究总院西安分院张秀仪三位顾问，对《图鉴》编撰的全过程给予了悉心的指导。中国矿业大学王洁、金奎励、陈家良、秦勇、唐跃刚、张井、金法礼、李素琴、马雪梅提供了有关资料，田宝霖、王士俊提供了煤中植物残体的研究成果和资料；云南煤田地质局杜万荣提供了云南禄劝角质残植煤样品；台湾大学蔡龙珆提供了台湾省煤样和资料；江汉石油学院李贤庆提供了大量煤样，钟宁宁提供了有关资料；江苏油田尹玲、祝幼华，大港油田张敏锋提供了烃源岩样品；广西煤炭厅陈家良提供了煤样；中国地质大学陈基娘、康西栋，煤炭科学研究总院西安分院何德长、鲁杏林、郝琦、叶道敏、余江滨、林骥等提供了资料；江西煤田地质局李文恒、龚绍礼、江苏煤田地质局胡圣洪提供了南方有关资料；陕西煤田地质局王双明等提供了有关资料；江西煤田地质 223 队颜跃进提供了乐平树皮煤样品；第一勘探局叶建平、河北煤田地质研究所王志宏、北京煤田地质队李萍提供了煤样和资料。有关中国含煤地层、构造、沉积环境等方面的背景资料，主要依据中国煤田地质总局近几年来组织的《华北晚古生代聚煤规律》、《鄂尔多斯盆地聚煤规律及煤炭资源评价》、《黔西、川南、滇东晚二叠世含煤地层沉积环境与聚煤规律》、《华南二叠纪含煤地层沉积环境及聚煤规律》和《全国第三次煤炭资源预测与评价》等大课题的研究成果。《图鉴》初稿完成后，倪斌、梁继刚、王钟堂、孙文涛、袁国泰、毛节华、金克林、尚冠雄、林大杨、汪曾荫等进行了详细审查，提供了很多宝贵意见。《图鉴》的英文摘要由秦勇翻译，任文忠、吕燕生审校；图版说明由任文忠、唐跃刚翻译，任文忠审校。黄凯芬自始至终负责课题的组织、协调工作，为《图鉴》的圆满完成做出了重要贡献。在此，对众多专家、学者所给予的帮助和指导，谨致谢忱。

由于编者水平所限，书中疏漏和不尽人意之处，敬请读者批评指正。

中国煤田地质总局《图鉴》课题组

1996.05.10

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Atlas for Coal Petrography of China

Abstract

Coal petrography is a discipline in which coal is studied by means of the petrographic methods. It is also a frontier science closely related to the disciplines of coal geology, paleontology, coal chemistry, and coal technology etc.. Based upon coal petrography, the characteristics of the petrographic constituents, origin, texture, properties, and technical properties of coal are investigated mainly with the aid of physical methods such as microscope, combining with macroscopic observation and some testing methods.

Until the nineteen thirties, the viewpoint that coal is derived from plant residues was firstly established by the European scientists using the optical microscope, and the various parts of palaeobotanical residues in coal were accurately described. In 1924, the term "coal petrography" was suggested firstly by R. Potcnié, a German coal petrographer, in his work "Einfuhrung in die allgemeine Kohlenpetrographie" and was universally accepted, which symbolized the formal establishment of the science. From 1925 to 1928, E. Stach, a German coal petrographer, applied successfully the technique of both polished coal block and oil-immersion objectives to the examination of coal, and created the technique of polished grain mounts. In the early twenties, coal petrography developed progressively into a independent discipline, and started to expand into the practical application.

The study of coal petrography in China began in the thirties of this century. In 1933, Xie Jiarong found and named the "Lopingnite", an important genetic type of coals, from the Leping, Jiangxi, China, which was one of the important academic achievements in international coal science at that time. In the same year, Wang Zhuquan published his work "Study on coal seams and coal petrography in Cixian, Hebei, China". The two outstanding geologists may be rated as the forerunners in the field of coal petrography of China.

Since the founding of the People's Republic of China in 1949, the research of coal petrography in China has been greatly advanced with the rapid development of coal exploration, exploitation and processing in a large scale. In the early fifties, the organizations for the study of coal petrography were established respectively by the Academia Sinica , the Ministry of Geology and Mineral Resources , the Ministry of Coal Industry, the Ministry of Metallurgical Industry, the Ministry of Oil Industry and so on, by which the professional contingent was trained and the identification of coal samples from the coal exploration was undertaken. Until the sixties, the professional contingent of more than one handred employees had come into being, the basic study of coal petrography had been carried out besides the identification of samples from exploration. As a result, the macroscopic and microscopic characteristics of coals formed during major coal-forming periods, especially, the inherent correlation between the petrographic constituents and the chemical-technical properties of coals, were prelimilarily considered and summarized. From the se-venties onwards, the study of coal petrography had been constantly expanded and deepened, and overlapped and combined with related sciences, and successfully applied to the correlation of coal seams, the classifications of coalification stages and types, the classification of coals, the assessment of coal washability, the combustion, gasification and liquefaction of coals, the preparation of

coal-water slurry, the coking blends and the prediction of coke quality as well as the exploration of petroleum and natural gas. All the activities laid a foundation for joining to the international trade and classification of coals. It has been shown that the method of coal petrography is the most convenient to identify the quality of coal products, and begin to be applied to the coal market at present.

In the early eighties, the academic organization "Coal Petrography Group of Coal Geology Committee", under the China Society of Coal and the China Society of Geology, was established. Meanwhile, much attention was paid to the standardization of the terms and method of coal petrography. For example, the terminology of coal petrography was normalized respectively in the Chinese Great Encyclopedia and the Coal Encyclopedia; twelve National or (and) Coal Industrial Standards were suggested, in which ten standards were promulgated and carried out, and the method and rules for unified assessment to improve the quality of coal petrography examination were drawn up under the organization of the "Standardization Committee of Ministry of Coal Industry". As for the testing and analyzing approaches, the internationally advanced techniques and instruments such as computer and image auto-analyzer have been extensively used, which advances the study of coal petrography to a higher level as a whole. In the past more than forty years, the coal petrography in China has greatly contributed to the economic construction of China, and would expand further its application in the future.

Coal is main energy in China, and makes up more than 70 percent of national energy consuming constitution. China is very rich in coal resources, and the measured and indicated as well as inferred reserves add up to about 5.52×10^{12} tons, and was preserved extensively in all the provinces or autonomous regions of China. In those resources, brown coal shares about 5 percent, bituminous coal about 85 percent (coking coal approximately 25 percent) and anthracite about 10 percent. The coal production of China is the largest in the world. Especially, the reserves of anthracite is so large that it has a significantly important position in the world coal reserves . The coal deposits in China were accumulated throughout the geohistory from Cambrian to Quaternary. Major coal-forming periods include the Carboniferous, the Permian, the Triassic, the Jurassic, the Cretaceous and the Tertiary, among which the Jurassic is the most important one. The coal-forming plants evolved from lower Thallophyta to higher Angiosperm with rich kinds of flora. Coal ranks range from brown coal to anthracite, with a certain amount of natural coke. The petrographic constituents of the coals formed during all the coal-forming periods are greatly various, and the genetic types of coals are complete. Humic coal is dominant of coal resources , with other genetic types of coals such as sapropelite , humosapropelic coal , cutinitic liptobiolith, lopingnite, resinitic liptobiolith as well as the Yunnan light brown coal whose origin remains debated still at present.

The work "Atlas for Coal Petrography of China" consists of two parts, i. e. , fundamentals of coal petrography and petrography of coals formed during major coal-forming periods. In the Atlas, the macroscopic constituents, macerals, mineral matters, microlithotypes as well as the texture and structure of coals were systematically expounded, the petrography of the coals, which formed during major coal-forming periods and occur in a few of the large-scale coalfields, is summed up, and the outline of coal petrography in China is set up.

1. The lower Paleozoic "Stone-like Coal" in China was predominantly derived from the Lower Thallophyta. It has a sapropelic origin, and has become the high-rank sapanthracite due to a long-term coalification. The stone-like coal was mostly accumulated in the epicontinental environment with deep waters or the rift zone, remarkably different from the coals formed during other geological periods. The occur-

rence of the middle Devonian coal in Luquan, Yunnan, China, represented that, from the early Paleozoic to the Late Paleozoic, the coal-forming plants had developed from sea to continent and the coal-forming environments migrated from deep waters to littoral lowland, which raised the curtain on the large-scale coal-accumulating process during the Late Paleozoic.

2. In the Early Carboniferous, the forest swamps occurred in littoral environment with flourishing of terrestrial plants and, then, the earliest humic coal with commercial value in China was accumulated. The coals are generally characterized by rich vitrinite and rich pyrite except for the coal that occurs in Jinzhushan, Hunan. The latter is extremely poor in sulfur, and is the high-quality anthracite seldom found in the South China.

3. The Permo-carboniferous coals in the North China are predominant of humic those, with the thin beds or interbeds of sapropelite and humosapropelic coals. The macerals in the coals consist mainly of vitrinite, adding up from 50 percent to 80 percent. The content of inertinite ranges commonly from 15 percent to 35 percent, and tends to increase from the southeastern part to the northern margin of the North China basin. The exinite is relatively poor, generally less than 10 percent, but is notably rich in the northern margin of the basin and in the areas where the sapropelite occurs, with more than 30 percent in some coal plies. As for the content of vitrinite, the coals in the Taiyuan formation take first place, those in the Shihezi formation come second, and those in the Shanxi formation remain last. As for the Taiyuan formation, the vitrinite in coals underwent a relatively strong degradation, and is mostly hydrogenous or fluorescing . The coals are relatively rich in pyrite and in vitrain band , with a rather regular and horizontal bedded structure, which gives expression to the paralic low moor with deeper waters. As for the Shanxi formation, the vitrinite in coals underwent a weak degradation, and the coals show mostly the lenticular, thready and micro-wave bedding, revealing the character of limnic low-transitional moor with relatively shallow waters. The coal seams in the Shihezi formation are developed only in the southern North China basin. The content of exinite in the seams is rather high, mostly more than 10 percent, and tends to increase in ascending order of seam horizon, up to 20 percent. In the macerals of exinite group, the barkinite is relatively rich, and the barkinite in the upper seams of the Upper Shihezi formation shows some characteristics similar to the barkinite in the Lopingnite of the South China, which gives an insight into the course during which the paleoecological environment in the North China plate tended to become similar to that in the Yangtze plate and the two plates progressively matched each other at that time.

4. The lithological character of the Upper Permian coals in the western South China varies regularly eastwards from the Xikang-Yunnan palaeocontinent with the transformation of coal-accumulating environments from the alluvial facies, through the deltaic and littoral plain facies, to the carbonate platform facies. Overall, the ratio of vitrinite to inertinite (V/I) and the content of pyrite tend to increase, and the contents of inertinite,. exinite and mineral matters tend to decrease , that is to say, there exists a progressively increasing trend of both vitrinite degradation and organic matter abundance from the west to the east. Commonly, there exists the barkinite in the coals contained in alluvial and deltaic facies. The coals of the Upper Permian Longtan formation in Leping, Changxing, Guangde and Yixin of the eastern South China, where typical barkinitic liptobiolith occurs, are well-known for rich-barkinite in them.

5. The Upper Triassic strata were mostly deposited in the paralic environment, in which the content of vitrinite tends to deduce and that of mineral matters tends to increase from the south to the north and from the east to the west. The semivitrinite and the inertinite are relatively rich in the coals of the

southwestern South China where the macrinite and the inertodetrinite take a very high proportion to the macerals of inertinite group. So, it was shown that there existed the swamps with rather shallow waters, and frequent fluctuation and brief exposure of water table, giving rise to the formation of thin-layer trimacerite.

6. As the Jurassic coals are concerned, the seams with relatively or extremely rich inertinite are developed widespreadly in an east-west tonal area stretching from the Datong, Ningwu and Ordos basins lying to the south of the Yingshan Mountain Ranges, through the middle Qilianshan Mountain Ranges, to the Turpan-Hami and Yili basins in the Tianshan Mountain Ranges. In the area, the content of the inertinite in coals ranges commonly from 35 percent to 50 percent, up to 80 percent, most notable in the Dongsheng and Shuishijing mining districts of the Ordos basin, and in the Datong, Minhe and Yili basins. The exinite in the Jurassic coals is poor, generally less than 3 percent, so that there is a relationship of growth and decline between the contents of vitrinite and inertinite. The seams are mostly related to the alluvial depositional system, and were formed in both drier forest swamps and raised bogs with very shallow waters. As the sea water had regressed far from the coal-accumulating areas since the Mesozoic, the drought-enduring plants such as Ginkgo and Coniferales flourished, which laid a matter foundation for coal accumulation. The low-ash coals were generally deposited in the drier moor where the water was nearly stagnant with weakly input of inorganic matters. Moreover, there occur often the seams with rich vitrinite, sometimes up to more than 90 percent, in the Junggar, Turpan-Hami and Yanji basins, and some basins in the middle Qilianshan Mountain Ranges as well as the northern Shaanxi of the Ordos basin, and there are also the seams with very poor mineral matters in a few areas. Those seams were formed in the water-covered forest swamp related to the depositional systems made up by both lacustrine delta and shallow-water lake.

7. The Lower Cretaceous coals, occurring mostly in the eastern Inner Mongolia and the Northeast China, are characterized by rich vitrinite or huminite, but the content of the macerals in the terrestrial coals varies greatly. As for the exinite group, the resinite is commonly seen, with the resinitic liptobiolith in a few coalfields, the suberinite is easily found, and the phyllovitrinite occurs extensively. Those characteristics show a significant difference of the Lower Cretaceous coals from the Lower - Middle Jurassic coals and indicate an increasing impact of the coniferous plants to the primay coal-forming matters.

8. The Tertiary coals are primarily characterized by very poor inertinite and rich telinite or textinite with well-preserved cell tissues. The Lower Tertiary coals occur mainly in the Northeast China, and are rich in vitrinite or huminite, poor in inertinite and rare in exinite, commonly with larger-grained resinite (amber) that might be concentrated as an amber coal. The Upper Tertiary coals, distributed mainly in Yunnan, are characterized by rich vitrinite, poor exinite and very varied inertinite, and there exists the Baipao coal, a light lignite. The Tertiary coals in Taiwan consist mainly of vitrinite and exinite, with minor inertinite, and the content of the desmocollinite in the coals is closely related to the hydrogen index indicating the hydrocarbon-generated potential.

9. In general, only the peats are formed in the Quaternary. However, the Quaternary soft brown coal occurs in the Tengchong basin, Yunnan, and it is very rich in huminite, richer in exinite and relatively poor in inertinite. The Tengchong region lies on the transitional zone between the Eurasian and Indian plates where the phenomenon of high geothermal gradients is remarkable, and the activities of the Quaternary volcanoes are violent. The geological setting has promoted the transformation of the peat into soft brown coal.

The major achievements in the work "Atlas for Coal Petrography of China" are as follows:

1. A sufficient attention has been paid to the recent achievements in paleobotany made by Chinese scholars, and some methods of paleobotany used for reference. The analyzing and identifying results to the thallogen from coals suggested that the thallogen not only was the primary matters of the lower Paleozoic stone - like coal , but also participated in the accumulation of coals during succeeding geological periods.

2. Based upon the study on paleophytoanatomical textures of textinite, telinite, fusinite and cutinite, many new species of paleophyte have been found and identified, and, then, new understandings on the species that were transformed really and truly into peat have been acquired, which would give certain impetus to the study on coal-forming plants deduced only by sporopollen analysis of coals or identification of fossils from the roof and floor of coal seam. In the meantime, the origin and species of the plants, from which huminite, telinite and fusinite were derived, have been newly recognized in the light of their paleophytoanatomical textures, and, thus, the foundation for establishing new macerals is set up, leading to the identification of coal macerals to a new level.

3. So far as the maceral classification goes, nine new maceral varieties have been distinguished in light of their paleophytoanatomical textures and supplied into the classification scheme of this Atlas on the basis of the international classification of coal macerals. Five varieties of them are those of brown coal, i. e. , pinotextinite, betulotextinite, taxodiotexitinite, fungotinite and pinopollinite. Another four varieties are those of bituminous coal, including ginkgotelinite, lepidophytofusinite, psaroniofusinite and ginkgofusinite. The macerals that were previously suggested by other authors, such as cordaitotelinite, lepidophytotelinite, pila-alginite and reinschia-alginite, were described in detail, with the corresponding photomicrographs attached to the Atlas. Basing upon those achievements, the authors have made a new contribution to coal petrography.

4. The lithological constituents and characteristics of the coals and their three-dimensional variances in some large-scale coal basins are systematically summarized, and the general framework of coal petrography in China are represented, which would provide a regional setting for the further study of coal geology and for the exploitation and rational utilization of coal resources in China.

5. It is not occasional that there is rich hydrogenous vitrinite in the Upper Paleozoic (Taiyuan formation) coals of the North China. This type of vitrinite occurs not only in the southeastern North China basin, but in the coals of the Datong, Pingshuo mining districts etc. , with a regional distribution. Though many standpoints had been suggested for the paleobotanical species from which the barkinite in the Upper Permian "Lopingnite" of the South China was derived, the authors consider preliminarily the barkinite as being an autochthonous maceral originated from the cortical tissue of gymnosperm in accordance with its features of cell texture and the aerial root tissues.

6. In the Atlas, most of the photomicrographs were taken under transmitted, reflected and fluorescent microscopes, with a few of the photomicrographs taken under scanning and transmitted electron microscopes so as to show the submicrostructure of some macerals. Simultaneously, some precious and rare photomicrographs of the zoolite in coals and the dispersed organic matters in hydrocarbon-generated rocks were collected, which has enriched and widened the Atlas. The lithological characteristics of brown coal, bituminous coal, anthracite and natural coke are normatively described, and laid out in order of fundamentals and coal-accumulating periods, which would fill the gaps that there was no reference book in coal geology.

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第一章 绪 论

煤岩学是用岩石学方法研究煤的一门学科。它是与煤田地质学、古生物学、煤化学和煤工艺学等学科相关的一门边缘科学。显微镜是煤岩学研究的主要仪器，兼用肉眼和其它技术手段，以物理方法为主，研究煤的岩相组成、成因、结构、性质及其加工利用特性。

从19世纪30年代起，欧洲科学家首先用显微镜确认了煤是由植物遗体形成的，并对古植物各组成部分特征作了精确描述。1924年，德国波托尼（R. Potonié）在《普通煤岩学概论》中第一次使用“煤岩学”一词，并得到公认，标志着这门学科的正式形成。1925～1928年，德国斯塔赫（E. Stach）成功地用抛光煤片和油浸物镜研究煤，并发明了粉煤光片。20世纪初，煤岩学逐渐发展成为一门独立的学科，并开始走向应用阶段。

我国煤岩学研究始于本世纪30年代，1933年谢家荣先生发现并命名江西“乐平树皮煤”是当时国际上的重要学术成就。同年，王竹泉先生发表了《河北磁县煤层煤岩学研究》一文，两位前辈堪称中国煤岩学研究领域的先驱。

新中国成立以来，随着大规模的煤炭勘探、开发和加工工业的高速发展，也促进了我国煤岩学研究的迅速发展。50年代初，中国科学院和地质、煤炭、石油、冶金等行业的科研、教学、生产部门，相继建立了煤岩学研究机构，并培训专业人才，承担起煤田地质勘探中的煤岩鉴定任务。到60年代已形成了上百人的技术队伍，除满足生产中的鉴定工作外，还开展了各项基础性的煤岩学研究，初步总结出各主要聚煤期煤的宏观和显微煤岩特征，并注意到煤岩组成与煤的化学工艺性质之间的内在联系。从70年代以来，煤岩学研究领域不断拓宽和深化，与相关的多门学科交叉、结合，相互渗透，在煤层对比、煤变质阶段和变质作用类型划分、煤炭分类、预测煤的可选性、煤炭燃烧、气化、液化、制备水煤浆、炼焦配煤和预测焦炭质量以及石油、天然气勘探等应用领域都取得了可喜的成果，为煤炭国际贸易和煤分类国际接轨创造了条件。煤岩学方法是鉴别煤炭产品品种最简便而有效的手段，并已开始应用于煤炭市场。

80年代初，我国成立了全国性的煤岩专业学术团体，隶属于中国地质学会和煤炭学会，定名为“煤田地质专业委员会煤岩学组”。与此同时，煤岩学术语、工作方法的标准化和规范化工作也受到重视：中国大百科全书和煤炭百科全书规范了煤岩学术语，在煤炭部标准化委员会的组织下，已研制出12项国家标准，其中10项已颁发执行，并建立了提高煤岩鉴定质量的统检方法和制度。在研究手段方面也广泛应用世界先进技术和计算机、自动图像分析仪等先进设备，使煤岩学的总体研究能力提高到一个新水平。回顾40多年来，我国煤岩学的研究和应用为国民经济建设作出了很大贡献，今后的服务领域还将继续扩大。

煤炭是我国的主要能源，占能源结构的70%以上。我国煤炭资源极为丰富，探明储量和预测资源量总计约5.52万亿吨。其中褐煤约占5%，烟煤约占85%（炼焦用煤约占25%）、无烟煤约占10%。广泛分布于全国各省（自治区）、市，产量居世界首位。尤其无烟煤储量之巨大，在世界占有相当重要的地位。在地史上，我国从寒武纪到第四纪都有煤层形成，重要的成煤期有石炭纪、二叠纪、三叠纪、侏罗纪、白垩纪和第三纪，侏罗纪是最重要的成煤期。成煤植物从低等的菌藻类到高等的被子植物渐变演化，门类繁多。煤类从褐煤到无烟煤均有分布，并有一定数量的天然焦。中国各地质时期煤的岩石学组成丰富多彩，煤的成因类型齐全。腐植煤是煤炭资源的主体，此外还有腐泥煤、腐植腐泥煤、角质残植煤、树皮残植煤、树脂残植煤，以及成因尚有争议的云南浅色褐煤等不同成因类型的煤。

《中国煤岩学图鉴》包括煤岩学基础和各主要成煤期煤的煤岩特征两部分内容：较系统地论述了宏观煤岩组成、煤的显微组分、煤中的矿物质、显微煤岩类型以及煤的结构、构造等内容；总结了中国各主要成煤期和若干大型、重要煤田的煤岩特征，建立了中国煤岩特征总貌的骨架。

1. 中国早古生代石煤的成煤原始质料以菌藻类低等植物为主，成因类型属腐泥煤类，由于热演化时间长，煤类皆为高阶无烟煤。石煤的成煤环境大多为陆缘较深水环境或裂谷带，这是有别于其它各时代煤的显著特点。云南禄劝中泥盆世煤的出现，揭示了从早古生代至晚古生代成煤植物从海洋转向陆地，成煤环境亦由深水向滨海低地推移的演化过程，揭开了晚古生代大规模聚煤作用的序幕。

2. 早石炭世随着陆生植物的大量繁殖，在滨海环境下形成森林泥炭沼泽，进而转变成中国大陆上最早具有工业开采价值的腐植煤，一般都具有高镜质组和高硫铁矿含量的特点。唯湖南金竹山地区硫含量甚低，为华南地区少有的优质无烟煤。

3. 华北石炭二叠纪煤以腐植煤为主，在晋北、晋西南、鲁西南、苏北、淮南等地区有腐泥煤、腐植腐泥煤薄层或夹层赋存。煤中显微组分以镜质组为主，为50%～80%；惰质组一般为15%～35%，由华北盆地东南部向北部边缘，惰质组含量有增高的趋势；壳质组较少，一般不超过10%，但在盆地北缘及腐泥煤出现地区，壳质组含量明显增高，某些分层可达30%。太原组煤中镜质组含量最高，石盒子组次之，而山西组煤中镜质组含量相对较低。太原组煤中的镜质组降解程度较强，多为富氢（荧光）镜质体，煤中矿物以硫铁矿较多，镜煤条带较多，呈较规则的水平层状构造，反映近海强覆水低位泥炭沼泽的特点。山西组煤中的镜质组降解程度相对较弱，多具有透镜状、线理状结构和微波状层理，反映陆相较弱覆水的低—中位泥炭沼泽特点。石盒子组煤层分布于华北盆地南部地区，煤中壳质组含量相对较高，多大于10%，由下部层位向上部层位，壳质组含量呈增高的趋势，可达20%，壳质组中树皮体很丰富，上石盒子组上部煤层中的树皮体，其特征与华南乐平煤中的树皮体相似，反映了当时华北板块与扬子板块逐渐趋向于相近的古生态环境和逐渐靠近的过程。

4. 华南西部晚二叠世煤，从康滇古陆向东随聚煤环境从冲积相区向三角洲相区和滨海平原相区再向碳酸盐岩相区变迁，煤岩特征亦相应地有规律变化。总的趋势为镜惰比（V/I）、硫铁矿含量逐渐增高，惰质组和壳质组、矿物总量及石英含量逐渐降低，而镜质组降解程度和有机质含量则有增高的趋势。冲积相区和三角洲相区煤层中普遍含有树皮体。华南东部乐平、长兴、广德、宜兴一带晚二叠世龙潭组煤中，以富含树皮体著称，其中有典型的树皮残植煤。

5. 华南晚三叠世，多为海陆交替相沉积，煤中镜质组含量有自南向北、自东向西呈逐渐减少的趋势，煤中矿物总量则有逐渐增高的趋势。西南地区煤中半镜质组和惰质组含量相对较高，惰质组中粗粒体和碎屑惰质体所占比例甚高，表明成煤时泥炭沼泽覆水较浅，水位升降频繁，并常处于短暂干涸状态，因而常形成微三合煤微薄层。

6. 侏罗纪煤在阴山以南的大同、宁武、鄂尔多斯盆地，中祁连地区直至天山的吐鲁番—哈密盆地、伊犁盆地等这一东西向条带内，普遍出现惰质组含量较高或很高的煤层，一般为35%～50%、最高可达80%，如鄂尔多斯盆地的东胜和碎石井等矿区，大通盆地、民和盆地和伊犁盆地最为突出。又由于侏罗纪煤壳质组含量少，一般小于3%，故镜质组和惰质组含量互为消长，这些煤层的形成多与冲积沉积体系有关，而且是在弱覆水、较干旱的森林泥炭沼泽或高位泥炭沼泽环境下形成的。中生代以来随着海水远退，耐旱植物如银杏、松柏等大量繁殖，为聚煤作用提供了物质基础。在较干旱的泥炭沼泽中，一般水流活动性小，无机物沉积作用微弱，常形成低灰煤。另外在准噶尔、吐鲁番—哈密、塔里木、焉耆盆地和中祁连的部分盆地以及鄂尔多斯盆地的陕北地区，亦常有富镜质组的煤层出现，有的含量甚至在90%以上，少数地区煤中矿物质含量亦很低，这些煤层是在与湖泊三角洲及浅水湖泊沉积体系有关的覆水森林泥炭沼泽环境下形成的。

7. 早白垩世煤集中分布于内蒙古东部和东北地区。煤中高镜质组（腐植组）是最显著的特点，但陆相煤田中显微组分含量变化大。壳质组中树脂体较常见，少数煤田中还有树脂体富集的树脂残植煤，木栓质体在煤中易发现，叶镜质体普遍存在。这些特征与早、中侏罗世煤有明显差别，说明松柏类植物在成煤原始质料中所占比重增加。

8. 第三纪煤以惰质组含量很低和含有大量细胞结构保存完好的结构镜质体、结构木质体为主要特征。

早第三纪煤主要分布在东北地区，以高镜质组（腐植组）、贫惰质组和少壳质组，常含有较大粒径的树脂体（琥珀）为特征，并可富集成琥珀煤。晚第三纪煤主要分布在云南，以高腐植组、贫惰质组和稳定组含量变化大为特征，并赋存有浅色褐煤（白泡煤）。台湾第三纪煤中以富镜质组、壳质组和少惰质组为特征，煤中基质镜质体含量与反映生烃潜能的氢指数密切相关，亦为台湾第三纪煤的一个重要特征。

9. 第四纪一般只形成泥炭，而在云南腾冲盆地出现第四纪软褐煤。这是由于腾冲盆地处于欧亚大陆板块与印度板块的过渡地带，第四纪火山活动强烈、地热异常显著，从而加速了泥炭层转变成软褐煤的进程的结果。煤层具有高腐植组、富稳定组、少惰质组的特征。

《中国煤岩学图鉴》（以下简称《图鉴》）的主要成果：

1. 本《图鉴》充分重视近年来国内学者关于古植物研究的新成果，并借鉴了古植物学的某些研究方法。从煤中菌藻类的分析和鉴定结果表明，菌藻类不仅是早古生代石煤的成煤原始物质，而且参与了以后各时代的成煤作用。

2. 通过对结构木质体、结构镜质体、丝质体、角质体的古植物学解剖结构研究，鉴定出许多新的植物种属，对直接参与成煤的植物有了新的认识，使仅从煤层顶底板化石和孢粉分析确定成煤植物的研究状况向前推进了一步。并且在古植物解剖结构研究的基础上，对结构木质体，结构镜质体、丝质体的植物来源及其种类又有了新的认识，从而奠定了增添新的显微组分种的基础，使煤岩鉴定达到了一个新水平。

3. 在显微组分分类方面，根据植物解剖结构特征，在国际分类的基础上又补充划分了9个显微组分种，其中在褐煤中补充了5个种，即：松木结构木质体、桦木结构木质体、杉木结构木质体、真菌结构体、松粉体；烟煤中补充了4个种，即：松柏-银杏结构镜质体、鳞木丝质体、辉木丝质体、松柏-银杏丝质体。并对前人划分的烟煤显微组分种如科达木结构镜质体、鳞木结构镜质体、皮拉藻类体、轮奇藻类体等作了具体描述，并附有相应图片。这些工作是对煤岩学的新贡献。

4. 系统地总结了我国若干大型聚煤盆地煤岩组成和特征及其在时空上的变化规律，建立了我国煤岩特征总体的骨架。为中国煤田地质学的深化和煤炭资源合理开发、综合利用提供了区域背景资料。

5. 华北晚古生代太原组煤中富含富氢镜质体不是个别现象，不仅在华北盆地东南部赋存，而且在大同、平朔等矿区均有发现，具有区域性特征。对华南晚二叠世乐平树皮煤中的树皮体的植物属性有许多不同的论点，《图鉴》的作者根据其细胞结构和气生根构造特征，初步认为是裸子植物皮层原地堆积而成。

6. 本《图鉴》以透射光、反射光和荧光显微镜下的煤岩图片为主，为了揭示某些物质的微细结构，还辅以少量的扫描电镜和透射电镜下的图片，并收集到一些煤中动物化石的珍稀图片和烃源岩某些有机岩石成分的图片，丰富并扩充了本《图鉴》的内容。对褐煤、烟煤、无烟煤、天然焦等的煤岩特征都作了规范化的描述。按煤岩学基础和各主要成煤期的显微煤岩特征进行系统编排，填补了中国缺乏煤岩学工具书的空白。

第二章　煤岩学基础

煤是由古代植物遗体经成煤作用后转变成的一种固体可燃有机岩，其岩石组成比较复杂。用肉眼观察，可以分出不同的煤岩成分和宏观煤岩类型。用显微镜观察，可进一步分出各种显微组分和显微煤岩类型。按岩石学原理，显微组分是组成煤的最基本单位。

第一节　宏观煤岩组成

宏观煤岩组成是根据肉眼所观察的煤的光泽、颜色、硬度、脆度、断口、形态等主要特征而区分的煤岩成分及其组合类型。

一、煤岩成分

煤岩成分（lithotype of coal）　是指宏观可识别的煤的基本组成单元。腐植烟煤中可以划分出镜煤、亮煤、暗煤、丝炭等4种煤岩成分（E. Stach 等著，杨起等译，1982）。

1. 镜煤

镜煤（vitrain）　是光泽最强、均一，常具内生裂隙的煤岩成分。镜煤极易破碎成棱角状，断口呈贝壳状，在煤层中与其它煤岩成分界线分明，呈厚几毫米到几厘米的凸透镜状或条带状（图版48-*b*；图版72-*a*，*h*）。

2. 亮煤

亮煤（clarain）　是光泽略次于镜煤、非均一的具微细层理的煤岩成分。亮煤在煤层中可以成为独立的较厚分层。在同一煤级中，根据光泽强度可进一步将亮煤划分为亮亮煤和暗亮煤（王洁，1985）。

（1）亮亮煤（bright clarain）　光泽较强，仅次于镜煤（图版72-*c*）。

（2）暗亮煤（dull clarain）　光泽次于亮亮煤，有时较暗，不具贝壳状断口（图版72-*d*，*e*）。

3. 暗煤

暗煤（durain）　是光泽暗淡的煤岩成分。一般呈黑色，含较多矿物时呈灰黑色。致密坚硬，不易破碎，断口粗糙，密度较大。在煤层中可以成为独立的较厚分层（图版72-*f*）。

4. 丝炭

丝炭（fusain）　是外观像木炭、具丝绢光泽的煤岩成分。呈黑色，具纤维状结构，疏松质软，易碎。矿化丝炭则较坚硬。在煤层中多呈厚几毫米的扁平透镜体断续出现（图版72-*g*）。

二、宏观煤岩类型

宏观煤岩类型（macrolithotype of coal）　是煤岩成分的自然组合。在腐植硬煤中，依据煤的总体相对光泽强度，将其划分出光亮煤、半亮煤、半暗煤和暗淡煤4种宏观煤岩类型。最小分层厚度一般为5cm。也可依据自然分层中光亮成分的含量（镜煤与亮煤之和），加确宏观煤岩类型的划分。

1. 光亮煤

光亮煤（bright coal）　是光泽最强的宏观煤岩类型。结构近于均一，易破碎，常呈贝壳状断口。条带结构不明显，主要由镜煤和亮煤组成，二者之和大于75%（图版72-*c*）。

2. 半亮煤

半亮煤（semibright coal）　是光泽次强的宏观煤岩类型。由条带状的亮煤和暗煤交替组成。一般镜

煤与亮煤之和为50%～75%。有时，仅由暗亮煤组成（图版48-*b*；图版72-*a*，*h*）。

3. 半暗煤

半暗煤（semidull coal）　是光泽较暗的宏观煤岩类型。比较坚硬，主要由条带状暗煤和亮煤组成。一般镜煤与亮煤之和为25%～50%（图版72-*d*）。

4. 暗淡煤

暗淡煤（dull coal）　是光泽最暗的宏观煤岩类型。质地坚硬，密度大，主要由暗煤组成。一般镜煤与亮煤之和小于25%（图版72-*f*）。

在褐煤中，依据腐植碎屑中肉眼可辨认的木煤（腐植化的植物根、茎残体）和丝炭含量划分出木质煤、碎屑煤和丝质煤。

第二节　煤的显微组分

显微组分（maceral）是指显微镜下可辨认的煤的有机成分，以其透光性、透射色、反射率、反射色、结构、形态、大小、突起、荧光性、各向异性和硬度等差别而相互区分。显微组分来源于植物的各种组织和器官的残体及降解产物（衍生物）。成因和性质大体相似的显微组分，在硬煤中相应地归并为：镜质组、半镜质组、惰质组、壳质组；在褐煤中相应地归并为：腐植组、惰质组、稳定组。据显微组分的成因、植物组织结构的保存情况等特征，可将显微组分进一步划分为显微亚组分。根据可鉴别原始成煤植物的特征，可进一步划分显微组分种。

一、褐煤的显微组分分类和特征

（一）褐煤的显微组分分类

本书以国际煤岩学手册中褐煤显微组分分类为基础，结合我国褐煤工作实践，划分出4种显微组分种，补充了褐煤显微组分分类（表2-2-1）。

（二）褐煤的显微组分特征

1. 腐植组

腐植组是植物的木质纤维组织经腐植化作用转化而成的褐煤显微组分的集合。腐植组分，在油浸反射光下呈暗灰色到灰色，低突起；在透射光下呈褐黄色到褐红色；在蓝光激发下发褐黄色荧光。腐植组是褐煤中最主要的显微组分，它包括6种显微组分。

（1）结构木质体（textinite）　是植物细胞组织保存完好的腐植组分。主要由植物的根、茎的木质部形成。在透射正交偏光和荧光镜下，各向异性明显。细胞腔有时中空，有时被凝胶体、类脂物质、鞣质体等充填（图版1-*a*，*b*，*c*；图版57-*a*）。

根据解剖特征，结构木质体可区分出松木结构木质体、杉木结构木质体、桦木结构木质体和真菌结构体等。

①松木结构木质体（pinotextinite）　横切面见髓部的薄壁组织、初生木质部和次生木质部，次生木质部最发育，生长轮明显，早、晚材界线清晰，晚材中有树脂道（图版15-*a*，*b*）；径切面见交叉场，管胞径向壁具稀疏的单列圆形或椭圆形具缘纹孔（图版15-*c*）；弦切面见单列和多列射线，多列射线中有横向树脂道（图版15-*d*），有时在树脂道内壁上有粒状原生粗粒体（图版4-*a*）。

②桦木结构木质体（betulotextinite）　横切面见髓部的薄壁组织、初生木质部和次生木质部，导管横切面形状多为近等径的多角状；弦切面见单列射线；径切面见梯状穿孔板（图版15-*e*，*g*）。

③杉木结构木质体（taxodiotextinite）　横切面见明显的生长轮；径切面见圆形、单列或双列具缘纹孔；弦切面见单列射线（图版15-*f*）。

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