COAL GEOLOGY AND GEOCHEMISTRY

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Contents

Summary

Knowledge about coal must be obtained from coal geology and coal geochemistry: two important fields in coal science. In this short article, the origin of coal, coal geology, coal classification, coal exploration and mining, coal geochemistry, and coal mineralogy are introduced. The origin of coals must be considered in close relation to the origin of organic matter and the evolution of life, particularly plant life.

The formation and development of peat swamps in geological periods are the result of the evolution of plants, climate, and geographical conditions. Because it depends upon the stage of plant evolution, the accumulating intensity of coals is different in individual geological periods. Because of different forming conditions and coalification, different coals have different properties. For scientific/genetic, technical, or commercial purposes, coal must thus be classified. The nature of a classification system will depend upon the particular application for which the system is to be employed.

For extracting coal from underground, the scope of coal seams, the reserves of coal, and the geological structure of the coalfield must be known. Coal exploration can provide such information. Recently, because of findings relating to hydrocarbons in coal, and pollution from coal mining and coal utilization, many achievements have been made in the field of coal geochemistry.

One example is the development of biomarkers to investigate trace elements in coal. Because of the impurities in coal, coal mineralogy is important for industrial and geological practice. It can provide information about the origin, distribution, and characteristics of minerals, and their variations in coal processing.

1. Introduction

Coal geology, a branch of economic geology, deals with the geological character, origin, distribution, and the industrial and economic appraisal of both coal and coalfield. The subjects of coal geology include (a) the composition, properties, and origins of coal; (b) the characteristics and formation conditions of coal seams and coal measures; and (c) the genesis and distribution of the coal-accumulating basin. Coal geology can be further divided into coal petrology, coal geochemistry, coal sedimentology, etc. The origins and properties of coal, as well as the evolution of macerals and minerals, are regarded as the concerns of coal petrology. Coal geochemistry mainly deals with the origins, evolution and characteristics of organic and inorganic substances in coal and their effect on the environment and human beings.

2. Origins of Coal and World Reserves

As early as the 1830s, scientists in Europe recognized the structure of the plant tissue in coal by means of microscopes. Plant fossils were discovered in coal balls and the roof and floor of coal seams. Obviously, coals do not only originate from plants, but most coals that form in the peat swamp environment are *in situ* in origin. Therefore, the origin of coals must be considered in close relation to the origin of organic matter and the evolution of life itself, particularly of plant life.

The formation and development of peat swamps over geological periods are the result of the evolution of plants, the climate, and geographical conditions. In the twentieth century, many studies have focused on the forming conditions and processes of present-day peat swamps in order to make comparisons with fossilized swamps. Many remarkable discoveries about the origin and formation of coals have been made.

Only after land vegetation flourished over geological periods could what are now exploitable coals come into existence. The accumulating intensity of coals is different in individual geological periods due to the different stages of plant evolution. The distribution of coal reserves in geological periods is important for both practice and academic interest: that is, for both coal extraction and the investigation of the evolution of palaeoecological conditions on Earth.

Recent investigation has indicated that the palaeogeographic distribution of coal reserves in individual geological periods is determined by the climate and diastrophic conditions. That is to say, the climate controlled the geographic distribution of plants. One of the concerns here is to investigate the correlation of coal reserves with the climate and palaeogeographic, geotectonic conditions.

2.1 The Origin of Organic Matter and the Evolution of Life Systems on Earth

The oldest primitive organisms on the Earth known today are derived from the Precambrian period of South Africa. The radiometric age of the rocks determined by Pb/Sr methods is 3.1×10^9 years, which indicates that the beginning of life falls into the first third of the Earth's history. Abiogenic hydrocarbons produced by geothermal processes provided energy to the first true organism, which were probably anaerobic heterotrophs (Echlin, 1970).

The Earth's atmosphere in the early stage of evolution is of reducing character and oxygen-free. Oxygen appeared in the atmosphere approximately 3.0×10^9 years ago (Berkner and Marshall, 1965). The development of oxygen levels was closely related to the evolution of organisms. After the level of oxygen reached 1% of its present-day atmospheric content, oxidizing metabolisms, which furnished the organisms with many times more energy than the primitive fermentative process, could come into existence.

The “first critical phase” has been placed at the beginning of the Palaeozoic, i.e. in the period about 600 million years ago (Berkner and Marshall, 1965). Although the aerobic processes were made possible, the intensity of ultraviolet radiation was so high that the organic cells must have been protected by a thick water layer at least ten meters thick.

At the beginning of the Silurian (approximately 420 million years ago), the oxygen level reached 10% of its contemporary atmospheric level and the “second critical phase” took place. The oxygen level was high enough to protect the organisms from the deleterious effects of ultraviolet radiation, and terrestrial flora and fauna started to develop. The energy source for biological processes was photosynthesis, by which carbon dioxide and water are converted into carbohydrates with the simultaneous release of oxygen.

The type of flora in the individual geological periods is evidently different. Figure 1 shows the development of vegetation during the geological history. It is believed that the Upper Palaeozoic cryptogamous flora consisted of trees with thick bark and thin wood. Arborescent gymnosperms of Mesozoic times already had thick wood and thin bark and were rich in resin. Tertiary conifers also had highly resinous wood.

2.2 Formation of Peat Swamps

The accumulation of vegetation remains results in peat swamps under certain diastrophic, climatic, and geographic conditions. Peat deposits are the geologically youngest deposits of caustobioliths, the coal deposits being their fossil analogues. Three types of peat swamps can be distinguished: lowmoor, highmoor, and transitional peat swamps.

Lowmoor swamps are formed in lowlands by the gradual overgrowing of marshes or water basins. Their supplies of water are from both surface and groundwater. Their formation depends on the balance of microbial decay of dead plant material. Where microflora (bacteria, fungi) is capable of decomposing all material accumulated into mineral components, humus cannot heap up and peat cannot form.

Since the lowmoor swamps are fed with groundwater, which brings an abundance of dissolved nutritive substances, their vegetation cover differs from that of the highmoor swamps. The vegetation of the former is more varied, rooted under the water level in soil generally enriched in nutrients, particularly Ca and K.

In fossil lowmoor swamps, two types are differentiated on the basis of the mode of plant matter accumulation: stagnant peat swamps, formed by prolonged overgrowing of the water body, and irrigation peat swamps, formed by increasing water-logging of the area. The development of the two types is often linked up and repeats itself cyclically. It is controlled predominantly by diastrophism and climate.

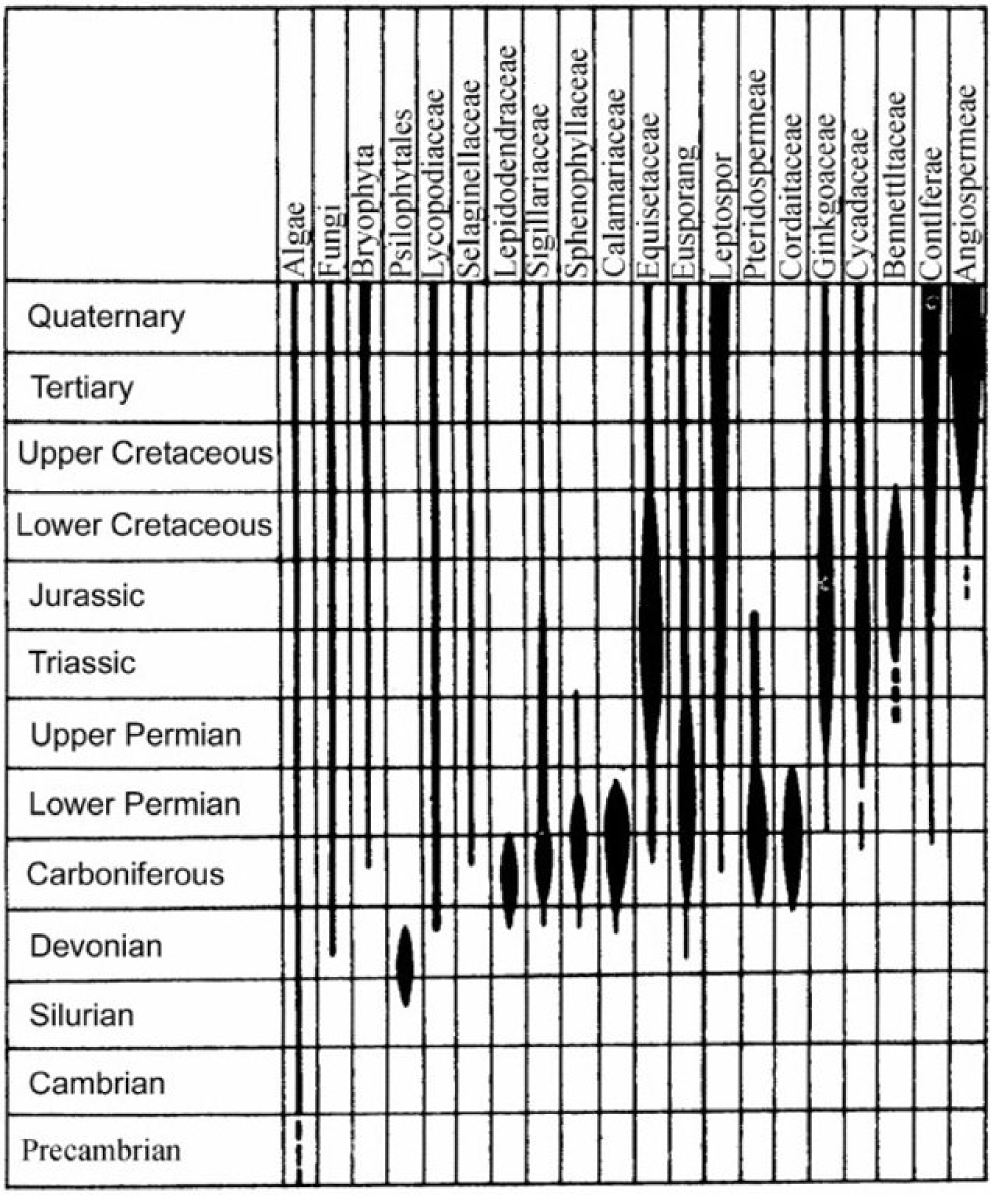

Figure 1. The development of vegetation during the geological history (after V. Bouska)

Highmoor swamps develop at higher elevations under cooler and more humid climatic conditions. They grow on soils poor in nutrients or in basins with impermeable clay bottoms, invariably above the groundwater level and fed almost entirely with atmospheric water. Some grasses and sphagnum moss represent the plant species.

The lower parts of sphagnum gradually die away and are transformed into true peat; the upper parts grow continuously and the bog may thus rise to several meters above the groundwater level. In the midst of the bog, where the environment is most humid, the moss grows most rapidly and the bog is upheaved.

Transitional peat swamps representing a transition between the preceding types develop where a higher swamp was formed on the lowmoor substrate.

Fossil peat swamps from which coal seams have developed were lowmoor swamps of tropical nature. Coal deposits corresponding to present-day highmoor swamps have not yet been found.

The accumulation of plant material depends on many factors that are basically controlled by diastrophism and climate. Diastrophic movements produce subsidence of some parts of the Earth's crust and upheaval of others, thus giving rise to source of areas and sedimentary basins.

The thickness of the basin filling and the cyclic structure are also affected by diastrophism. The climate governs the evolution and composition of vegetation, groundwater conditions being one of the major accessory factors.

Environments suitable for the accumulation of plant material developed only in some places on Earth, depending on the course of mountain ranges, climate zone, and the evolution stage of fossil flora. Also, the migration of the Earth's axis created favorable conditions for the formation of coal deposits, even in the areas that are glaciated at present.

2.3 The Distribution of the Coal Reserves in Geological History

The evolution stage of fossil flora determines the distribution of the coal reserves through geological history. After land plants occurred, enormous coal reserves could exist. The oldest coal occurrences are the anthracite from the Jatulian of Finland, Precambrian coals from Kazakhatan, and some coal deposits in America. A small amount of coal of algal origin is discovered in the Cambrian and Silurian periods. Bituminous coals of Devonian age are found on ancient shields (Russian Platform, Siberian Shield, Canadian Shield).

The coal seams 0.3–0.6 m thick from the Upper Silurian age found in the area of Tashkent and Kokand are the oldest exploitable coal seams in the whole world. Also, the deposits of Devonian bituminous coal on the Medevezhi Islands and in the northern part of the Kuznetsk basin at Barzas, south-east of Tomsk are mineable; several coal seams there are as much as 3.5m thick.

The first large sources of land plant matter giving rise to enormous coal reserves appeared in the late Carboniferous and Permian eras and the first important coal deposits were preserved. The amount of coal reserves of these ages occupies about 56% of total world reserves.

The second important coal deposits developed in the Jurassic. The third developed in the Cretaceous and Tertiary periods, the thickest coal seams in the world being formed in the Tertiary era.

The relative distribution of the coal reserves of the world through geological history is shown in Figure 2. Table 1 shows the coal reserves of the world and their relative distribution through geological history as defined by a number of researchers.

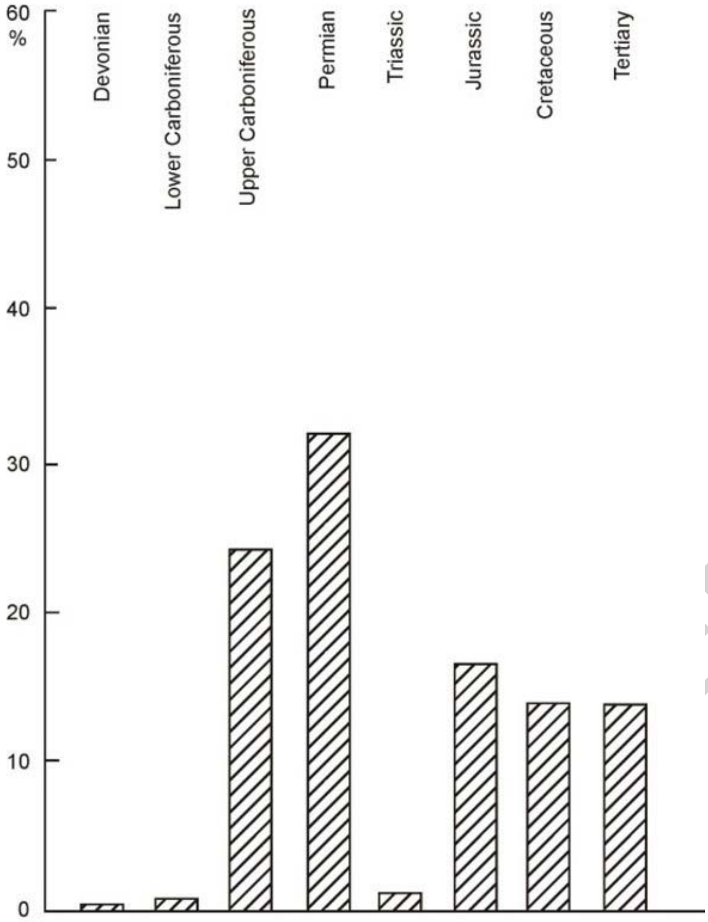

Figure 2. The relative distribution of the coal reserves of the world in the geological history (after V. Bouska)

Geological Period	**1937**		**1973**		**Bestougeff, 1980**	
	Reserves, 10^9t	**%**	**Reserves, 10^9t**	**%**	**Reserves, 10^9t**	**%**
Devonian	0.2	0.002	2	0.001		
Carboniferous	1836	24	2890	21	2460	24.3
Permian	1308	16.9	3780	27	3210	31.7
Triassic	42	0.5	6	0.04	40	0.4
Jurassic	312	4	2300	16	1701	16.8
Cretaceous	26	0.4	2900	21	1347	13.3
Tertiary	4211	54.4	2124	14.6	1367	13.5

Table 1. The coal reserves of the world and its relative distribution through geological history

After the Carboniferous period, the coal deposits of the different geological periods developed and coalfields were extensively distributed throughout the world. But the coalfields of the different geological periods are not of uniform distribution across the world but are concentrated in a certain area. The large coalfields of the Carboniferous age are distributed along a latitude course in the Northern Hemisphere: mainly in the

USA, Russia, the U.K., Germany, Poland, and China. The large amount of coal reserves from the Permian period are concentrated in the Eastern Hemisphere along a longitude course, mainly in Russia, China, Australia, South Africa, and the Antarctic. The coal reserves of the Jurassic are mainly concentrated in Asia, in countries such as Russia and China, along a latitude course. The coal reserves of the Cretaceous are distributed in the eastern part of Asia and the zone in the west of North America along the Pacific. The coalfields of the Tertiary are extensively distributed throughout the whole world although the area of individual coalfields is small. Most of these are concentrated in North America, Western Europe, northeastern Asia, Siberia, and China.

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Biographical Sketch

Prof. Ke-chang Xie was born in 1946. He is doctor of engineering, instructor of doctoral students, chairman of Shanxi Key Laboratory of Coal Science and Technology, editor in chief of "Conversion of coal," subeditor of "Chemical engineering of coal," editor of *Fuel Processing Technology*, *Fuel Chemistry Journal*, and *C1 Chemistry and Engineering*. Prof. Xie once studied in the University of South Carolina in USA as a scholar. Prof. Xie's research fields cover coal science and technology, and heterocatalysis. He has led and finished 15 research projects including 1 international, 5 national, and 5 provincial projects. His researches have won 1 Second-class Prize of Science of National Ministry of Education, 5 First-class and 1 Second-class Prize of Science of Shanxi Province. Prof. Xie has published more than 220 papers in important academic journals and international meetings and 1 book. As a professor, he has tutored 15 doctoral students. Now, Prof. Xie is president of Taiyuan University of Technology, and chief scientist of National "973" Project, member of Academic Committee of National Key Laboratory of Coal Conversion, director of Society of Chemical Engineering, member of AIChE.