THE ORIGIN OF COAL AND WORLD RESERVES

Fangui Zeng
Shanxi Key Laboratory of Coal Science and Technology, Taiyuan University of Technology, China

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Contents

Summary

In the short article, the origin of coal and coal reserves in the World have been introduced. Only after the land vegetation flourished in geological periods, the exploitable coals could come into existence. Because of the stage of the plant evolution, the accumulating intensity of coals is different in individual geological periods. Coal is an aggregate of heterogeneous materials composed of organic and inorganic substances. All coal deposits were formed in the peat swamps. Different types of plant flourished in the peat swamps, which primarily reflects conditions of climate, water level, and water chemistry of the swamps. Three types of peat swamps can be distinguished: (a) lowmoor, (b) highmoor, and (c) transitional peat swamps. The formation of the peat swamps depends on following factors: a) the evolutionary development of the plant, b) the climate, and c) the geographical and structural position of the region. Macerals (Optically homogeneous discrete organic material in coal) are derived from and named after the particular plant tissues commonly preserved in peat swamps. Three group

macerals can be found in coal, i.e. vitrinite, exinite and inertinite.

The first large sources of land plant matter giving rise to enormous coal reserves appeared at the late Carboniferous and Permian and the first important coal deposits have been preserved. The amount of the coal reserves of these ages occupies about 56% of total world reserves. The second important coal deposits developed at the Jurassic. The third developed at the Cretaceous and Tertiary and the thickest coal seams in the world are found at the Tertiary. The new analysis of proved recoverable reserves of coal demonstrates that out of a total of 984 billion tons, bituminous coal reserves (including anthracite) constitute 509 billion tons and sub-bituminous and lignite 475 billion tons. Six countries hold over 75% of proved recoverable reserves: the USA possesses 25%, the Russian Federation takes second place with 16% and China, Australia, India and Germany have 12%, 9%, 8% and 7% respectively.

1. Introduction

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 the land vegetation flourished in geological periods, could the 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: 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 controlled by the climate and diastrophic conditions. That is to say, the climate controlled the geographic distribution of plants. One of the interests here is to investigate the correlation of coal reserves with the climate and palaeogeographic, geotectonic conditions.

2. Origin of Coal

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 in 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 one percent 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 ten percent 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. It is believed that the Upper Palaeozoic cryptogamous flora was represented by 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

Coal is an aggregate of heterogeneous materials composed of organic and inorganic substances. All coal deposits were formed in peat swamps. Different types of plant flourished in the peat swamps, primarily reflecting conditions of climate, water level, and water chemistry. Organic materials in the swamp are thus derived mainly from plant remains that have undergone various degrees of decomposition and physical and chemical alteration after burial. The formation of the peat swamps depends on the evolutionary development of the plants, the climate, and the geographical and structural position of the region.

Plant evolution played an important part in the makeup of the plant source material in the swamp, ultimately affecting the petrologic composition of the coal. Coals forming in a peat swamp are essentially *in situ* in origin. On the other hand, some peat and even coals may be reworked and redeposited by a fluvial system and are called *allochthonous* in origin. Coal deposits derived from extensive accumulation of driftwood also belong to this category.

If the accumulating peats are subsequently buried and preserved, any region where conditions are favorable for the accumulation of peat, is a potential region for coal formation. The back swamps of floodplain, lake margins, lagoons, coastal plains where tidal fluctuation is low, and glaciated regions with poor drainage are all good environment for peat accumulation. The conditions for producing thick layers of coal are that the region must be constantly subsiding, or the groundwater level must be rising slowly but steadily, and the accumulation of plant debris must keep pace with the rising water level.

Peat deposits are the geologically youngest deposits of caustobioliths, coal deposits being their fossil analogues. Three types of peat swamps can be distinguished: (a) lowmoor, (b) highmoor, (c) 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 ground-water. 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 ground-water, 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: (a) stagnant peat swamps, formed by prolonged overgrowing of the water body; (b) irrigation peat swamps, formed by increasing water-logging of the area. The development of the two types is often linked up and reaps itself cyclically. It is controlled predominantly by diastrophism and climate.

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 ground-water 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 ground-water 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, ground-water 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. 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 Origin of Coal Maceral

Optically homogeneous discrete organic material in coal is named maceral (derived from the Latin *macerare*, to macerate, to separate). All macerals are classified into three groups: vitrinite, exinite (or liptinite), and inertinite. Macerals are derived from and named after the particular plant tissues commonly preserved in peat swamps. Vitrinite is derived from variously decomposed woody tissues, and exinite is derived from spore and pollen coats, cuticles, resins, and other fatty secretions. On the other hand, inertinites are derived from partial carbonization by fire of various plant tissues in the peat swamps stage, and others are perhaps derived from intensive chemical degradation induced by microorganisms. Each group includes a series of macerals, which can be regarded as belonging together, either because of similar origin (such as exinite), or because of the mode of conservation (vitrinite and inertinite).

Vitrinite is the most frequent and important maceral group occurring in bituminous coals. Cellular structures derived from vegetable material are sometimes visible in vitrinite under a microscope. The cell walls are called telinite. In many cases, it is difficult to distinguish between telinite and collinite so they both tend to be recorded as vitrinite in maceral analyses. Pure telinite is rare. Telinite and vitrinite generally originate from trunks, branches, stems, leaves, and roots. Judged against the three maceral groups, vitrinite has medium reflectance and carbon and hydrogen content.

The exinite group consists of sporinite, cutinite, suberinite, resinite, alginite, and liptodetrinite. In low-rank coals, the exinites are distinguished from vitrinite by a higher hydrogen content. On carbonization, they yield much tar and gas. In high volatile bituminous coals (more than 30% V.M. in the vitrinite), the exinites more or less maintain their composition. But with the transition from high to medium volatile bituminous coals, at a V.M. yield of 28%, they undergo a relatively rapid change which is called as the “coalification jump.”

The inertinite group comprises macerals fusinite, semifusinite, macrinite, micrinite, sclerotinite, and inertodetrinite. The characteristic optical property of intertinite macerals is their high reflectance. Among the three maceral groups, the fusibility of the inertinite macerals in coking coals is weak or nil. Therefore, the word “inert” is used to describe the more or less non-reactivity of inertinites. But micrinite is not inert. In fact, it differs in its origin from the rest of the inertinites.

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Biographical Sketch

Fangui Zeng, is the postdoctoral researcher of Shanxi Key Lab. of Coal Science and Technology and one of the academic staff of the College of Mining Engineering, Taiyuan University of Technology, China. He gained his Masters degree in Xi’an Mining Institute, China, on June, 1991. His Ph.D. was awarded by China University of Mining and Technology on June, 1997. Recently, his research interest is the computer simulation of coal structure evolution during coalification and coal/fluid interaction.