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Review article

On the fundamental difference between coal rank and coal type

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ABSTRACT

This article addresses the fundamental difference between coal rank and coal type. While theoretically settled long ago as being different aspects of coal systems science, the two concepts are still often confounded. In recent years, this has resulted in the publication of several works stating that coal type changes with coal rank. Coal type refers solely to coals' depositional origin and the maceral–mineral admixture resulting from that origin. Coal types typically fall in to two categories: humic coals, developed from peat, and sapropelic coals, developed from organic mud. Either type may be allocthonous or autochthonous, and within types, further refinement of depositional environment can be made. Coal rank refers to the changes in geochemistry and resultant changes in reflectance caused by increasing thermal maturity of the coal. Thus, it provides an overprint of maturity on existing coal types. With proper techniques, such as use of crossed polars and etching, maceral forms can be differentiated even at high ranks, and the original coal type determined.

Contents

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1. Introduction

1.1. What is coal?

Coal is a complex combustible sedimentary rock, composed largely, but not exclusively, of helophytic (±aquatic) plant debris and plant derivatives. Originally deposited primarily as peat, secondarily as mud, to be discussed in more detail below, it transitions to coal through physical and chemical processes brought about by compaction and heat with prolonged burial at depths of up to several kilometers and over periods of up to several hundred million years. Thermal metamorphism from igneous intrusions, while important in some settings, will not be discussed in detail here.

At the most basic level, coal properties are a function of three fundamental parameters of coal composition, each of which is determined by some aspect of the coal's origin and evolution (after Diessel, 1992; Suárez-Ruiz et al., 2012; Taylor et al., 1998; Ward, 1984; among others):

- *organic petrological/geochemical*, including the nature of the organic constituents (macerals), but also with consideration of the organic geochemistry of the macerals and non-maceral organic compounds incorporated in the coal structure;
- *inorganic petrological/geochemical*, including the minerals (crystalline and amorphous inorganic components) and any inorganic entities associated with the organic structure of the maceral components; and
- *coal rank*, the extent of diagenetic/metamorphic transformation in the macerals and minerals, reflecting the maximum temperature to which the coal has been exposed and the time it was held at that temperature and, to a lesser degree, the pressure regime through the latter time and temperature. For most coals, this indirectly reflects the depth of burial and geothermal gradient prevailing at the time of coalification, although heat from igneous intrusions and hydrothermal fluids can also be an influence. The expression as parameters such as huminite/vitrinite reflectance and geochemistry is a function of the irreversible chemical changes, such as increased aromatization, undergone during metamorphism. With a few notable exceptions, to be discussed, while macerals will undergo changes in composition with metamorphism, they do not transform into different macerals. *Provenance prevails through the rank series.*

Ideally, each of the fundamental components is independent of the other two. In reality, this is not the case. Organic and inorganic compositions are, at the onset of coalification, inextricably linked as they are both the product of the environment of peat accumulation. As coalification progresses, both the nature of the macerals and the minerals may vary with coal rank. Maceral chemistry can also influence coal rank; for example, perhydrous vitrinite will have a lower reflectance than 'normal' vitrinite of the same rank (Gurba and Ward, 1998; Hutton and Cook, 1980; Kalkreuth, 1982; Li et al., 2010; Petersen and Vosgerau, 1999). So, while coal petrology can be expressed by a number of fundamental parameters, each largely independent of each other, we need to be cognizant of the inter-relationships among the parameters.

Coal type and *grade* are related but more genetic concepts. Type reflects the nature of the plant debris from which the original organic matter was derived, including the mixture of plant and non-plant components involved (wood, leaves, algae, fungi, etc.). Coal type reflects the depositional environments at the time of peat accumulation, and the amount of biogeochemical degradation experienced by organic components prior to burial. Coal type is expressed as the maceral composition of the coal and is independent of coal rank. Humic and sapropelic coal types, to be discussed in this paper, are the fundamental end members of coal type. Within the humic coals there is also a range from bright (vitrinite-rich) to dull (liptinite- and inertinite-rich) materials (lithotypes). Cady (1942), building on discussions of White and Thiessen (1913), Stopes (1919, 1935), Thiessen (1920a,b,c, 1921, 1926, 1930), Hickling (1932), Thiessen and Sprunk (1936), and Sprunk et al. (1940), defined the term 'phyteral' to refer to the fossil plants in coals. Timofeev et al. (1962) and Timofeev and Bogoliubova (1964) developed a similar approach. Phyterals are composed of macerals, but are themselves useful descriptors of coal type in that they can potentially be recognized throughout the rank series, even in cases where the constituent macerals may become difficult to differentiate, such as in anthracite and meta-anthracite.

Grade reflects the extent to which the accumulation of plant debris has been kept free of contamination by inorganic material (mineral matter), including the periods before burial (i.e., during peat accumulation; syngenetically), after burial (epigenetically), and during rank advance. Regardless of its type or rank, a high-grade coal has a low overall proportion of mineral matter, and, hence, a high organic-matter content.

1.2. Coal forming environments: humic and sapropelic coals

The distinction between humic and sapropelic coals dates at least to Potonié (1893) and has been well established in coal geology since that time. Both coal types are functions of the depositional environments and consequently of the botanical constituents that form coal deposits.

Confusion between the two major coal types is not new. Potonié (1908) temporarily confused matters, placing all anthracite at the high-rank end of the gyttja–sapropel type series, rather than also at the high-rank end of the peat–lignite–bright coal series. While this mistake was rectified in later works (e.g., Potonié, 1912), the misinterpretation has persisted. More recently, workers such as Sen (1999), Sahay (2006, 2008, 2010a,b), and Jones (2009) have confounded the inter-relationships between humic vs. sapropelic coals and coal rank vs. coal type. Sen (1999), building on 30 years of observations in coal geology, points out that Indian scientists consider Gondwanan coals in the Indian subcontinent to be allochthonous, and argues persuasively that non-bright bands are sapropelic, while bright bands represent floated and concentrated log deposits. However, while non-bright