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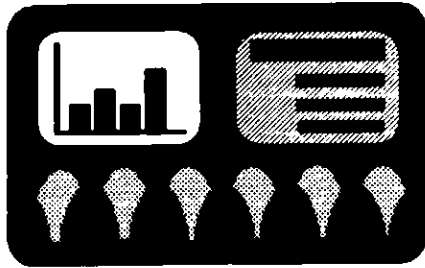
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Conference Report



King Coal and Prince Peat: A Carboniferous Dynasty

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The Carboniferous coal of Europe and North America has made an enormous contribution to the world's technological development. Organized mining was underway in Germany during the Middle Ages and in the English Midlands by 1450. In Canada, the early European settlers were quick to exploit their local coals: New Brunswick coal was exported to New England as early as 1639, and Nova Scotia coal was used at the Louisbourg fortress by 1720. The first project of the Geological Survey of Canada was carried out on the Carboniferous coal measures of Joggins, Nova Scotia, by William Logan in 1842.

These facts indicate the past eminence of coal as an energy source. In these days of increased environmental consciousness, however, deep concern is being voiced over emissions of SO₂

and CO₂ from burning of coal. Alternative sources of energy, including coal-bed methane, are a topic of wide debate. Some still argue that the world's enormous reserves of coal are likely to supply much of our energy requirement for the foreseeable future. Is Old King Coal hale and hearty or in his dotage?

In the early 1950s, a series of international conferences on the origin and constitution of coal was held at Crystal Cliffs, Nova Scotia. After a Nova Scotian hiatus of nearly 40 years, the topic of coal was addressed at a two-day international symposium entitled "The Euramerican Coal Province: Controls on Tropical Peat Accumulation in the Late Paleozoic", held 25-26 May 1992 as part of the Geological Association of Canada (GAC) Annual Meeting at Wolfville, Nova Scotia. The symposium was supported financially by the Global Sedimentary Geology Program (Canadian Committee), the Natural Sciences and Engineering Research Council of Canada, and the Nova Scotia Department of Natural Resources, and was sponsored additionally by the Sedimentology Division of the GAC. The symposium was attended by more than 60 geoscientists from Canada, the United States, Europe and Australia, and included specialists in coal petrology and technology, paleobotany, palynology, modern tropical peats, geochemistry, Carboniferous stratigraphy, and sedimentology. Two participants in the original Crystal Cliffs conferences, A.T. Cross and P.A. Hacquebard, attended the symposium.

The key issue underlying the symposium was the validity of studies of modern peat-forming ecosystems in understanding peat-forming ecosystems of the Carboniferous. The first day of the symposium focussed on modern peats, the paleobiology and dynamics of the Carboniferous peat-forming ecosystem, and the use of coal petrography

and palynomorph data to generate paleoecological reconstructions. The second day dealt with broader issues of tectonic, climatic and eustatic effects on Carboniferous basins and peat accumulation. Keynote talks (40 minutes) were delivered by A.D. Cohen ("Coastal plain peat deposits of the tropical Americas"), A.C. Scott ("The influence of fire in Carboniferous ecosystems"), W.A. DiMichele and T.L. Phillips ("Paleobotanical and paleoecological constraints on models of peat accumulation in the Late Carboniferous"), A.M. Ziegler ("Precipitation patterns, plant productivity and peat preservation"), and C.B. Cecil ("Lithologic response to climate processes in Carboniferous strata of the United States"). Participants contributed enthusiastically, even in the absence of coffee or beer, to formal discussions that ran at length at the end of each day. Papers arising from the symposium will be published in *Palaeogeography, Palaeoclimatology, Palaeoecology*, and a full set of symposium abstracts can be obtained from J.H. Calder.

Some significant issues that arose from keynote talks and from discussion are outlined below. In view of the many points eloquently raised, we have not given individual attribution for all the issues discussed, but rather have attempted to summarize the general tenor of the discussion.

How Useful are Modern Analogues for Interpretation of Euramerican Coals?

W.A. DiMichele (Smithsonian Institute) and T.L. Phillips (U. of Illinois) stressed that we have to take the Carboniferous on its own terms because the Carboniferous flora has *no modern botanical equivalent*. Floral reconstructions are commonly oversimplified and fatally biased by our experience with modern, angiosperm and gymnosperm-domi-

nated systems. The Carboniferous flora included remarkable groups such as the medullosan seed ferns, which grew to approximately 10 m in height, but were parenchymatous rather than woody ("gigantic weeds"). Mires composed of such elements would have been "forested", but would not have yielded much woody material. Many lycopsids, unlike modern trees, had a high bark:wood ratio and, on clastic substrates, they tend to be preserved as bark cylinders filled with sediment (and containing entombed reptiles in some Nova Scotian strata). Whole lycopsid trees died after reproduction, so that forests were probably patchy due to the simultaneous rise and demise of floral cohorts. It is doubtful whether forest canopies similar to those in modern rainforests existed in the Carboniferous. Upland floras were in existence by the late Westphalian, but probably did not yield a firm ground cover; no comparison can be drawn with the extraordinary angiosperm grasses, most of whose biomass lies in their root systems. It was a fundamentally different world from our own.

Floral reconstructions are also strongly biased by the type of material analyzed. Compressed floras preserved in shale were readily found and isolated, and they have formed the basis for most reconstructions. These floras are, however, an unreliable guide to Carboniferous peat-forming ecosystems because the plants grew in detrital, rather than peat-forming, settings, and because they yield a floral assemblage dominated by elements resistant to transport and decay. In contrast, plant-bearing concretions in coals ("coal balls") are receiving increasing attention because they preserve an uncompressed, peat-forming assemblage that has undergone relatively little decay. Even coal balls may provide a biased view if, as has been suggested, they formed within planar mires fed by chemical-rich groundwater, but did not form in raised mires fed largely by rain. Extraction of plant material from the coals themselves is difficult, but etching of coal slabs for paleovegetal analysis is yielding significant new data. Palynological studies are now widely used to complement megafossil work, and finds of *in situ* sporangia on identified plants have been important in establishing palynomorph affinities. Some groups, however, produced copious palynomorphs and are over-represented in reconstructions, whereas others are not

recognized in conventional microspore analysis.

The *geometry and scale* of modern peat-forming systems would seem to provide a reasonable analogue for the Carboniferous because the same broad principles should have governed the interaction of mires with their environment since the advent of land vegetation in the Silurian. Hydrologic factors have always had a pre-eminent effect on peat accumulation, and there should have been, as at present, a fundamental hydrologic distinction between groundwater-fed ("planar") and solely rain-fed ("domed") peat. To this extent, the principle of actualism may apply to the Carboniferous. There is some evidence, however, that the physiological adaptations of the Carboniferous flora favoured the abundant nutrients and water cover offered by groundwater-fed systems.

One keynote address (A.C. Scott, U. of London) dealt with the importance and recognition of fire in Carboniferous ecosystems. A catastrophic Carboniferous fire in Ireland probably resulted in a burn of 95,000 km², and was apparently associated with major erosion and an enhanced detrital flux. Sedimentologists have seldom differentiated fossil charcoal clasts from other coaly matter in sedimentary sequences, potentially overlooking a key element of depositional history.

Recent research on tropical peats in southeast Asia and the Americas has made a major contribution to our understanding of mire development because the importance of regional eustatic and climatic changes can be assessed. These studies have implications for the Euramerican Coal Province in terms of *chemical and hydrological conditions* for peat formation. In recent years, raised mires fed solely by rainwater have been recognized increasingly as potentially major contributors to Carboniferous depositional systems. Such mires are low in ash and sulphur, being above the normal range of floods and groundwater recharge, and may provide a good explanation for some Carboniferous low-ash and low-sulphur coals. Other economic coals, however, have been convincingly interpreted as originally planar peats. Explicit criteria for the distinction of planar and raised paleomires continue to be elusive, and no single approach was thought to yield definitive identifications. It was noted (A.D. Cohen, U. of South Carolina) that,

in Central and South America, domed and planar peats are closely associated, with lateral transitions common, and that the domes are frequently truncated as a result of fluvial erosion, thus reducing their preservation potential.

Although an increasing amount of work on modern peats was reported, many studied peats are relatively thin and rich in terrigenous material. They would not result in mineable coal after undergoing compaction (one metre of bituminous coal probably represents 5-10 m of original peat), and their generally high ash content suggests that they would eventually form carbonaceous shales. Not all studies of modern peat-forming systems are necessarily relevant to the origin of economic coals.

Can We Use Coal Petrography to Identify Peat-Forming Conditions, Plant Groups and Vegetal Communities?

Peat undergoes substantial diagenetic change during its conversion to coal, but we know relatively little about the immensely complex peat-to-coal transition. Which components of a peat will be preserved during burial and what geochemical pathways will be followed during this transition? Important knowledge may come from some Indonesian basins which have peat at the surface and lignite at depth, with a similar floral assemblage in both types of deposit. There is, however, a nomenclature problem, and comparable classification systems are needed to enable tissue and matrix components recognized in peats and lignites to be compared with those of coal. It will prove difficult to bridge the gap in petrographic nomenclature between peat and lignite, let alone the gap between lignite and bituminous coal. Artificial coalification may provide clues about the peat-to-coal transition, but needs to be carried beyond the lignite stage.

The vitrinite group, the major component of Carboniferous coals, has largely been misinterpreted as originating from wood. Lycopsid bark was apparently an important contributor to the coals, but the end-product of non-woody, medullosan trees, which dominated some peat-forming ecosystems, remains enigmatic.

There was a consensus among the paleobotanists present that conventional coal-maceral analysis and nomenclature are of limited value for Carboniferous paleoecological reconstructions.

tion unless they are used in conjunction with other techniques. Paleobotanical description of coal under the microscope, which may entail special preparation techniques, is likely to be attempted more frequently, and petrographers who are knowledgeable about Carboniferous plant-tissue composition and ecology may make significant advances in our understanding of maceral origins. A challenge for coal petrologists will be to recognize macerals that represent such floral entities as non-woody medullosan trees. Not all Carboniferous trees would have been preserved equally or similarly.

Concern was expressed by paleobotanists about the validity of *maceral-based numerical indices*. Maceral-based indices have the advantage that they can readily be derived from maceral data generated during routine petrographic analysis, and they are increasingly being used to suggest, *inter alia*, original vegetal type, tree density, and geochemical and groundwater conditions that prevailed during peat accumulation. The problem is that the definition of such indices is based on our present, partial understanding of coal maceral origins, along with an assessment of factors that govern modern mires. Attempts to use coal petrography in paleoenvironmental analysis were lauded, but many contributors noted that the botanical basis of such indices remains in doubt. Indices designed to reflect hydrologic and geochemical factors, however, may offer important insight into ancient mires. Because petrography does not give the whole story, such indices should not be used blindly and in isolation to determine mire paleoecology.

There has been little historical consensus about sampling procedures for coals. How many samples are appropriate? At what spacing? Each millimetre-thick layer of a coal might represent a different biofacies, and the succession of such facies might, from the paleobotanical perspective, be as significant as the change from a graptolite shale to a coral bioherm from the sedimentological perspective.

How Do We Distinguish the Effects of Climate, Tectonism and Eustasy on Carboniferous Peat Accumulation across Euramerica?

Botanists and paleobotanists have generally considered *climatic factors* to be crucial in governing the growth and pre-

servation of vegetation. A.M. Ziegler (U. of Chicago) stressed the profoundly seasonal nature of rainfall over large portions of the earth and the fundamental linkage between climate, geographic setting, and vegetation. He used a short, computer-generated film-loop to illustrate with graphic visual effect the remarkable seasonal variation in the earth's vegetative cover. Peat accumulation is generally restricted to areas that receive rainfall almost continuously through the year, apart from high-latitude areas where diminished evapotranspiration aids peat preservation.

Climatic signatures should be evident in many types of sedimentary deposit other than coal. C.B. Cecil (United States Geological Survey) discussed climatically sensitive lithological indicators, including paleosols, eolianite, evaporites and non-marine limestones. Paleosols, linked as they are to vegetation, the atmosphere and ground water, have great potential significance for paleoclimate analysis. The weathering of source rocks and the generation of sands rich in quartz or in less stable minerals may also depend on climate. The rapidity and magnitude of changes in Quaternary climate suggest that successions of rock types as different as coal and sandstone could reflect climate change. The distinction of flow-fed from rain-fed paleomires (coals) would have great value as a climatic indicator, but awaits the unequivocal recognition within coal beds of this primary hydrological distinction. Geochemical and isotopic analysis holds considerable promise in resolving questions of temperature, seasonality and salinity, although constrained in part by fundamental questions of oxygen and carbon dioxide levels in the Carboniferous atmosphere.

Work in Indonesia and Malaysia reported by S. Neuzil (United States Geological Survey) indicates that Holocene raised peats are found close to the equator where precipitation exceeds evapotranspiration for more than nine months annually. However, *eustatic sea-level fluctuation* exercises an important control on peat accumulation through its influence on climate and the availability of an exposed platform suitable for peat accumulation. Peat and other organic-rich deposit. In Indonesia, Malaysia and northern Australia border shallow, epeiric seas, such as the Sunda Shelf and Gulf of Carpentaria, which seem to be near a eustatic

highstand and whose maritime influence contributes to the equability of the climate. The onset of Holocene peat accumulation in these areas is attributed both to climatic change and to a minor regression which exposed an extensive coastal lowland platform for peat accumulation. Thus, eustasy may govern the timing and positioning of peat accumulation in coastal settings.

The importance of comparing coeval basins of Euramerica was illustrated by studies of Maritime Canadian coal basins, in which local tectonic effects are much more apparent than, for example, in the midcontinental United States basins. The fault-bounded, intermontane basins of Maritime Canada experienced strongly seasonal climate, in part through rain-shadow effects, through much of the Late Carboniferous. Locally, however, peat accumulated through groundwater recharge from basin-margin alluvial fans (Springhill Coalfield) and where rapid subsidence in pull-apart basins maintained groundwater levels high enough for mires and lakes to be established (Pictou Coalfield). Eustatic effects are evident in the Sydney Coalfield where cyclothems contain paleo valleys cut by sea-level lowering and coals formed under minor stillstands during transgressive periods. Several of the Canadian basinal sequences show a "coal window": a stratal interval for which tectonic, climatic and/or eustatic factors were optimal for the growth and accumulation of vegetation.

In the 1960s, studies of modern environments provided a series of well-documented case studies of deltas, coastal and alluvial systems which were used enthusiastically to interpret ancient coal-bearing successions. Emphasis was placed on the complex lateral relationships of peats and clastic systems, and the geometry of coal deposits was considered a primarily environmental attribute. More recently, we have seen a renewed interest in cyclothems, with stratal continuity attributed to the enormous extent of cratonic epeiric seas or to the migration of peat-forming systems through time. These contrasted models have important implications for evaluation of coal resources and for mine planning. Numerous workers at the symposium commented on the great areal extent of many economic seams and the rarity of demonstrably equivalent clastic deposits. Suggested explanations were variously

DATING METHODS OF QUATERNARY DEPOSITS

variously stratigraphic and environmental: the migration of peat-forming systems across coastal plains during transgressions when sediment supply was minimal, climatic change leading to suitable conditions for peat formation over wide areas, diversion of sediment away from peat-forming systems due to tectonic activity (blind thrust propagation), and doming of peats with exclusion of channels and clastic supply. On a broader scale, the amalgamation of Eurafrican continental masses in the equatorial belt was a major factor in the occurrence of widespread peats.

The analysis of the marginal-marine zone has always been a thorny problem in sedimentology, especially for coal-bearing strata which commonly span the marine to freshwater transition. The recent discovery of assemblages of agglutinated foraminifera and thecamoebians (testate rhizopods) in the Sydney Coalfield has opened a fruitful avenue for future work. The assemblages can be matched at the generic and, probably, specific level with assemblages found in modern marshes and estuaries. In these localities, the foraminifera indicate marine influence and reduced salinity and the thecamoebians indicate freshwater conditions. These remarkably conservative invertebrate assemblages permit actualistic environmental analysis; most other common Carboniferous biota became extinct long ago.

In summary, it was evident that the classic vegetation, coals and strata of the Carboniferous can still draw a crowd and engender debate. Especially encouraging at the Wolfville conference was the frequently expressed interest in holistic, integrated work on paleobotany, palynology, coal flora and macerals, and sedimentology in order to understand the fascinating Carboniferous environment. Old King Coal is still a merry old soul and is not considering abdication. He has entered into a fruitful alliance with Prince Peat that seems likely to ensure the survival of the dynasty for decades to come.

The Geological Association of Canada is pleased to offer a pre-publication price on its forthcoming publication *Dating Methods of Quaternary Deposits*, an expanded and revised version of *Dating of Pleistocene Deposits and Their Problems (Geoscience Canada Reprint Series 2)*. This 8 1/2" x 11" soft cover volume, edited by N. Rutter and N. Catto, contains 18 papers by 17 authors, including short papers on some of the very newest methods. Expected date of delivery is late summer 1993; post-publication prices are not yet established, but prices will likely increase when publication is released. The pre-publication offer will apply from 15 May to 31 August 1993, **so reserve your copy today** by returning the form below.

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