Discussion: "Comments on the maturation of coals" by Vinay K. Sahay

Jennifer M.K. O'Keefe[1], Joan S. Esterle[2], James C. Hower[3], and Shifeng Dai[4]

Search and Discovery Article #70059 (2008)
Posted November 20, 2008

[1]Department of Physical Sciences, Morehead State University, Morehead, KY 40351
[2]The University of Queensland, Brisbane, Queensland, Australia
[3]University of Kentucky, Center for Applied Energy Research, Lexington, KY 40511 (corresponding author: hower1a@caer.uky.edu, 1-859-257-0261)
[4]State Key Laboratory of Coal Resources and Safe Mining, China University of Mining and Technology, Beijing 100083, P.R. CHINA

Introduction

Sahay (2008), in a limited study of Cenozoic lignites from the Panandrho mine, Kutch basin, western India, hypothesized that coals of high volatile bituminous rank and lower should be classified as the sapropelic coal type. In drawing this conclusion, he ignored both the fundamental distinction between coal rank and coal type and the nature of the chemical changes associated with coal metamorphism. Coal rank, the measure of the degree of metamorphism, is a function of the geological history of the coal, in particular the thermal history. Its expression, as parameters such as vitrinite reflectance and geochemistry, is a function of the irreversible chemical changes, such as increased aromatization, undergone during metamorphism. Coal type is an immutable function of the depositional environments at the time of peat deposition and the post-depositional biogeochemical alterations of the maceral content in the peat stages of maturation. Coal type is expressed as the maceral and mineral composition of the coal and is independent of coal rank.

Discussion

Peat

Peat type is a function of the original plant type and degree of decomposition during the early phases of peat accumulation and early burial diagenesis, possibly with later enrichment from fluid migration during the coalification process (Teichmuller, 1989). "Humic peats" are dominated by lignin-rich woody, or cellulose-rich herbaceous plants. Among humic peats, the increasing decomposition will result first in the breakdown of cellulose, followed by lignin. Lipid-rich materials (spores, waxes, cuticles, resins), which are the most resistant plant parts, may concentrate amongst decomposed humic attritus (Stach et al, 1982), increasing the hydrogen content of the peat . The decay scale of humic peats is from well-preserved fibre-rich "fibric" peat, to moderately-decomposed "hemic" peat and well-decomposed "sapric" peat. "Sapropels," or gyttjae, are those putrified organic oozes formed from algae and detrital plant material at the bottom of a lake or ponded area.

A comparison of unpublished Rock-Eval pyrolysis data (J.S. Esterle, A. Stankiwiesz, and R.M. Bustin, circa 1992) from the tropical Baram River Holocene peat deposits with that of older and higher-rank lignite to bituminous coals of Tertiary age from Indonesia (Hadiyanto, 1992) is shown in Figure 1. Random reflectance measurements of the pre-huminite macerals in the Baram peats average 0.23 %, but can be up to 0.40 % in the decomposed sapric peats (Esterle and Ferm, 1994). Coal-sample data from the West Aceh Basin in Indonesia are fully described in Hadiyanto (1992; Hadiyanto and Faiz,1998). The samples vary in rank from lignite to subbituminous coal (Rvo=0.23 % to 0.60 %) and in age from Pliocene to Oligocene (Hadiyanto, 1992). Both the paleoclimate and vegetation which contributed to the formation of these coals was relatively tropical and woody, similar to that occurring today (Anderson and Muller, 1974).

A commonly used comparison for examining Rock-Eval data is a plot of hydrogen index (HI) against Tmax. This index, which emulates the van Krevelen diagram, reflects both the degree of thermal maturity and the kerogen type. Little discrimination occurs between the peat types as described in the field. Most of the peat types follow the Type III kerogen line for humic-rich coals, as might be expected for woody and herbaceous, plant-derived peats. A number of values occur above the HI=200 mg/gm line. One sample, the decomposed sapric peat from the Baram River occurs as an outlier with extremely high HI (403 mg/gm). There is a trend in increasing maturity from the peat samples to the Indonesian coal samples, but these samples would still be considered “humic” coals. The Panandhro Lignites also fall within this trend, and would therefore, be considered humic instead of sapropelic.

The humic nature of the Indonesian peats is corroborated by GC-MS data (Figure 2). Only the severely decomposed sapric peat sample, that also has a high Hydrogen Index, contains any significant (30%) lipid material.

Lignite

The Paleogene (upper middle Eocene) Claiborne Group lignites from Carlisle County, western Kentucky, are very-low-rank coals (0.23 $\%R_o$) that are dominated by alternating detrohuminite- and clay-rich bands with lesser amounts of sporinite, funginite, telohuminite, and gelohuminite (O’Keefe, 2008). As such, it is similar in character to the more indurated Panandhro lignites and carbonaceous shales (Sahay, 2008). At this low rank, atomic H/C and atomic O/C plots, like those of the Breckenridge coal and Cleveland shale (discussed below), show little difference between the geochemistry of the bands (Figure 3). These deposits contain a mixture of type II and type III kerogens (Figure 3), consistent with liptinite-rich detrohuminite (Figure 4). This admixture of kerogen types is strikingly similar to that noted by Sahay (2008) for the Panandhro Lignites and Carbonaceous Shales.

The Claiborne Group lignites and associated clays in western Kentucky are, however, not sapropelic coals. By definition, a sapropelic coal is one that formed under anaerobic, putrefying conditions, resulting in a hydrogen-rich coal. These coals often formed in lakes or pools where spores or algae mixed with mud. As such, the petrography is expected to be dominated by sporinite or alginite and gelified macerals. The Claiborne Group lignites and associated clays, while containing abundant liptinites, are dominated by detrohuminite, not gelohuminite. O’Keefe (2008) used palynology, especially fungal palynomorphs, combined with maceral ratios, to clearly demonstrate that the Claiborne Group sediments in western Kentucky experienced aerobic decomposition. The detrohuminite in these sediments likely formed from a woody hash left by decaying trees, similar to that which forms around decaying trees in modern temperate lowland swamps, such as the Congaree National Swamp Monument in South Carolina, USA. Dominance of woody macerals indicates that this is a primarily a humic deposit, not a sapropelic one. That said, O'Keefe (2008) noted that there are small areas of the deposit that can be classified as sapropelic: in regions where standing water was common and the dominant organic detritus entering the mire was sporinite, thin (mm-scale) areas of cannel coal formed.

Bituminous coal

A very different situation exists for the Claiborne Group coals (0.53 %R_o, Hook and Warwick, 1999) of Webb County, Texas. With a petrographic composition dominated by gelinite and sporinite, with some algal contributions, the San Pedro and Santo Tomas coals may reasonably be termed sapropelic coals (Warwick and Hook, 1995). This represents a different petrographic composition from the typical Eocene lignites of Texas, generally dominated by better preserved humic macerals (Mukhopadhyay, 1989), and a different petrographic composition than the Claiborne Group lignites of western Kentucky. Interestingly, atomic H/C and atomic O/C plots for the Claiborne Group coals of south Texas (Figure 5, SanFilipo, 1999) are very similar to those for the Claiborne Group sediments of western Kentucky. Direct comparison of these plots is somewhat challenging, howeveCoalr, due to the difference in rank, lignite-to-subbituminous (with possible high volatile C bituminous) in Texas versus lignite in Kentucky, between the two deposits. Regardless, this similarity, coupled with the very different petrography of the two examples, argues that atomic H/C and atomic O/C plots are not a good way to differentiate humic and sapropelic Paleogene coals.

In consideration of higher-rank coals, the Pennsylvanian Breckenridge (also spelled Breckinridge) coal from Hancock County, western Kentucky, is a high volatile C bituminous torbanite dominated by a combination of a fine lamalginite and *Botryococcus* telalginite with lesser amounts of bituminite, vitrinite, and inertinite. By virtue of its maceral composition, it is a sapropelic coal. Hower et al. (1986) studied a series of core samples from the Breckenridge torbanite and determined that the atomic O/C versus H/C plots, the classic van Krevelen diagram, placed the samples well within the type I and type II kerogen paths (Figure 6). Mastalerz and Hower (1996) and Hutton and Hower (1999) also discussed the chemistry of torbanites and the chemistry of the constituent macerals. The Breckenridge lithotypes have ratios similar to density separates of the high volatile C bituminous Devonian Tasmanites-rich Cleveland shale of Kentucky (Taulbee et al., 1985). For comparison to humic coals, the atomic O/C versus H/C ratios for the high volatile C bituminous Pennsylvanian Springfield and Herrin coals, Western Kentucky coalfield, were also plotted. The >80% vitrinite (mineral-free basis) coals are within the type III kerogen path. At this rank, therefore, there is no justification for considering all coals to be sapropelic. The humic, high-vitrinite Springfield and Herrin coals have a distinct chemistry from the sapropelic alginite-rich black shale and torbanite.

Conclusions

Sahay's (2008) assertion that all low-rank coals are sapropelic is troubling. Basing it on a comparison between coals of significantly different ages, and thus significantly different original plant constituents is more so. Low-rank coals formed primarily from gymnosperm- or aromatic-rich angiosperm-woods (such as eucalyptus, myrtle, etc.) would naturally be enriched in resins, while still being classified as humic coals, as their origin was woody. His contribution displays a fundamental lack of understanding of the botanical origin of coal and of coal depositional environments in general. Even in coals that are largely humic, we would expect sapropelic horizons, especially near the top of the deposit, where pools of stagnant water may have been present. Indeed, Esterle and Ferm (1986) noted just such an occurrence of cannel coal at the top of the Pennsylvanian high volatile A bituminous Hance coalbed, Bell County, Kentucky.

Assessments of numbers, in this case atomic O/C versus atomic H/C and RockEval parameters, without understanding the basic science behind the numbers is, in most cases, a guarantee of erroneous results. Statistics, in Sahay's (2008) case, in the guise of a critique of conventional coal science without the fundamental knowledge of the distinctions between coal rank and coal type, can lead to seriously misleading conclusions. A basic understanding of coal petrology would have led to defensible results and to firmer conclusions.

References

Anderson, J.A.R. and Muller, J., 1975, Palynological study of a Holocene peat and a Miocene coal deposit from N.W. Borneo: Rev. Palaeobot. Palynol., v. 19, p. 291-351.

Esterle, J.S., and Ferm, J.C., 1986, Relationship between petrographic and chemical properties and coal seam geometry, Hance seam, Breathitt formation, southeastern Kentucky: International Journal of Coal Geology, v. 6, p. 199-214.

Esterle, J.S., and Ferm, J.C., 1994, Spatial variability in modern tropical peat deposits from Sarawak, Malaysia and Sumatra, Indonesia: Analogues for coal: International Journal of Coal Geology, v. 26, p. 1-41.

Hadiyanto 1992, Organic petrology and geochemistry of the Tertiary formations at Meulaboh area, west Aceh Basin, Sumatra, Indonesia: Thesis (Ph.D.)--University of Wollongong (Dept. of Geology), 1992.

Hadiyanto and Faiz, M.M., 1998. Coalbed methane prospects in Indonesia. International Conference on Coal Seam Gas and Oil. March 23-25, Brisbane, p 18.

Hook, R.W., and Warwick, P.D., 1999. The San Pedro and Santo Tomas coal beds (Claiborne Group, Eocene) of Webb County, Texas *in* Warwick, P.D., Aubourg, C.E., and Willett, J.C., Tertiary Coals in South Texas: Anomalous Cannel-Like Coals of Webb County (Claiborne Group, Eocene) and Lignites of Atascosa County (Jackson Group, Eocene) - Geologic Setting, Character, Source-rock and Coal-bed Methane Potential, U.S. Geological Survey Open-File Report 99-301, p. 13-21.

Hower, J.C., Taulbee, D.N., Kuehn, D.W., and Poole, C., 1996, Petrology and geochemistry of the Breckinridge seam - a torbanite from western Kentucky: Proceedings, 1986 Eastern Oil Shale Symposium, Lexington, Kentucky, p. 267-280.

Hutton, A.C., and Hower, J.C., 1999, Cannel coals: Implications for classification and terminology: International Journal of Coal Geology, v. 41, p. 157-188.

Kopp, O.C., Bennett III, M.E., and Clark, C.E., 2000. Volatiles lost during coalification: International Journal of Coal Geology, v. 44, p. 69-84.

Mastalerz, M., and Hower, J.C., 1996, Elemental composition and molecular structure of *Botryococcus* alginite in Westphalian cannel coals from Kentucky: Organic Geochemistry, v. 24, p. 301-308.

O'Keefe, J.M.K., 2008. Paleogene Mirelands of the Upper Mississippi Embayment, western Kentucky: Unpublished Ph.D. dissertation, University of Kentucky, Lexington, KY, 2287 p.

Sahay, V.K., 2008, Comments on the maturation of coals: A Commentary: Search and Discovery, Article #70038 (2008) (http://www.searchanddiscovery.com/documents/2008/08002sahay/index.htm).

SanFilipo, J.R., 1999. Some speculations on coal rank anomalies of the South Texas Gulf Province and adjacent areas of Mexico and their impact on coal bed methane and source rock potential, *in* Warwick, P.D., Aubourg, C.E., and Willett, J.C., Tertiary Coals in South Texas: Anomalous Cannel-Like Coals of Webb County (Claiborne Group, Eocene) and Lignites of Atascosa County (Jackson Group, Eocene) - Geologic Setting, Character, Source-rock and Coal-bed Methane Potential, U.S. Geological Survey Open-File Report 99-301, p. 37-47.

Stach, E., Mackowsky M.-Th., Teichmüller, M., Taylor, G.H., Chandra, D., and Teichmüller, R., 1982. Stach's Textbook of Coal Petrology. Bornträger, Berlin, 3rd ed.

Taulbee D.N., Barron L.S., Robl T.L., and Hagan M., 1985, Kentucky oil shale kerogen studies: Part I. Chemical and pyrolytic characteristics of maceral concentrates: Proceedings, 1985 Eastern Oil Shale Symposium, Lexington, Kentucky, p. 291-300.

Teichmüller, M., 1989, The genesis of coal from the viewpoint of coal petrology: Int. J. Coal Geol., v. 12, p. 1-87.

Warwick, P.D., and Hook, R.W., 1995, Petrography, geochemistry, and depositional setting of the San Pedro and Santo Tomas coal zones: Anomalous algae-rich coals in the middle part of the Claiborne group (Eocene) of Webb County, Texas: International Journal of Coal Geology, v. 28, p. 303-342.

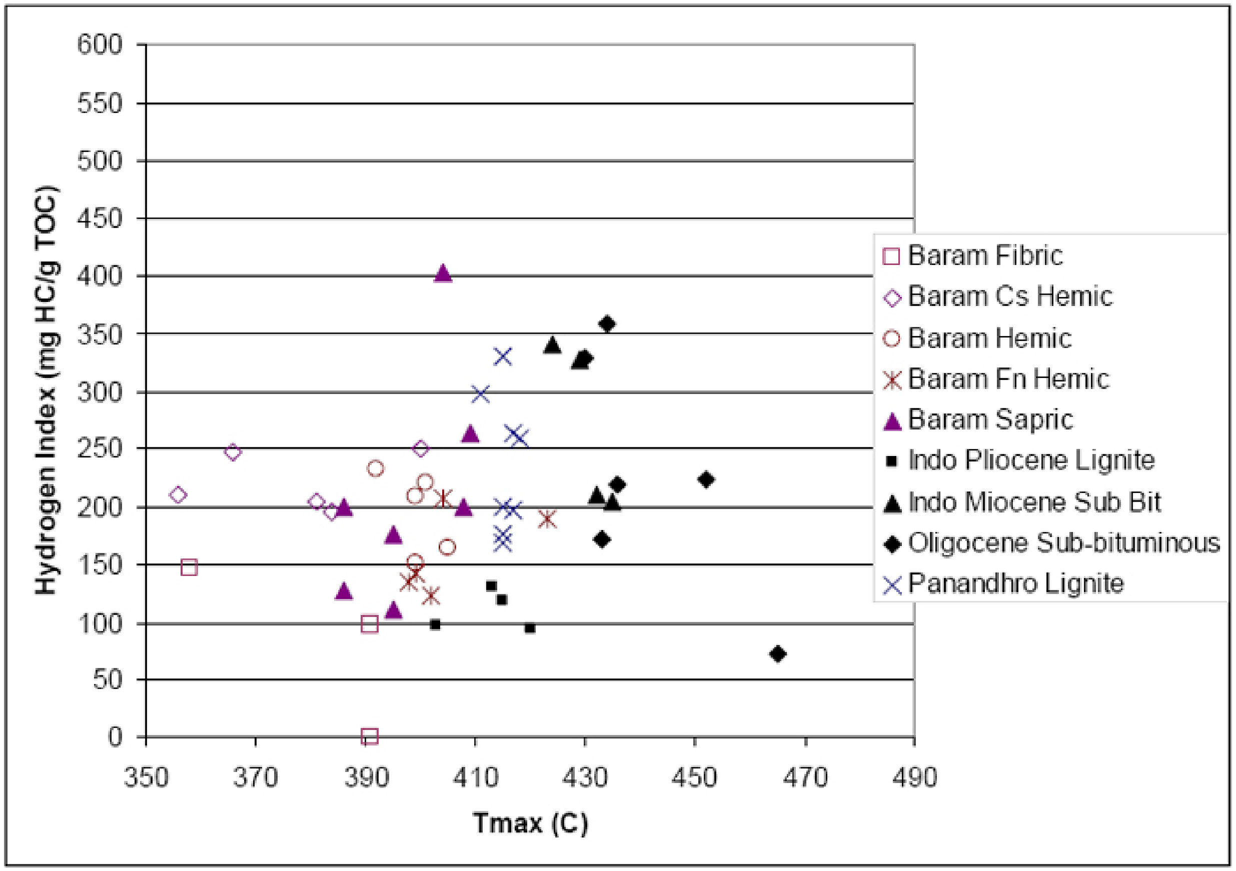

Figure 1. Rock-Eval data for Indonesian peat, lignite, and subbituminous coal (J.S. Esterle, A. Stankiwiesz and R.M. Bustin, unpublished data, ca. 1992) compared with the Panandhro lignite (Sahay, 2008).

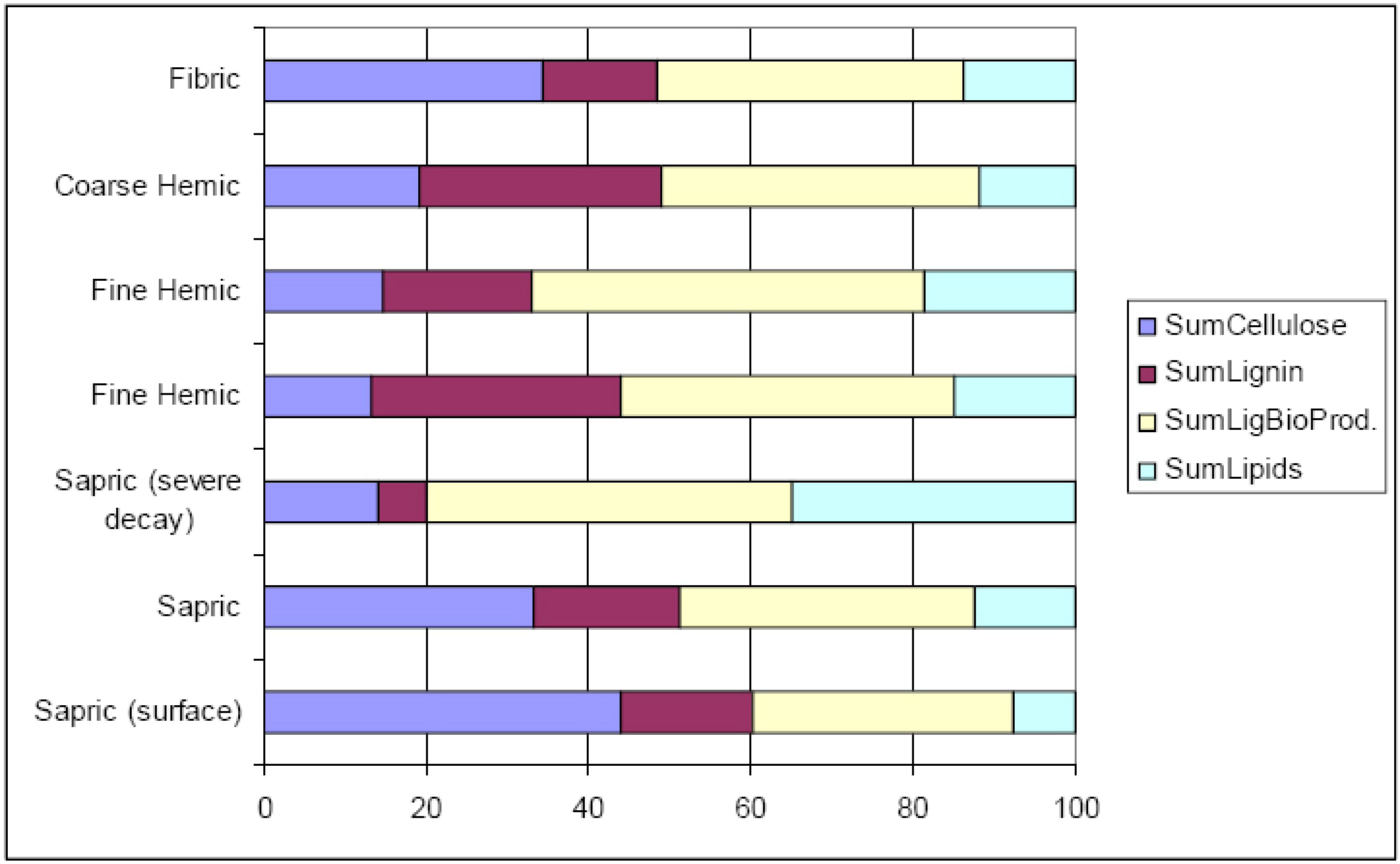

Figure 2. GC-MS data for Indonesian peat (Esterle and Ferm, 1994).

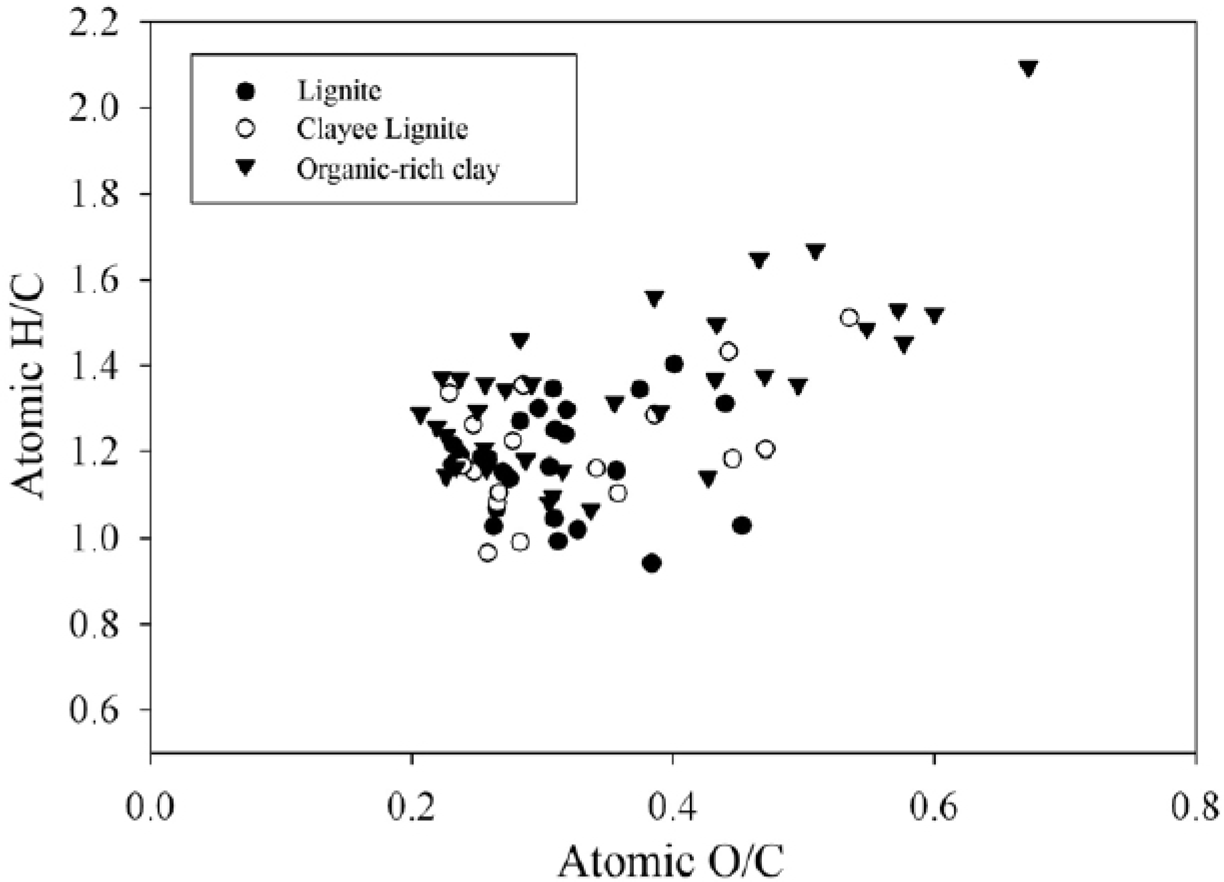

Figure 3- Atomic H/C vs. O/C for Eocene Claiborne Group lignites, Kentucky.

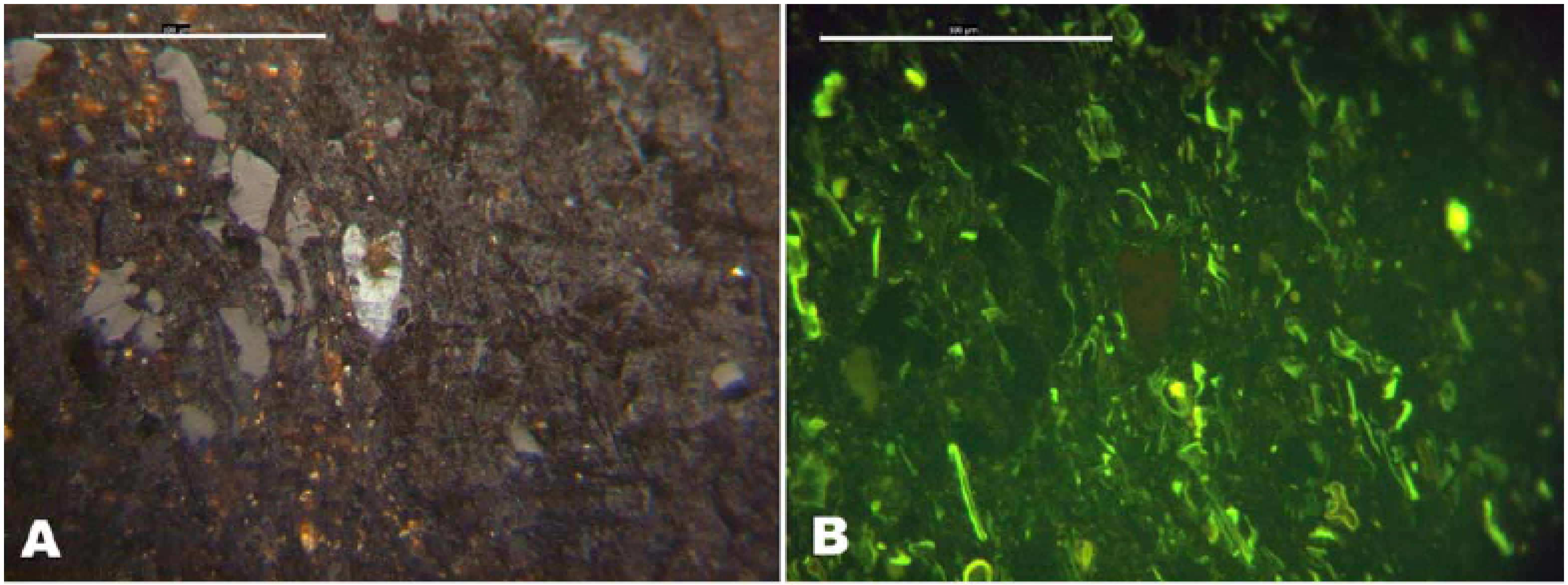

Figure 4 – Detrohuminite, Eocene Claiborne Group lignites, Kentucky.

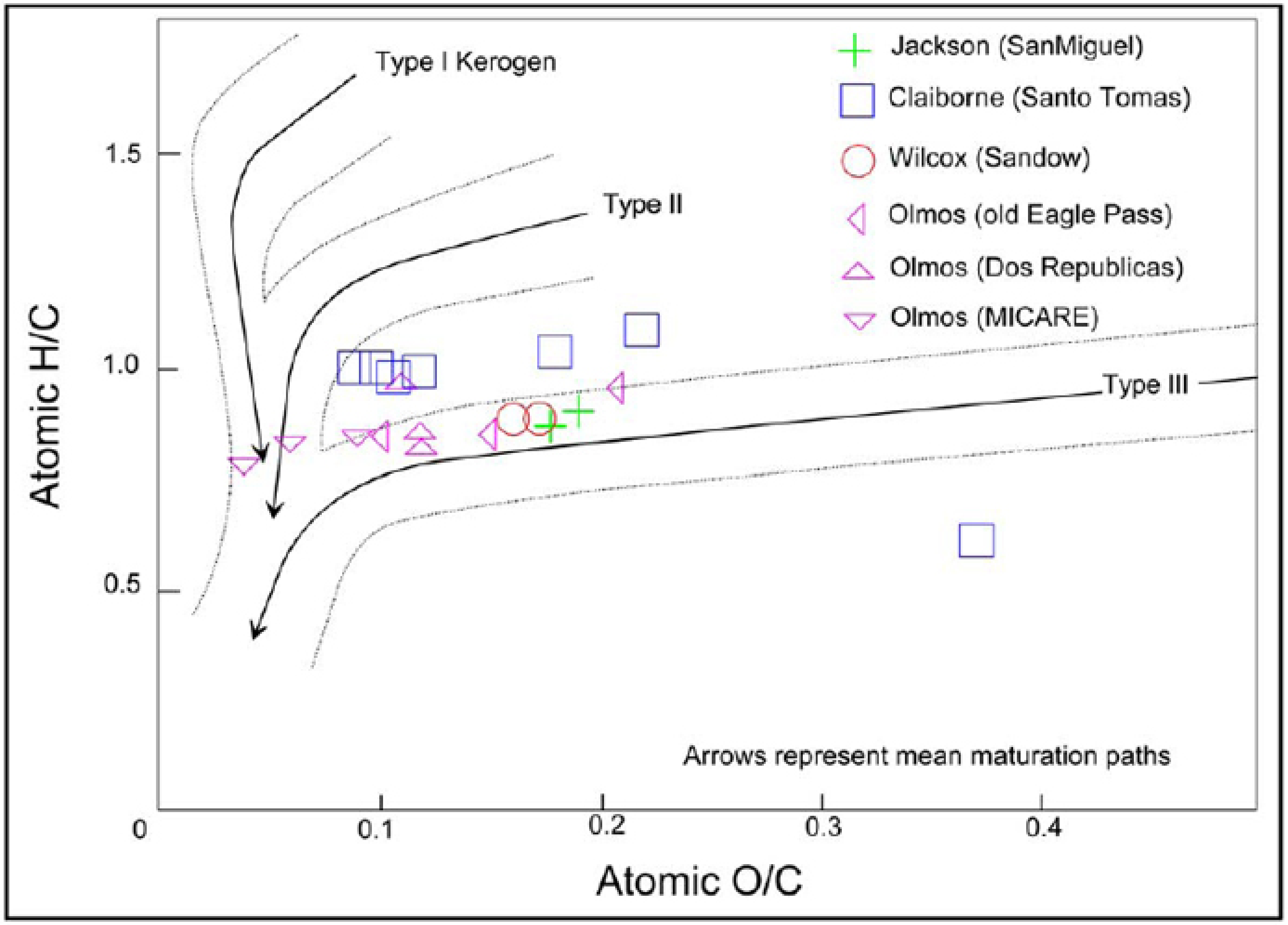

Figure 5 – Atomic H/C vs. O/C for Eocene Claiborne Group coals, Texas (SanFilipo, 1999).

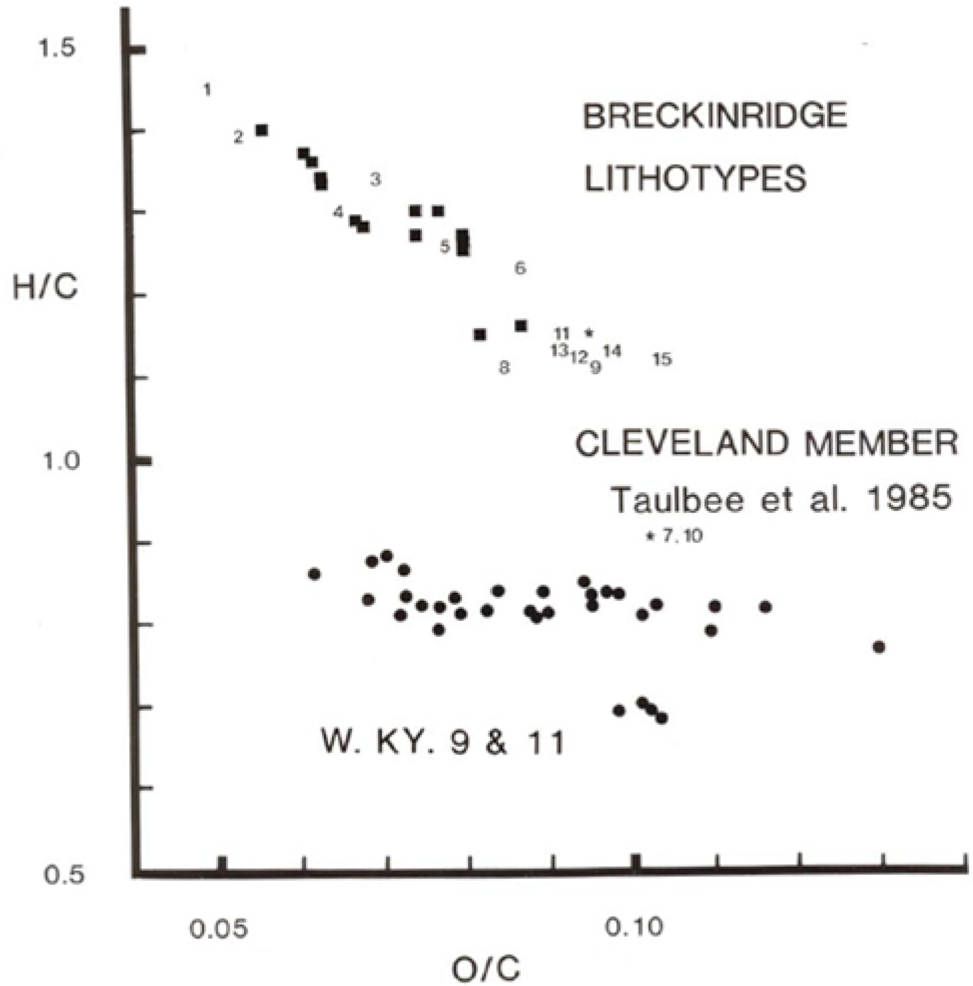

Figure 6 - Atomic H/C vs. O/C for lithotypes of the Pennsylvanian Breckenridge torbanite (solid circles); density-gradient-centrifuge-derived separates of the Devonian Cleveland member of the Ohio shale (numbered in order of increasing density); and whole channel and bench samples of the Western Kentucky No. 9 (Springfield) and Western Kentucky No, 11 (Herrin) coals (solid squares). All samples are from Kentucky.