IDENTIFICATION OF MACERALS IN LAKHRA AND CHAMALANG COALS

By

Shafqat Nawaz, Sumaira Kanwal, Usman Rahim and N.Sheikh*,Khurram Shahzad
Centre for Coal Technology, University of the Punjab, New Campus, Lahore

ABSTRACT

Microscopic examination of thin sections of coal, under reflected and transmitted lights, revealed some conspicuous entites of carbon which were called macerals. Based on difference in their characteristics, macerals were classified into three major groups: vitrinite, exinite, and inertinite including a number of subgroups.Vitrinites were found ideal for coking, exinites for pyrolsis and inertinites for combustion only.Keeping in view the above considerations, the present study was undertaken to identify the macerals in Lakhra and Chamalang coals to assess their importance in the light of macerals present in them. Lakhra coal was found to contain sporinite maceral which is an important subgroup of exinite. In reflected light it appeared golden yellow which is a main characteristic of sporinite as it is evident from the photomicrographs. Sporinite,if abundantly present in coal, is useful for gasification and liquefaction processes. The Chamalang coal has telinite maceral which is a leading subgroup of vitrinite. The photomicrographs, taken in reflected light show its structure and the colour compatible to the gennine telinite, which has good coking properties. This study supports the validity of Chamalang coal which contains telinite maceral and is being blended with imported coal at Pak Steel Karachi to produce good quality coke for use in the blast furnace for iron making.

Keywords Macerals, Petrography, Reflectivity, Maceral Photoimages

INTRODUCTION

Coal consists of two major classes of materials: 1,inorganic crystalline minerals 2,phytogenitic, noncrystalline carbon(Simon and Nisar, 1986). Earlier it was observed that carbonaceous part of subbituminous and bituminous coals possessed some bright bands due to separately accumulated vegetal matter during the coalification process. But such bands were not distinctly visible in coals of younger ranks and anthracites.These banded structures of coal or lithotypes were called macrolithotypes(Muller et al., 1990).

When a deep look into the structures of lithotypes was given through petrographic studies of this sections of coal, a complex mixture of fine organic constituents was observed and these constituents were called microlithotypes or macerals. In each rank of coal macerals were identified and were characterized by their general appearance like shape, structure, colour and reflectivity when viewed under petrographic microscope in reflected and transmitted lights(Huo et al., 1995;Winans and Crelling, 1984).

Petrologists identified a number of macerals in coals and divided them into the following three main groups(Speight, 1994) .

Vitrinite: It is also called huminite as it is rich in humic substances present in subbituminous and bituminous coals. It is medium reflected maceral and looks light grey in reflected and light orange in transmitted light. It possesses botanical structure and, due to its woody origin, it contains relatively more oxygen and has good reactivity.

Exinite: It is also called liptinite and contains a fair amount of hydrogen. It is composed of old metaspores, cuticles and resinous materials. It looks dark brown in reflected and transmitted lights.

* Corresponding Author: Dr. Naseer Sheikh, Centre For Coal Technology, University of the Punjab, Quid-e-Azam Campus, Lahore, Pakistan

Inertinite: It is also called inert or non reactive maceral. It contains more carbon and is mostly present in anthracites. It is characterized by cellular structure of wood showing intracellular spacings. It looks dark to light grey in reflected and light yellow in transmitted lights.

The above mentioned main groups have further been subdivided and their detailed description is given in the following Table(Speight, 1994). Apart from the subdivision given in the Table, more subdivisions are being reported in the literature.

Table -1: Subdivision of the Three Maceral Groups and Their characteristics

Maceral group	Macerals	Morphology	Origin	Appearance under microscope
Vitrinite	(i)Tellinite	Well preserved cellular structure	Humified remains derived from cell walls of trunks, branches, roots and leaves.	Dark to light grey in reflected and light orange in transmitted light.
	(ii)Collinite	structureless	Reprecipitated humid organic matter which filled the cell cavities.	Dark to light grey in reflected and light orange in transmitted light.
	(iii)Cutinite	Appendaged bands	Humified waxy coatings of cuticles, leaves, shoots and their stems.	Dark to light grey in reflected and light orange in transmitted light.
Exinite	(i)Resinite	Cell filling layers	Formed from plant resins and waxes.it has high hydrogen content present in lignite and bituminous coals.	Dark to light grey in reflected and light orange in transmitted light,medium reflectivity.
	(ii)Alginite	Fossil form	Fossil algae mostly present in boghead coals	Dark in reflected and light yellow in transmitted lights,low reflectivity.
	(iii)Cutinite	Fossil form	From leaves,spores,pollens	Grey in reflected and yellow in transmitted light.
	(iv)Sporite	Spores visible	From other castings of spores and pollens	Same as above
	(v)Fluorinite	Structureless	Lipids (fats, proteins and essential oils origin)	Same as above
	(vi)Bituminite	Structureless	Algal origin, bitumen related materials	Same as above
	viiLiptodetrinite	Structureless	Detrital form of exinite	Same as above
Inertinite	(i)Fusinite	Well defined cellular structure	Carbonized plant material, fossil charcoal like, derived from wood and leaf tissues.	White in reflected and opaque in transmitted lights, highly reflected
	(ii)Macrinite	Structureless	Oxidized gel material(humic mud)	White in reflected and opaque in transmitted lights
	(iii)Micrinite	Structureless rounded grains	Degraded and oxidized form of macerals during coalification.	Dark grey in reflected and yellowish brown in transmitted lights.
	(iv)Sclerotinite	Fossil form	Mainly fungal remains(in lignite and subbituminous coals)	Highly reflective, white in reflected and opaque in transmitted lights

Petrography

One of the most important contributions of petrography is the establishment of structures of macerals as well as the knowledge of their physical and chemical properties.

It may be pointed out that while describing the importance of coals in terms of carbon content only is misleading when there are several other important aspects especially the types of macerals present in coals and the physical and chemical properties of macerals(Stach et al.,1982).

The maceral groups or subgroups present in coal has a strong bearing on their effective utilization in conversion technologies such as combustion, carbonization, liquefaction and gasification, etc. For the production of synthetic gaseous and liquid fuels, coals with hydrogen-rich exinites are especially preferred. The low temperature carbonization or the coking process requires vitrinite macerals. Maximum tar production is possible only through exinites which contain an increased hydrogen content. The inertinite group macerals are hydrogen deficient and are not suitable for coking,pyrolysis and tar production. The inertinite group macerals are unreactive for coal conversion technologies and are good only for combustion(Fryer et al., 19750).

The object of the present petrographic study is to identify the macerals in Lakhra and Chamalang coals and to assess their effective utilization in the industrial sector. For carrying out the petrographic investigations, modern and sophisticated research aids have been used.

EXPERIMENTAL

COLLECTION OF COAL SAMPLES

Two representative bulk samples from Lakhra and Chamalang coal fields,each weighing 20kg,were collected with the assistance of Pakistan Mineral Development Corporation(PMDC). A brief description of coal deposits of the above referred coal fields is given below.

LAKHRA COAL: The total measured coal reserves of Lakhra (Sindh)are 1328 million tones(Energy Year Book, 2007). The average thickness of three coal seams is 1.5 meters. Presently the central seam is under production at an average rate of one million tonnes per year. The coal is mostly utilized in WAPDA power plant at Khanote (Sindh) (Ghulam Mustafa, 1986). The rank of coal is Lignite-A to Subbituminous-C.

CHAMALANG COAL: This coal field exists in Balochistan having an established reserves of 6 million tonnes(Energy Year Book, 2009). Its quality is comparatively better than the coals available in other locations in the province. It is partially used in Pak Steel, Karachi, by blending it with the imported coals. The rank of the coal ranges from High Volatile Lignite-A to High Volatile Bituminous-C.

Prior to petrographic study for identification of macerals, the quality of coal samples was assessed by proximate analysis(James, 2005). The results are given in the following Table.

TABLE-2: Proximate Analysis of Lakhra and Chamalang Coal Samples

Contents	Lakhra Coal(central seam)	Chamalang Coal(upper seam)
Moisture, %	19.93	4.62
Volatile Matter ,%	30.31	37.93
Ash , %	17.93	9.52
Fixed Carbon , %	27.51	44.46
Total Sulphur , %	4.32	3.47
Gross Calorific Value kcal/kg	4567	6591

SAMPLES FOR PETROGRAPHY

Petrography of coal is comparatively a recent development to characterize its constituents physically and chemically. Coal is an extremely complex heterogeneous and fragile, so the preparation of thin sections for petrographic study poses some problems. However, petrography of coal is now used to identify coal constituents, especially its organic entites,or macerals(Huo et al., 1995). From each lot of bulk samples, belonging to Lakhra and Chamalang, three lumps of 10-20 cm in size, were taken for the preparation of thin sections.

PREPARATION OF THIN SECTIONS

CUTTING: With the help of the cutting machine, the size of lumps were reduced to 5cm.A liquid resinous mixture of araldite and hardrer(5:1) was applied on the surfaces of all the cut-samples which filled the pores of samples and made them harder. Samples were further cut to the required size according to standard procedure(ASTM D2797, 2004).

GRINDING: The specimens were initially ground by hand using silicon carbide of grit size No.240, 320, 400, 800 followed by mechanical grinding on machine where all necessary steps needed for grinding were followed. The ground slices of specimens were cemented cold on glass slides with araldite-E.

POLISHING: Polishing was done in three stages. The first and second stage polishings were carried out in high speed polishing machine using silicon carbide grades, 500,1000,1200 (600mesh size) till no relief appears on the surface of specimens. Finally the polishing was done on velvet cloth, impregnated with alcohol(Speight, 1994).The possible thickness of thin sections required for examining under reflected light was obtained.

MICROSCOPIC EXAMINATION OF THIN SECTIONS

The petrography of coal-bearing strata is being increasingly used to solve many geological problems. The use of petrographic microscope allows for rank and facies determinations and to estimate the degree of genesis in coal more precisely and more quickly. However, for identification of macerals in coal, the petrographic microscope has played a significant role.

For the identification of macerals in thin sections of this study, Olympus Bx5I, high resolution petrographic microscope, was used. The image analyzer was attached with the microscope to get images. The microscope was used according to the operating manual.

The examination of thin sections was carried out in both direct reflected and polarized lights. The reasons for using exclusively reflected light is that the reflectance of various macerals, which is desired with required accuracy, is possible only by reflected light. Moreover, the opaque looking macerals are better examined in reflected light. For the study of thin sections under transmitted light, extremely thin sections of coal are required which are difficult to make. The microscopic images, therefore, were examined in reflected light with magnification of 100x, 200x, 400x and 800x(Hou et al., 1995).

RESULTS AND DISCUSSION

PETROGRAPHYOF LAKHRA- COAL THIN SECTIONS

The thin sections of Lakhra coal were prepared according to the procedure described earlier. Specimens were examined by Olympus-Bx51 microscope and photomicrographs were taken at magnification of 100x, 200x, 400x and 800x. The description of photomicrographs is given as under.

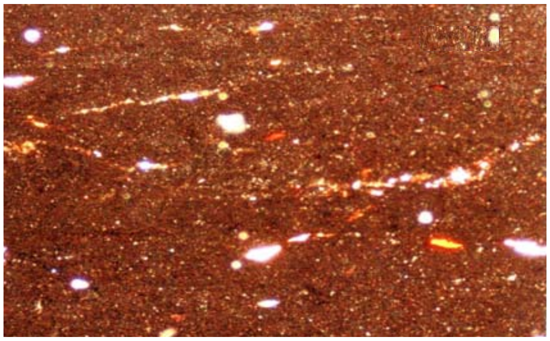

Fig. 1: Photomicrograph of Lakhra –Coal Thin Section under Reflected Light (100x)

The photomicrograph in Fig- 1 is a generalized view of the specimen at 100x in reflected light. The image shows a broad view indicating microstructures of scattered yellow pigments containing globular to oval shaped bodies which, in reflected light, appear reddish brown with darker cores and lighter peripheral margins, whereas the white bodies are gangue impurities like shale, sandstone and limestone, etc. The image also reflects amber resin flakes which are derived from resins as well as from balsams, latexes, fats and waxes. The main maceral is **sporinite** which is distinctly visible in right side of the lower part of the image in bright yellow colour.

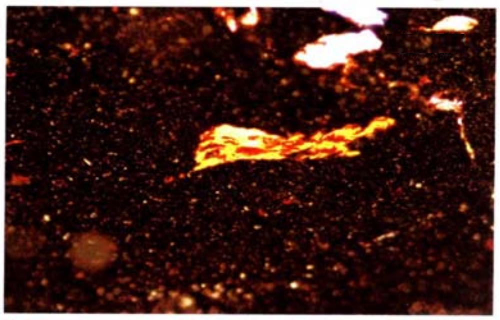

Fig-2:Photomicrograph of specimen of Fig1 taken in reflected light at 200x

Fig-3: Photomicrograph of Fig1 taken in reflected light at 800x

The photomicrographs in Fig-2 and Fig-3 have been magnified at 200x and 800x respectively so that the sporinite is seen on larger scales. The term sporinite is used to designate the skins of spores and pollens in lignites to subbituminous coals. Sporinite is by far the most important maceral of exinite(liptinite) group.

The exinite originates from relatively hydrogen-rich plant materials (e.g. spores, cutins, resins, waxes, balsams, latexes, fats and oils) as well as from bacterial degradation products of proteins, cellulose and other carbohydrates.

The structure shown in Fig-3 indicates maga and microspores which begin their existence in the sporangium of spores into a compressed pattern.

On close examination of the photomicrographs the sporinite maceral of exinite group may be identified based on its structure and yellowish colour (Gutjahr,1996). This enables some of its important physical properties to be recognized. For example, on polished surfaces of low rank coals the sporinite appears darker and in thin sections it looks brighter than vitrinite. The colour of sporinite is accordingly evident as golden yellow to golden brown as in Fig: 2 and 3. It may be pointed out that with increasing rank the yellow colour becomes darker and changes to grey.

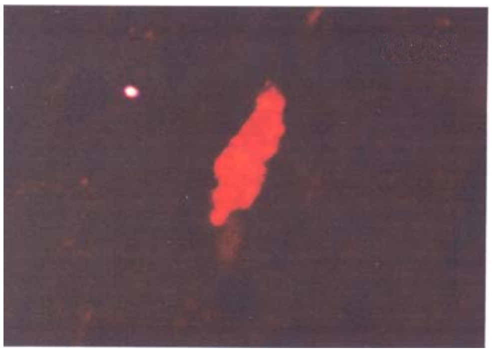

Fig-4: Photomicrograph showing woody material under reflected light(200x)

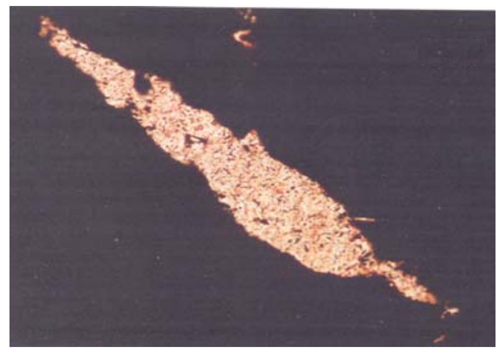

Fig-5:Photomicrograph limestone under reflected light (200x)

In fig -4 there is a red coloured image which indicates the remains of a woody tissue of plant (Davis and Spackman, 1964). This further confirms the maceral's main group of exinite (liptinite) to which sporite belongs as a sub-group.

In photomicrograph of Fig-5, there are yellowish stainings and at certain places these stainings are orange brown or light pinkish brown, which indicates the presence of limestone. The Lakhra coal formation consists dominantly of limestone.

In coalified residue of spores (in sporinite) has an aliphatic-aromatic skeleton without fatty acid anhydrides (Schapiro and Gray, 1960). When the coal containing sporinite is carbonized in Fischer aluminium retort, owing to its chemical composition, yields relatively more yield of tar.

PETROGRAPHY OF CHAMALANG- COAL THIN SECTIONS

The International Council of Petrologists has established the standard rules for petrographic microscopy which provides guidelines to identify macerals with respect to their appearance and colours in reflected light. Accordingly the thin sections of Chamalang coal samples were prepared and examined by Olympus-Bx51 microscope in reflected light. The observations are recorded as follows.

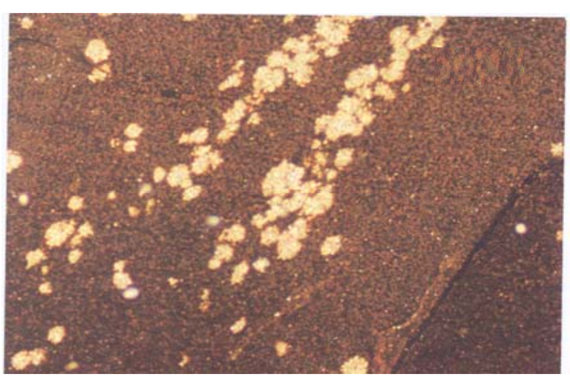

Fig-6:Photomicrograph of Chamalang coal Thin Section under reflected light (100x)

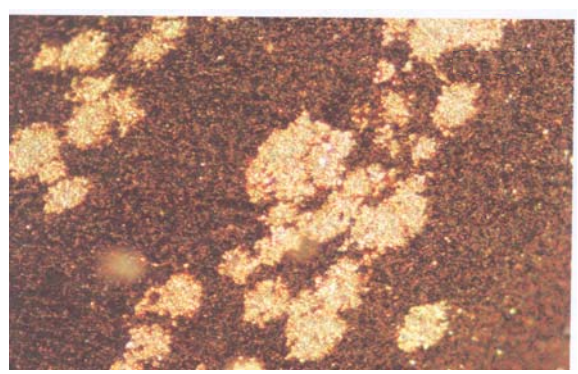

Fig-7: Photomicrograph of Chamalang Coal Thin Section under reflected light (200x)

The photomicrographs in Fig-6 shows a structure of Telenite which is an important member of subgroup of vitrinite also called huminite. This shows very small round and oval shaped bodies in brownish colour. Their cellular structures are derived from vegetal matter and their cell walls are called telinite, comprising tella that means tissues (Carpenter and Anne, 1988). Often its cell cavities are filled with subgroup collinite. In Fig-7, on the upper part of photomicrograph, the cell walls appear to be partially compressed which is exclusively a characteristic of telenite.

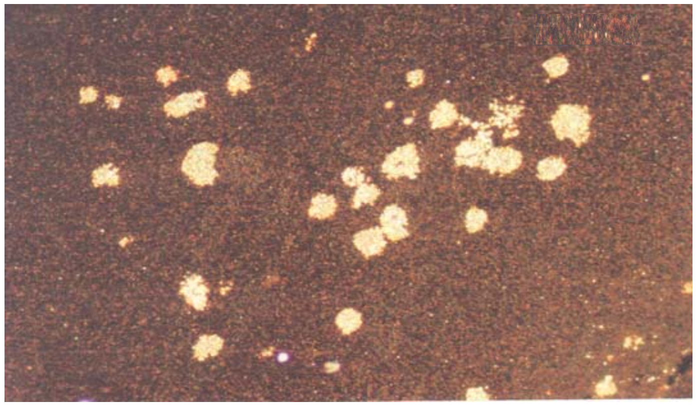

Fig-8: Photomicrograph of Chamalang-coal Thin Section under Reflected Light (100x)

In Fig-8, there are round yellow-coloured bodies showing false bright yellow colour with metallic luster.These are pyrite (FeS_2) grains and look different (brighter) in colour than telinite. The sample contained an appreciable amount of pyrite.

The main maceral as identified in Chamalang coal samples is **telinite** which is important subgroup of the major group vitrinite also called huminite. The macerals belonging to subgroups of vitrinite originate mainly from the humic acid formation of humic substances which are dark coloured compounds of complex composition. These compounds possess varying molecular weights, have aromatic nucleus and contain hydroxyl (-OH), and carboxylic (-COOH) functional groups (Bumhan and Sweeney, 1989). It is assumed that lignin is a precursor of vitrinite.

The brownish cellular structure derived from vegetal matter is visible in telinite ,which is particularly present in low rank coals. It is composed of various humins and consists of an aromatic nucleus surrouneded by a peripherial aliphatic groups(OH,COOH,CH_3). With increasing rank these perpherial groups are lost and aromatic nucleus becomes larger. Thus the oxygen content decreases progressively with increasing rank, but the hydrogen content remains almost the same in coals of low ranks.Chamalong coal mainly contains telenite of vitrinte group. The macerals of this group have better coking power (Palmer et al., 1990).

CONCLUSION

Lakhra-Coal: The Lakhra coal deposits of the Sindh province are the largest operational coal reserves in Pakistan. The rank of coal is Lignite –A to Subbituminous-C. It is low grade coal and contains fairly high sulphur content.It is largely used in WAPDA power plant at Khanote (Sindh).

The petrographic study of thin sections of Lakhra coal under reflected light reveals that the macerel **sporinite** is dominantly presnet in it. The sporinte appears yellow to reddish brown which is its main chrachterstic. The sporinite is an important maceral of exinite (liptinite) group which has originated from plant material such as spores, resins, cutins, waxes, fats and oils and also resulted from bacterial degradation products of proteins, cellulose and other carbohydrates.Sporinite is a better hydrogen-rich maceral and, owing to its chemical composition,it yields relatively more liquid and gasous products and its yield of tar is exceptionally high. The coal of Lakhra is low grade, containing high amount of sulphide sulphur and high ash forming impurities. The significance of maceral is therefore depressed until coal is fairly cleaned. The maceral may play a significant role when, the coal is extensively cleaned.

Chamalang Coal: The chamalang coal deposits are situated in Balochistan province. The coal is comparatively of better quality than those coals found in other locations of the province. The rank of coal ranges from High Volatile-A to High Volatile Bituminous-C.

The petrographic study of thin sections of chamalang coal, under reflected light has dominantly exhibited **telinite** maceral which belongs to vitrinite (huminite) group. The maceral telinite has cellular structure originated from vegetal matter like trunks, branches, stems and roots of trees. This maceral is relatively oxygen-rich and is mostly present in low to high subbituminous coals.

The macerals of vitrinite group especially telinite has better coking power. For that specific reason, Chamalang coal is largely sold to Pak Steel, Karachi, where it is blended with the imported high grade coals. The blended coal is subjected to carbonization process and a good quality metallurgical coke is produced for use as reducing agent in blast furnace where iron ore is converted to iron metal.

ACKNOWLEDGEMENT

The authors would like to extend their sincere thanks to Mr. Syed Abbas Sultan, Principal Scientific Officer and Miss Anjum Rashid, Senior Scientific Officer of Geology Department, Atomic Energy Mineral Centre, Lahore for providing all the necessary facilities alongwith their technical assistance for the preparation and microscopic examination of thin sections.

REFERENCES

ASTM-(2004), D 2797 (Preparing Coal Samples for Microscopic Analysis in Reflected Light) American Society for Testing Materials, Pheladelphia, USA pp. 296-298

Bumhan, A.K., JJ Sweeney(1989), " A Chemical Model of Vitrinite and Reflectance". Geochemica Acta Vol. 53, pp 2649-2657

Carpenter, Anne M (1988) Coal Classification: IEA Coal Research, London

Davis, A. and W.Spackman (1964), Fuel 43, London, pp 215-224

Fryer, J.F. et al (1975) "Proceedings of Symposium on Coal Evaluation", Sr.No. 76, Alberta Research Council, Edmonton, Alb, Canada

Ghulam Mustafa Ilayas (1986) "Coal Resources of Pak", Proc. I[st] Pak Nat. Coal Conf. Karachi p.281

Gutjahr,C.C.M. (1996) "Pollen Grains and Spores and their Application",Leidse Geol Meded 38, p.29

Huo,X. et al (1995), "Study of Some Coal Macerals" Int. J. of Coal Geol. Vol.27 No.1 pp 23-32

Hou,X. et al (1995) "Application of Imaging TOE-SIMS to Study Coal Macerals",Int .J.Coal Geol. Vol.27 No.1, pp 23-32

Ibid, Tables 4.6, 4.8, pp 89-91

James, S.(2005), "Hand Book of Coal Analysis", Willey & Sons. USA

Muller, J.F. et al (1990), "Advanced Methodoligies of Coal Characterization", Elesvier, Amsterdam, Chapter 18

Pak Energy Year Book (2007) Table 4-1, Ministry of Petroleum &Natural Resources, Govt. of Pakistan p. 71

Pak Energy Year Book (2009), Ministry of Petroleum &Natural Resources, Govt. of Pakistan, p. 81

Palmer, S.R. et al (1990), "Characterization of Coal Macerals", ACS Symposium Series No.429, pp 296-315

Simon,F.O. and Nisar Ahmad(1986), "Chemical, Physical and Mineralogical Characterization of Coal", Coal Resources of Pakistan, Proc.I[st] Pak.Nat.Coal Conf.Karachi pp 186-197.

Speight, J.G. (1994), "The Chemistry and Technology of Coal", 2[nd] Ed, Maceral Dekker, New York, p.88

Stach, E. et al (1982), "Text Book of Coal Petrology", 3[rd] Ed, Stuttgart, Berlin, Germeny pp 87-100

Schapiro, N. and R. J. Gray (1960) "Petrographic classification applicable to coals of all ranks": Proceed. Ill. Min. Inst

Winans, R.E. and T. C. Crelling(1984), " Characterization of Coal Macerals" ACS Publication