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THE TRANSITION FROM BITUMINOUS TO ANTHRACITIC COALS

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With reference to thin section techniques and the normal sectioning of coal the following comments have been made: "... the method fails with anthracites and other coals rich in carbon ..." (Seyler, 1925, p. 117) and "anthracite has failed to respond.." (Turner, 1925, p. 127). More recently, Plumstead (1957, p. 12) has stated: "... they can no longer be studied by transmitted light for the anthracite has lost transparency even in the very thinnest sections". These comments are very similar to many others made before and after the dates cited, principally by the European coal petrologists. There is no doubt that anthracite and semianthracites have presented great technological barriers to the thin section workers. Petrologic study of these higher rank coals has been sorely neglected when compared to the wealth of information developed for those coals lower in rank.

Recently, however, a technique has been developed at the Anthracological Laboratories of The Pennsylvania State University for the preparation of creditable thin sections of semianthracite and anthracite. The two most important factors which differ from previous methods used are the mounting medium and the extended preparation time. An epoxy resin (Biggs Bonding Agent R-313) is used and allowed to "cold-set". Allowing the resin to "set" without the use of heat lengthens the curing time but also minimizes the stresses and strains set up due to heating and cooling of the microscope slide, the mounting medium and the coal block. So-called standard techniques are employed for preparation of the coal surface, "cut-off", and removal of excess material from the slide. The mounting of the block (as previously mentioned) and the finishing operations are where variations occur. Fine finishing is carried out on a Belgian hone as would normally be done. After this step, hand finishing with erasers or corks dipped in cerium oxide or red rouge are used to bring the sections to completion. It is this last step that is very tedious and time consuming.

The thin sections of anthracite prepared to date are not of the high quality it is possible to attain when one works with bituminous and other lower rank coal. However it is possible to view many of the organic entities present under transmitted light. The anthrinoids, micrinoids and fusinoids are present and may be studied in considerable detail. Thus far no representatives of the "resinoid" or "exinoid" maceral groups have been encountered in a recognizable form.

Geology and many of the other scientific disciplines owe a great deal to William Morris Davis. His presentation of the concept of "structure-process and stage" is applicable in most fields. With special reference to coal and the evolution of plant materials to form peat, lignite, subbituminous, bituminous and anthracitic coals it is of particular significance. In all coal seams a particular set of constituents exists at each point in this progression. These materials are acted upon by a set of physical and chemical forces which act or have acted for a period of time. Thus we have structure - the materials at hand, process - the forces acting upon these materials, and stage - the time for which these forces have acted and the degree to which the constituents have progressed to produce the subject materials.

The original "structures" we have to work with, the progenitors of all the macerals, are the plant materials deposited in the original coal swamp. It is not the purpose of

this article to trace the evolutionary development of these plant materials through the various coalification stages, but to look more closely at the maceral relationships encountered in the high-volatile, low-volatile and anthracite coals. It seems evident that there are more macerals present in the medium- and low-volatile coals than there are in either those of high-volatile or anthracitic rank. This is at first surprising but evaluation of many hundreds of thin sections makes this apparent.

It has been generally felt that in the coalification series of peat to anthracite, that the degree of complexity of composition decreases with an increase in fixed carbon and a decrease in volatile matter. Overall this is true, but there is an increase in the total number of macerals present when medium- and low-volatile bituminous coals are examined. Figure 1 is an attempt to show this phenomenon diagrammatically. No exact numerical values have been determined for the macerals present in the peat, lignite and subbituminous coals. However they far outnumber those present in coals of higher rank.

The decrease of macerals as one goes from peat to the high-volatile bituminous coals is explained by the fact that certain maceral types present in the early stages of coalification are lost completely during the increase in rank of the coals. Also two or more macerals may combine to form one type higher in the coalification series. The sudden increase in numbers of entities present in the medium- and low-volatile bituminous coals poses certain problems. The series which has been approaching near homogeneity in anthracites and meta-anthracites here deviates in pattern. Why does the general picture of a decrease in numbers suddenly reverse its trend and show an increase, numerically and in complexity, about the medium- and low-volatile bituminous range? This increase in numbers and complexity of the macerals occurs primarily in the vitrinoid and exinoid groups. These substances have resisted change during "process" longer than the others and after the others are somewhat stabilized, they break down to form new constituents. These are recognizable by structure (and texture) and by color. Thermal decomposition data also support these differences in vitrinoids and exinoids (Spackman, Brisse and Berry, 1957).

Within the anthracites thus far examined, three maceral groups have been recognized - the anthrinoids, micrinoids, and fusinoids. There are three principal anthrinoids all of which are opaque in sections of normal thickness. In the exceptionally thin sections used in this study one of these macerals appears as a red to red-brown homogeneous material and the second is dull, drab brown and appears to be very homogeneous. A material which may have been derived from the semi-fusinite in a lower rank "stage" is also present and included in the anthrinoids.

The fusinoids are represented by fusinite only, and this material occurs in masses which appear either lens-shaped or round. Certain of the masses are similar to those which have been identified as sclerotia or sclerotinite by Stach (1934, 1956a, 1956b) and as resin rodlets by Schopf (1939) and Kosanke and Harrison (1957). Micrinite is the only micrinoid encountered so far and it occurs principally as very finely divided stringers of opaque matter in the red anthrinoid.

The use of thin sections in anthracite petrology and petrography is not expected to replace the use of polished surfaces but it has been shown that they should be further employed to gain valuable supplemental data for polished surface work and that they can add greatly to our knowledge of the coalification series and the problems of coal genesis. By looking at coal with the "structure, process and stage" concept always in mind, we can more adequately evaluate this organic sediment.

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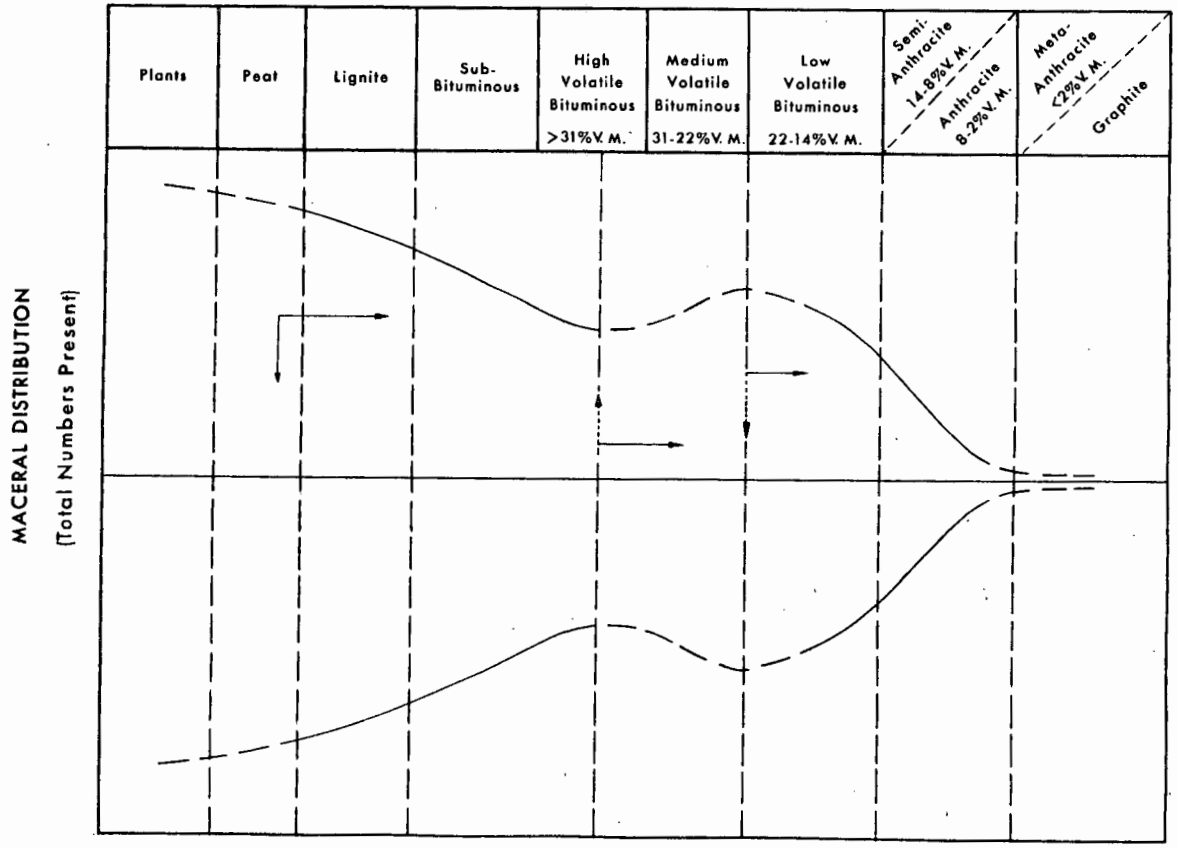

MACERAL CONTENT AND COALIFICATION SERIES

Figure 1