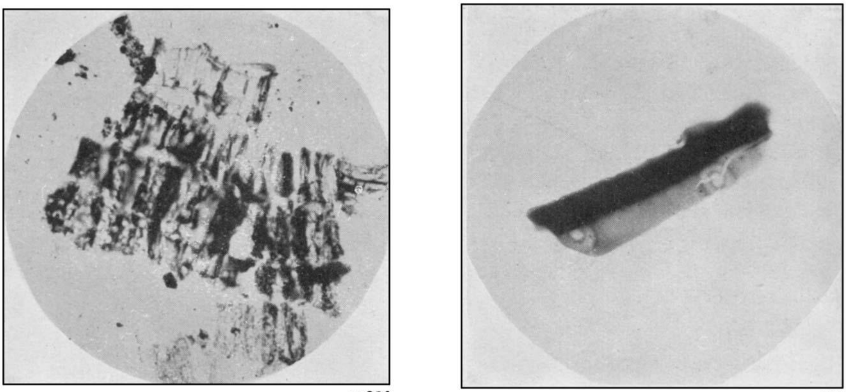
CLXXXII.—*Resins in Coal. Studies in the Composition of Coal.*

By Wilfrid Francis and Richard Vernon Wheeler.

We have shown (J., 1925, **127**, 112) that bituminous coal consists essentially of ulmin compounds in which morphologically organised plant-tissues, that have escaped ulmification, are dispersed. The ulmins, when first formed as the products of mouldering decay of vegetable matter, are characterised by ready solubility in alkaline solutions, but their derivatives, in the condition in which they normally exist in bituminous coal, are insoluble. Solubility in alkaline solutions can, however, be conferred on the ulmin compounds of bituminous coal by such mild oxidation as is afforded by treatment with air at low temperatures (up to 150°) or with hydrogen peroxide. The soluble ulmins so produced, which we have termed "regenerated" ulmins, are not identical in character with the insoluble ulmins in newly-won bituminous coal, for the external groupings of the molecules are modified during oxidation, the more easily detached being eliminated to form simple oxygenated compounds, with the substitution of carboxylic groupings which render the residue definitely acidic in character. The nuclear structure, however, remains unaffected. This nucleus we have shown (J., 1925, **127**, 2236) to be built up of compact systems of benzenoid groupings connected together by heterocyclic structures, such as pyrrole and furan or their derivatives.

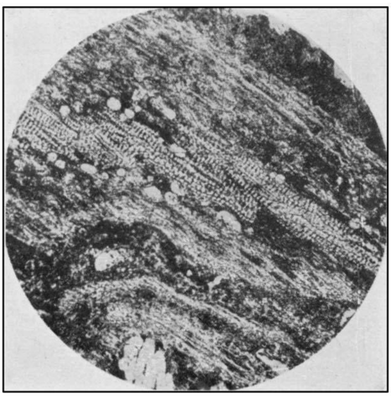
The bulk of bituminous coal consists of ulmins having molecular structures of this character. In banded bituminous coals, such as constitute the majority of British coals, the dull (durain) bands contain a proportion, usually between 20 and 30%, of morphologically organised plant entities, amongst which spore exines and cuticles predominate, that have undergone but little change from their original condition during the processes of decay suffered by the accumulations of plant material from which the coal was formed. Of the bright portions of coal, the clarain contains but small proportions, up to about 5%, of such plant entities, whilst the vitrain contains none.

In our previous papers we noted that, for the sake of simplicity, the existence in coal of natural plant substances devoid of morphological organisation, such as "resins," could be ignored, but expressed the intention of dealing with these substances separately. In order to do so, it is necessary for us to enlarge on the statement, contained in a footnote to our paper on the constitution of the coal ulmins (*loc. cit.*, p. 2236), regarding the character of vitrains; for the



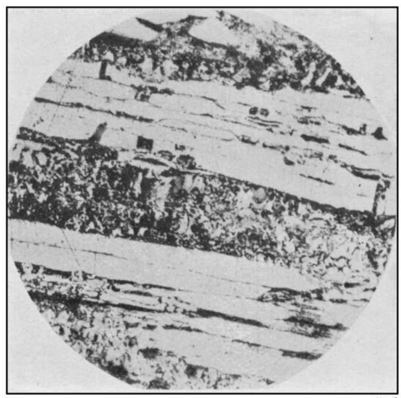
× 330 × 330

Fig. 1.



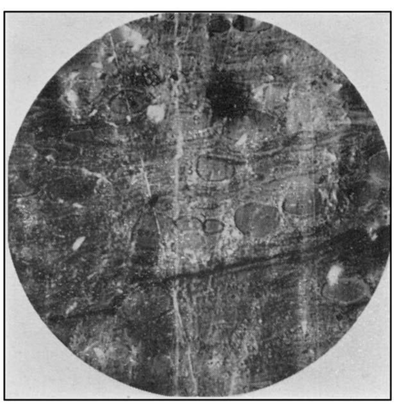
× 130

Fig. 2.



× 130

Fig. 3.



× 150

Fig. 4.

[*To face p.* 1411.]

existence of resins in a bituminous coal is best revealed in the vitrain portion.

The vitrain portion of a banded bituminous coal has for long been considered by British investigators to be essentially structureless, having been so qualified in Stopes's original descriptions of the banded ingredients of bituminous coal (*Proc. Roy. Soc.*, 1919, *B*, **90**, 470), based largely on an examination of transparent sections. Partly through the use of a new method of examining, by reflected light, coal surfaces that have been polished and etched, and partly as the result of the remarkably fine technique for the preparation of transparent sections of coal developed by Dr. R. Thiessen, of the United States Bureau of Mines, who has been good enough to prepare for us sections of a number of specimens of vitrain from British coals, it is now realised that a completely structureless vitrain, if it exists at all, is a rarity.

A description of the structures to be observed in most vitrains is reserved for another communication. It will suffice here to state that, in all of the many examples of vitrain that we have examined, the appearance of plant cells, usually derived from cortical tissues, can be disclosed. We purposely refer to the "appearance" of plant cells, because these structures cannot be separated from the coal mass intact and preserved, as can the cuticles and spore exines, and it is clear that, being ulmins, they are pseudomorphs of the original structures.

For the work described in this paper, vitrain from the Hamstead coal, which we have used for much of our previous work, was chosen because its oxidation by hydrogen peroxide could readily be controlled. During a carefully regulated oxidation of Hamstead vitrain, the soluble "regenerated" ulmins being removed from time to time by means of dilute sodium hydroxide solution, it was found that, when but little residue remained, the particles began to assume distinctive shapes. Some of the particles had the appearance of fibre cells, whilst in a few the shapes of tracheids, showing bordered pits, could be observed. All such shapes were, however, transient, disappearing as the ulmins dissolved. Nevertheless we were able to secure examples and retain them long enough to photograph them under the microscope. Some are reproduced in Fig. 1.

The fragments to which, from the point of view of the present paper, the greater interest attaches, were dark-coloured and elongated. They were usually ribbed along their major axes and had clean-cut ends. On persisting with the action of hydrogen peroxide, followed by treatment with sodium hydroxide solution, these fragments became gradually lighter in colour and finally, when all the ulmins had been removed, appeared as yellow rods varying in length up to 0·02 inch. Their diameter was about one-tenth of their length.

From their general character and from the cellular appearance of the ulmin material surrounding them, there seems little doubt but that these rods were resin inclusions. A number of them were collected and extracted in a Soxhlet fat-extraction apparatus with chloroform, in which they were almost completely soluble, when a dark yellow semi-solid extract was obtained. The analytical results (Found : C, 80·6; H, 10·3%) are consistent with the assumption that the material was a resin.

Confirmation of the suggestion that the resin rods existed in this sample of Hamstead vitrain in the position that they had occupied in the woody tissues from which the vitrain was formed is obtainable from photomicrographs of portions of the same sample of vitrain as was used for the oxidation experiments, polished and etched with chromic and sulphuric acids. Two such photographs are reproduced in Figs. 2 and 3, the magnification in each instance being 130 diameters. In Fig. 2, the surface is at right angles to, and in Fig. 3 it is parallel with, the cell-walls. The resin inclusions appear as circular patches in Fig. 2 and as rods in Fig. 3.

The cellular structure that abounds in vitrain—in the present example it is of xylem—can be clearly seen in the photographs, and it may well be asked how such structures could have escaped notice. Although they are readily rendered visible by polishing and etching a vitrain surface, a method of examination that has but recently come into use, the structures are difficult to detect in a transparent section viewed by transmitted light, because they are not outlined on the transparent reddish-brown background by a contrasting colour, but are faintly visible (and then only when the section is exceedingly thin and well illuminated) by reason of slight differences in shade. For example, a photograph of a section (× 150) of the same sample of vitrain as was used for Fig. 2 is reproduced in Fig. 4. The circular patches so noticeable in Fig. 2 can be recognised, but no organised structures can be detected.

We are indebted to Miss M. M. Evans, of the Fuel Research Board's staff, for the preparations illustrated in Figs. 2 and 3, and to Dr. R. Thiessen for that illustrated in Fig. 4. Our thanks are also due to the Safety in Mines Research Board for permission to publish this paper.

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