Some Geological Aspects of Recent Research on Coal*

By Prof. H. G. A. Hickling

TYPES OF COAL AGGREGATE

IN coal, as in other fragmental rocks, size is the great sorting factor. The dominating component, vitrinite, exists for the most part in fragments much larger than those of any other component except fusain. It follows that as the average size of the particles in any coal aggregate decreases, so the proportion of vitrinite usually becomes less, while that of spores, cuticles, resins, fragmented fusain and residuum becomes greater. This introduces an important element of order where there might have been almost complete chaos.

Complete gradation from the brightest coals, consisting entirely of large fragments of vitrinitised tissue—that is, of vitrain lenticles only—through every stage of decreasing particle size, decreasing vitrinite content and decreasing lustre, to the most finely granular dull aggregate is to be expected and is easily found. But in most seams there is a small proportion of bands ('durain') which are unmistakably quite without lustre, and these are sharply separated from the 'bright' coal ('clarain' and 'vitrain'), even though the lustre of the bright bands may vary widely. The distinction of the two types of aggregate clearly corresponds to some difference in the mode of accumulation.

The really dull bands are usually (though not necessarily) characterised by a very much higher content of ash than the bright coal, and this excess always consists of a very fine clay which must have been water-borne. Both durain and clarain are of variable composition, and the one may shade into the other though they are commonly somewhat sharply separated. The clarain, however, with its dominating vitrinite constituent, tends to comparative uniformity of composition, while the durain may be far more varied. A rich content of spores, cuticles or resins may make the durain conspicuously rich in hydrogen; while a dominance of residuum, or a high content of fragmented fusain, may have the opposite result. It is the variable part of the coal.

RANK OF COALS

From the geological point of view, the greatest contribution which is made by the microscope to the study of coal is, that it enables us to determine definitely whether the difference in quality of two coals can or cannot be attributed to original

difference of composition. If they can be seen to consist of entirely similar plant materials in a similar state of preservation, then any considerable difference in quality must be attributed to some other factor. Conversely, we may compare the quality of coals which are visibly composed of different materials, and find what are the constant differences between them. The differences due to plant ingredients and mode of origin define the *type* of coal; those due to subsequent alteration denote the *rank*.

COMPOSITION OF COAL COMPONENTS

In common with most vegetable substances, coals consist mainly of carbon, hydrogen and oxygen, and as the first step in the discussion of this problem we may inquire how the proportions of these constituents vary among the different plant materials which may be isolated from any single piece of coal. The vitrinite is of very uniform composition. The group of cuticles, spores and resins is notably high in hydrogen, but is not exceptional in the ratio of carbon and oxygen. Any fusain present will be very deficient in both hydrogen and oxygen. The chemical composition of the residuum needs further investigation; the indications are that it is usually a little deficient in hydrogen and oxygen, but not to such an extent as in the case of fusain. The outstanding fact is that the different components vary strikingly in their hydrogen content (from about 3.5 per cent in fusain to 8.0 per cent in some spores), while only in the case of fusain is there any notable variation in the oxygen.

Now, if we take a very large number of representative analyses of lignites and bituminous coals (but exclude for the moment anthracites and cannels) we shall find the limits of variation of the chief constituents to be approximately as follows: hydrogen, 4.5–6.0 per cent; carbon, 65–90 per cent; oxygen (varying in almost exactly complementary proportion to the carbon), 30–5 per cent. We see clearly that the whole variation of hydrogen content is well within the range observed among the different plant constituents in a single piece of coal. But the observed range of oxygen content in different coals is, on the contrary, many times greater than could be produced by any known variations of the plant constitution. It is this difference of oxygen content, in fact, which chiefly denotes the *rank* of the

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coal, distinguishing the lignites, bituminous coals and anthracites.

A very significant feature of this variation in rank is the fact that it is *continuous* throughout its long range and the significance of this continuity is emphasised in an interesting way by the work of Prof. Bone and his colleagues, who have shown that the proportions of the different types of organic compounds present in the coal vary progressively throughout the series.

SIGNIFICANCE OF RANKS

The thesis towards which all my remarks have been preparatory is that the rank of a coal is the measure of the alteration in composition which the deposit has suffered in consequence of the rise of temperature and increase of pressure resulting from its burial in the crust.

What do we know of the relation between the rank of coals and their distribution in the rocks?

The fact which appears to me to establish most clearly that change of rank must be caused by some geological factors is its areal distribution. In every coalfield where substantial variation of rank has been noted and examined, the rank of any given seam is found to change *progressively* as it is followed across the field. If the variation be plotted on a map by means of lines representing volatile content, carbon content, or any suitable measure of rank, these lines are found to be arranged in an orderly pattern and—this is the important point—the same pattern is repeated by each seam within the area. Wherever the rank of one seam is increased, there also is that of the others. Whatever cause has affected one has affected all.

Valuable light is shed on this matter by the detailed information concerning the composition of many of our own coal seams and their variation which is being accumulated by the National Fuel Survey. Many of the seams examined, particularly in Northumberland and Durham, show large changes in rank as they are followed across the coalfields. Some of the seams are notably 'bright' coals, with a relatively high hydrogen content; others contain a larger proportion of durain and (commonly) a lower percentage of hydrogen. A careful comparison of the analyses shows clearly that the seams which are high in hydrogen retain that peculiarity regardless of change in rank, while those which are low remain low. The chemical evidence supports that provided by the detailed examination of the physical peculiarities of the seams, and the cumulative evidence leaves no room for doubt that in these instances the change of rank is quite independent of the original constitution of the seams.

HILT'S LAW

The simplest and most familiar evidence of a relation between rank and geological conditions is Hilt's law: that, in any single vertical section, the deeper seams are of higher rank than the upper seams. Apparent failure of the rule in some cases is doubtless due to the fact that original differences between seams may affect their present composition to a greater extent than small differences of depth. But when the differences of depth are substantial, exceptions are rare.

The value of Hilt's law lies, first, in the fact that it is unambiguous in its significance, and, secondly, in the fact that since we know something of the increments of temperature and pressure which correspond to given differences of depth, and can compare these with the changes of rank produced, it gives us the data necessary to reverse the process, and to consider the rank of coals as an indication of the temperatures and pressures to which they have been subjected. The temperature increments are clearly so small that most geologists have been inclined to attribute the effects mainly to pressure. It is impossible to discuss this matter within the limits of this address, so it must suffice merely to refer to the experimental work, which has shown how readily coal, even in its present condition, yields volatile products at very moderate temperatures, and to the fact that in the effects of igneous intrusions we have a series of beautiful natural experiments in the alteration of the rank of coals by heat alone. In some of these natural experiments the resultant effects on the coal appear to be in every respect analogous with the ordinary changes of rank; in others they are obviously different. In the latter instances it is not difficult to see that the results are due to the rapid application of somewhat considerable increments of temperature. There appears to me to be quite good evidence to show, on the contrary, that in those cases, in which considerable changes of rank of the normal type have been produced, the total increments of temperature have been quite small.

If it be true that the rank of coals has been determined mainly by the depths to which they have been buried, then it is natural to look for some relation between the varying rank of any seam and its present depth below the surface, or to relate the variation to axes of folding. Much has been written on this subject, and completely contradictory conclusions reached. But this is to be expected. The coal can only indicate the *maximum* temperature or pressure to which it has been subjected, since change of rank is almost certainly an irreversible process; decrease of temperature and pressure will not restore it to its former level. Now a little reflection will show that, after the completion of the coal-bearing series, the most

general result of subsequent folding will be elevation and denudation, leading to a decrease rather than an increase of load. In so far as this is true, the folding will not be reflected by any variation of rank; while, on the contrary, any circumstance which does lead to a further increment of temperature will leave its mark. Later burial of the whole series below an uncomformable cover may lead to a change of rank in the deeper parts of the seams, while leaving the upper portions untouched. The time factor, moreover, can by no means be left out of account. Geo-isotherms creep with exceeding slowness, even in terms of the rate of sedimentation and denudation. The duration of burial as well as its depth is therefore material. In fact, the whole sequence of events which have determined the maximum temperature and pressure reached at any point must have been much too complicated to be readily decipherable from the present disposition of the rocks.

In all these complications, however, one cardinal

principle remains. At any given place, both temperature and pressure must always have increased downwards—apart, of course, from the influence of igneous intrusions. So, while the interpretation of the lateral variation of rank is involved in many complicating factors, Hilt's law remains as a simple and significant sign. Even in this case the significance is liable to be obscured by the variation of the original coal substance of the different seams; but the technique of the microscopic study of coal has now reached the point at which, I believe, the effect of this factor can be almost completely assessed and eliminated. If this be so, then we are in a position to use coal as a geological thermometer—or, perhaps, combined thermometer and barometer—and we may set about calibrating it by means of a thorough study of Hilt's law and of the effects of igneous intrusions. But we must never forget that the thermometer has one peculiarity—it is a maximum thermometer only.

Obituary

Prof. Sylvain Levi

THE death is reported from Paris of Prof. Sylvain Levi, France's most distinguished orientalist, which took place suddenly on October 30, at the age of seventy-two years.

Sylvain Levi was born in Paris on March 28, 1863. From an early age he applied himself to the study of oriental languages, especially those of China and Tibet, and in 1886 he was appointed a lecturer in the *Ecole des Hautes Etudes*. He was a special lecturer in Sanskrit in the Faculty of Letters of the University of Paris from 1889 until 1894, when he was appointed to a chair in the *College de France*. At the time of his death, he was president of the *Societe Asiatique* and of the section of religious studies in the *Ecole des Hautes Etudes*. Among other honours he was an officer of the *Legion d'Honneur* and an *Hon. Litt.D.* of the University of Calcutta.

Lévi had travelled frequently and far in the East to further his researches, applying himself deeply to the study of epigraphy, manuscripts and art, notably in China, Tonkin, India and Nepal, spending three years in the last-named country. On several occasions he held temporary appointments in Asia, at one time being a tutor in Sir Rabindranath Tagore's school at Santiniketan at Bolpur, Bengal, and later in charge of the Franco-Japanese Institute at Tokyo.

Although Levi's approach to oriental studies had been through linguistics, his outlook and interests were never bounded by the limitations of the philologist or the purely literary scholar. His wide knowledge of eastern iconography, his sympathetic under-

standing of Eastern art, and his profound study of Buddhism, gave him an insight into the strength as well as the weaknesses of Indian culture, tradition and character, such as have been possessed by few European scholars. It was this quality, perhaps, more than any other, that gave Levi his position of authority and influence among British orientalists, to whom, indeed, he was perhaps more closely akin than to the members of the German school of orientalists of his day. He was continuously in close touch with the Royal Asiatic Society and the India Society; and it is said that it was largely owing to his advice and his evidence before the committee, of which Lord Reay was chairman, that the School of Oriental Studies of the University of London was founded.

Among Levi's more important works, apart from a large number of valuable contributions to the journal of the *Societe Asiatique* and other specialist publications, are a study of the Indian theatre (1900), monographs on Nepal (1905-8), "Buddhachariya", an epic life of the Buddha by Asbaghosha, a dictionary of Buddhism from Chinese and Japanese sources, and two books on India, which appeared in 1925.

WE regret to announce the following deaths:

Prof. Jakob Schetelig, professor of mineralogy and geology in the University of Oslo.

Dr. Eugene W. Shaw, chief geologist of the Iraq Petroleum Co., formerly of the U.S. Geological Survey, on October 7, aged fifty-four years.