ON LOPINITE, A NEW TYPE OF COAL IN CHINA

By C. Y. Hsieh§

With 2 plates & 2 text figures

CONTENT

1. Introduction

To the east of Nanchang, the capital of Kiangsi Province, there crops out a continuous belt of Permian coal series[1] trending approximately in the direction from N. E. to S. W. Broadly speaking, this coal belt forms a synclinal structure, though in detail it is much more complicated, as folding, faulting and perhaps overthrusting have all played important rôle in its construction. The syncline pitches towards S. W., so that the outcrops tend to close in a northeasterly direction as can be seen from the accompanied sketch (Fig. 1). The extent of the coal field is limited by different formations at different places; in Chinghsien, for instance, the coal series lies directly above a Permian limestone,

§ Prof. at the National University of Peking, and Geologist of the Geological Survey.

1 The geological occurrence of the coal seams in Loping, Poyang, Yükan & Chinhsien districts is largely compiled from a report on the Polo Mining Co. (1925) by C. C. Liu, several unpublished reports of Dr. W. H. Wong, Messrs. L. F. Yih & C. Y. Hsieh, and a published report of H. C. Tan. (Bull. G. S. C. 14, 1930).

while at Yükan and Loping, it is usually in fault contact with a phyllite formation of older Palæozoic age.

The thickness of the coal measure varies from 250-400 m, the maximum thickness being found chiefly in the Poyang-Loping districts. It is composed essentially of an alternation of sandstone and shale, together with, as at Mingshan in Loping, several layers of limestone. Only one principal coal seam varying

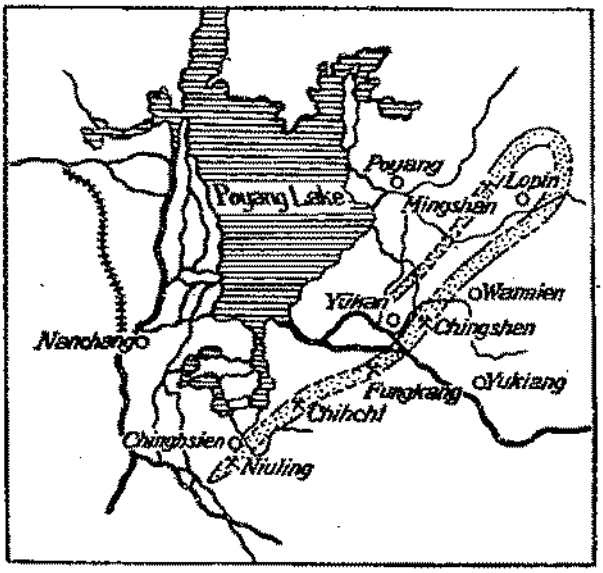

Fig. 1. Sketch showing the distribution of coal-bearing area in Loping, Poyang, Yükan and Chinhsien districts, N. E. Kiangsi. Scale 1:2,100,000.

from 3-10 feet or more in thickness is now worked, though several minor coal seams mostly unworkable occur also both above and below the principal one. At Mingshan the most famous coal mine in Loping district, coal seams were reported to be quite regular and persistent, whereas in other places there shows usually great variation in thickness. The topography of the region is characterized by rolling hills of low relief, a feature indicating late mature erosion.

Now the interesting thing which makes the topic of the present paper lies in the particular nature of the coal which is so remarkable that it should form a special type by itself. It is a kind of coal exceptionally rich in volatile matter which may amount to 60% or more and in some cases it may nearly double the amount of the fixed carbon. For this reason, in the classification of Dr. Wong[2] it has been taken to be a liguitic bitumite or lignite, similar to the coals of Fushun, Pataoho, Hsinchiu etc. Its remarkable nature, however, was also noted by Dr. Wong as can be seen from the following statement: "The Loping coal although very low in carbon like the younger coals is remarkable by its low moisture content, a feature which seems to be special to the Palæozoic coals." In another paper[3] Dr. Wong added: "The Permian coal of Loping constitutes a special type found in several other fields in Yangtze valley, for instance, in Yükan of the same Kiangsi Province". For reasons to be given below, this coal from Loping can never be called a lignite; neither could it be classified among the ordinary bituminous coals. As a matter of fact it constitutes a special type that has not yet been previously described, and accordingly a new name, the *Lopinite* is herewith proposed.

The following is a discussion of this new type of coal from chemical, microscopical and genetic points of view.

2. Proximate Analyses

The proximate composition of the Lopinite and its allied coals is listed in the following table (Table I):

There are altogether 14 analyses of the Loping coals made by different analysts based upon samples of widely different localities. Consequently harmonious results are not to be expected; yet on the whole the different analyses all show a constant and remarkable feature i.e. extremely high in volatile matter and low in moisture. There are 11 out of 14 analyses in which the

2 Wong, W. H. Classification of Chinese coals—Bull. Geol. Surv. China, No. 8, 1926, p. 52.

3 Wong. W. H. Coal Composition in triangular diagram—Bull. Geol. Soc. China Vol. 6, No. 1, 1927.

TABLE I. PROXIMATE ANALYSES OF LOPINITE & ITS ALLIED COALS.

No.	Locality	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Calorific power (Cal.)	Spec. gravity	Ash-Free-Basis Moisture	Ash-Free-Basis Volatile matter	Ash-Free-Basis Fixed carbon	Analyst
1.	Loping	0.47	62.73	33.08	3.72	2.06	8015	1.25	0.49	65.15	34.36	Miss Hung, Geol. Surv. China
2.	,, , S. district	0.47	47.15	42.05	10.35	3.333	7422	1.30	0.52	52.60	46.90	Yawata Iron Works, Japan
3.	,, ,,	0.93	35.11	37.75	26.21	5.801	5886	1.54	1.26	47.60	51.20	,,
4.	Tungchuncheng, Loping.	0.31	45.94	40.15	13.60	2.585	7142	1.33	0.36	53.20	46.50	,,
5.	,, ,,	0.43	53.71	38.06	7.80	3.874	7748	1.25	0.47	58.20	41.40	,,
6.	,, ,,	0.41	48.53	40.34	10.72	2.679	7393	1.31	0.46	54.40	45.10	,,
7.	Yungwulhang, ,,	1.74	16.40	16.90	64.96	5.467		1.70	4.97	46.80	48.35	,,
8.	,, ,,	0.56	50.25	39.15	10.04	2.481	7321	1.26	0.62	55.90	43.40	,,
9.	,, ,,	0.65	51.21	42.89	5.25	3.207	8130	1.25	0.68	54.00	45.20	,,
10.	,, ,,	0.56	44.14	41.02	14.28	2.228	7014	1.33	0.65	51.50	47.90	,,
11.	,, ,,	0.20	50.17	36.87	12.76	4.49	7418	1.32	0.23	57.60	42.30	,,
12.	,, ,,	0.47	47.68	44.17	7.68	2.214	7631	1.27	0.51	51.70	47.90	,,
13.	,, ,,	0.72	36.65	43.10	19.54	2.784	6318	1.44	0.89	45.50	53.50	,,
14.	Pulo Co., Loping.	1.00	50.90	39.00	9.10	4.83			1.10	56.00	43.00	Hanyang Iron Works
15.	Niuling, Chinghsien.	0.24	38.16	48.63	13.36		6868	1.34	0.26	43.80	55.90	Chem. Lab. Ministry Agri. & Commerce
16.	Kwangta Co., Tayuanlin, Chinhsien.	0.70	28.02	49.87	21.41	9.19	6820		0.89	35.9	63.9	,,
17.	Taotzeling, Yükan.	0.33	40.11	59.56	14.27		8085		0.33	40.11	59.56	,,
18.	Chulowa, ,,	0.40	44.31	55.29	12.24		8140		0.40	44.31	55.29	,,
19.	Kwanshanling, ,,	0.44	31.04	60.48	8.04	1.88	7920		0.47	33.73	65.73	,,
20.	Tamiaoshan, Changhsing	0.65	34.77	38.98	25.60		5467		0.87	46.73	52.40	Miss Hung, Geol. Surv. China
21.	Szemotun, ,,	1.78	30.37	40.31	27.54		5516		2.46	41.91	55.63	,,
22.	,, ,,	0.82	30.93	39.83	28.42		5455		1.15	43.21	55.64	,,
23.	Kwanhsing Co., ,,	0.50	33.20	42.95	23.35		5876	1.29	0.65	43.31	56.04	,,

percentage of volatile matter much exceeds to that of the fixed carbon, while the extreme case is found in No. 1, the volatile matter content being nearly twice that of the fixed carbon. In the coals of Chinhsien and Yükan the volatile matter is also quite high (mostly over 40%) though it is all less than that of the fixed carbon. On the whole the coal is rather high in sulphur varying from 2-5.5% and owing to the fact that pyrite grains are rarely found it is inferred that most

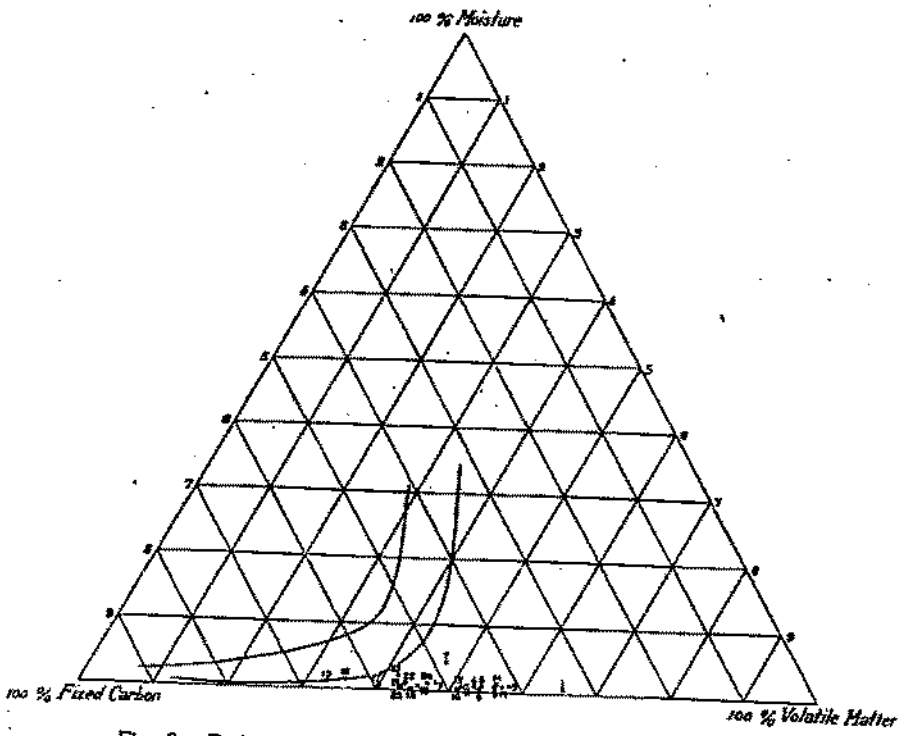

Fig. 2. Position of Lopinite (No. 1-19) in the triangular diagram of proximate chemical analyses. No. 20-23 are analyses of coals from Changhsing, Chekiang.

of the sulphur occurs in organic forms. Ash content is extremely variable and which can approximately be told from its specific gravities. The Calorific power is rather low varying from 6000-8000 B.T.U. or more. Under the

microscope, these coals show similar structures and are therefore to be classified under the same group.

In order to show more clearly the relationship between Lopinite and other coals in China, the chemical analyses of the above table are plotted in a triangular diagram (Fig. 2). In this same diagram is plotted together the variation curve of coals of normal sequence as has been done firstly by Dr. W. H. Wong[4] and afterward modified by H. S. Wang[5]. In the paper just cited Dr. Wong has already noticed the isolated position of the Loping coal (dot 17 in his diagram) and came correctly to the conclusion that the latter should constitute a special type. In a modified form of the triangular diagram Mr. H. S. Wang argued that by including the dot No. 17 (i.e. the Loping coal) there will form two parallel curves within which lies the continuous series of coal ranging from lignite up to anthracite. But the unnatural position of the dot No. 17 and the broken form of the lower curve is quite evident. The most simple explanation is that the coal of Loping is a distinct type and does not belong to the rest of the coals.

Now in our Fig. 2 in which a great number of analyses of Loping and allied coals are plotted, the relationship becomes more and more clear. The No. 1 analysis which represents perhaps an extreme case of the Loping type lies in the most distant part in the diagram while the rest of the dots are found mostly in the region of 50-60% of volatile matter. The coals of Yükan, Chinhsien though carrying smaller amount of volatile matter and lying consequently more close to the field of normal sequence, yet it is remarkable to see that most of the dots occupy a position still quite outside of the normal field. There is no doubt that these coals form the transitional cases between the Lopinite and the normal type.

In a similar triangular diagram for plotting proximate analyses of some American coals, Prof. Fisher[6] has noticed that cannel coal lies far outside of the

4 Wong, W. H. Coal composition in Triangular Diagram—Bull. Geol. Soc. China, Vol. 6, No. 1, 1927.

5 Wang, H. S. The rectangular graphs as applied to the proximate analyses of Chinese coals — Bull. Geol. Soc. China. Vol. 1, No. 2, 1928.

6 Fisher, D. J. Notes regarding the coalification process—Journal of Geology, Vol. 35, No. 7, p. 640.

field of the normal sequence, which fact points to a different origin and derivation of the latter coal. It is evident that so far as proximate analyses in triangular diagram is concerned, Lopinite may belong to the same field as the cannel coal, though the former contains an entirely different vegetal constituents.

3. Behavior of Low Temperature Distillation

Low temperature carbonization assay on Loping coal made recently by Mr. C. C. Hsiao[7] shows again that this coal is a most remarkable one. "Aside from its exceedingly high fusibility and swelling, the oil yield exceeds that of any other coal by more than two times". Recent investigation of our chemist K. Y. King demonstrates that the Lopinite has in addition a special property in increasing the agglutinating value when it is used as a blending constituent together with non-coking or moderate coking coals. The coal of Yükan and Chinhsien have not yet been tested, but on account of their similar chemical and microscopical characters as the Loping coal, similar result of low temperature carbonization may be predicated. The following is given the result of test for the coals of Loping.

Low temperature carbonization test on Loping coal.

(After C. C. Hsiao).

Semi-Coke	54.28
Oils	33.05
Liquor NH_3	3.12
Gas	8.11
Sp. gr. of oil	.893
Vol. of gas	
Sp. gr. of gas	.660

4. Other Chemical and Physical Characters.

From its high content in volatile matter the Loping coal might be suspected for lignite, although the low moisture content clearly distinguishes it from

7 Hsiao, C. C. Low temperature carbonization assay of some bituminous coals. Bull. Geol Survey, China, No. 21, 1933.

the latter kind. Perhaps the surest way of differentiating lignite from the low type of bituminous coal is by following the German method of some simple chemical tests. This is done by boiling coal powder in either potassium hydroxide or dilute nitric acids; in the case of lignite the solution will be stained brown or reddish brown. In all the coals investigated there gives invariably negative results to these simple tests; therefore their non-lignitic nature is clearly proved.

To the naked eye the coals from Loping & Chinhsien are usually dull and compact, showing a well marked cleavable or sheeted structure, so that it can be easily splitted into thin slabs or sheets along the bedding planes. To this character is derived the local name at Loping "Pantzemei"[8] which means slabby coal. Along the bedding planes there appears frequently shining patches or layers, though on the whole the coal is characterized by a uniform dull luster. Banded or laminated structure of alternately dull and bright layers such as commonly seen in ordinary bituminous coal is absent, but on close examination there may reveal occasionally thin streaks of bright coal in alternating with the dull one thus giving an extremely fine laminated appearance. The specific gravity of the coal varies from 1.25-1.70 depending much upon its ash content, while its streak is black to dark brown

The coal from Yükan shows a slightly different physical characters. It is more bright and massive with the sheeted structure not so marked. This is evidently due to crushing, polishing and granulation which the coal has suffered during tectonic movement and which has rendered the coal a more glossy appearance.

All these coals just described can be easily ignited by a match fire and gives in burning a long flame and asphaltic odour.

5. Microscopic Structures

Owing to the compact and tough nature of the coal and its rich content of transparent tissues, the making of thin section becomes comparatively an easy matter. This can usually be accomplished by the ordinary grinding method

8 Liu, C. C. Report on the Polo coal mines in Kiangsi Province (1925).

without resort to any special procedure of preparation and mounting such as has been marvellously worked out by Dr. Thissen & others. The final stage of grinding to the required transparency should, however, be made by rubbing on a Belgium hone which is the best and indispensable tool to every coal petrographer. Two kinds of sections i.e. vertical and horizontal were made and studied, and the results of investigation may be briefly described as follows:

(1) Coals from Loping, Kiangsi.

The vertical section of the Loping coal shows to be made up essentially of alternating layers of opaque to semi-opaque matter and transparent tissue, the latter on morphological ground has been identified to be mostly periderm which includes both the remains of phelloderm and cork tissue*. We know from Botany that true cork is rare or wanting in Cryptogams, even in the Pteridophytes, and since this coal under study is of Permian age, so the presence of any great quantity of real cork tissue in the coal seems to be rather questionable. On the other hand the rectangular brick-shaped cells suggesst strongly that some of them at least are real cork tissues.

The color of this tissue varies from yellow, brown or reddish brown all depends upon the thickness of the section. Under crossed nicols these tissues are distinctly anisotropic and showing a marked polarization color. The thickness of the layer may vary from extremely fine (5 μ) to 160 μ or more. Most of the layers are regularly and parallelly arranged; not infrequently they may also irregularly disposed with one layer interpenetrating or interlocking the others.

Although the preservation of the phelloderm and cork tissue is not very perfect yet there shows usually good structures as to make possible their exact identification. Practically all the tissues shown in the vertical sections represent cross view which is characterized by parallel and brick-shaped cells. In

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* Thin sections and specimens of Loping Coal have been sent to Dr. Thissen. In replying, Dr. Thissen writes as follows: "Your interpretation of the coal from Loping, Kiangsi is quite correct. My opinion is that it consists largely of periderm, and includes remains of both phelloderm and phellem or cork, the former, the phelloderm, comprising probably the bulk of the coal." Microchemical test with Soudan III gives, however, negative result. This does not imply at all the impossibility of our interpretation, as vegetable tissues in coal may have been profoundly changed as to be insensitive to such test.

some layers these cellular structures are entirely wanting, and frequently the structure showing layers are alternately arranged with the homogeneous one the latter is believed to represent either phellodern itself (which owing to its comparatively less resistant nature is liable to suffer destruction) or the altered woody material.

The longitudinal view of the periderm tissue can be seen in the horizontal section of the coal, i.e. the one cut parallel to the bedding planes of the coal seams. In these sections phellodern and cork tissues are abundantly found and which occur mostly in forms of irregular pieces attaining sometimes considerable dimension (up to one cm or more in diameter). In some of these pieces cellular structure consisting of rectangular to polygonal shaped cells bounded by rather thin and straight cell walls are distinctly preserved. The sizes of each cell vary from 48 × 64 μ to 64 μ × 80 μ. Besides the larger pieces, there occur in the horizontal section also some thin streaks or lenticles representing evidently cross section of these irregularly or obliquely deposited cork tissues. In these streaks etc., the characteristic brick-shaped structures are again distinctly shown. All the tissues, like in vertical section, show a distinct polarization color under crossed nicols.

Occasionally, there is shown in the horizontal section some roughly cylindrical tissues showing rectangular cells (a cell form similar to cork tissue) arranged in a concentric way. This kind of tissue may represent transverse section of some young stem in which the peripheral portion is well preserved. The central portion is occupied by humified, probably woody material.

The opaque to semi-opaque matter in the coal represents evidently the more lignified or coalified substances which may be derived either from the periderm* itself or from the woody materials. The examination of thinned polished section[9] by both transmitted and reflected light shows however that these opaque matter exhibit in most cases some cellular structure. Besides its occurrence as separate layers or lenses alternated with the transparent tissues, the opaque and more frequently the less-opaque to translucent matter may occur also

* This may represent the remains of phellodern cells.

9 Hsieh, C. Y. Thinned polished section of coal, a new technique in coal petrography—Bull. Geol. Soc. China. Vol. pp. 1932.

as streaks or patches inside the transparent tissue; this feature can best be seen in horizontal section in which certain cells may be translucent to opaque while the rest is distinctly transparent showing the usual brownish to reddish colors. This difference in color and transparency within same pieces of tissue can perhaps be explained by different degree of humification or decay due to bacterial action as will be explained latter.

The amount of the opaque to semi-opaque matter varies greatly in different parts of the section; in certain part it is greatly predominate, (Pl. I, Fig. 2) so that the transparent periderm tissue forms only subordinate constituent while in other part the reverse is the case. (Pl. I, Fig. 1).

The study of polished section under reflected light gives more information about the microstructure. To the naked eyes, the polished surface appears to be finely striated, the striation is due to the presence of a number of gray colored dull lines or laminæ which are higher in relief as compared with other constituents. Under the microscope, the dull lines or laminæ are proved to be periderm, as can be seen from the faintly but still distinctly marked cellular structures, while the rest is composed of thin lenticles of vitrain and some fusain. The transparent nature of the periderm can be well shown by examining under oil immersion; in this way the phelloderm as well as cork tissue changes to dark gray, whereas fusain and other opaque constituents becomes more bright in color. Under crossed nicols, the gray layers show frequently interior reflection color of red or brown, the true color of the periderm tissue. The same kind of color can also be observed under oblique illumination.

(2) Coals from Chinghsien, Kiangsi Province.

Several specimens of coal from two different localities in Chinhsien have been studied under the microscope. They show essentially the same kind of structure as the Loping coal except that the tissue seems to be somewhat crushed, and macerated and that the opaque or semi-opaque matter seems to be more abundant especially in that specimen from Kungta Company in N. E. part of Chinhsien. In the latter coal mineral fragments probably quartz are also frequently observed. The coal from Niuling is less abundant in opaque matter so it is of higher quality as compared with other one.

(3) Coals from Yükan, Kiangsi Province.

A polished section from Kwaninling, Yükan was studied. It is composed in the main of a number of dull lines, or layers usually folded and somewhat crushed, embedded in a vitrainic groundmass. Here and there are found fragments and lenticles of fusain and xylon, the former is, however, not so abundant as in the coal from Chinghsien. Under oil immersion these dull layers change also to a dark gray color, therefore they are undoubtedly periderm tissues.

The study of thin section of this coal confirms the presence of a great number of phelloderm and cork tissue which are usually bended, crushed and somewhat macerated. The cellular structure though faintly shown is in most cases clearly recognizable.

6. Maceration

In all the coals studied, perfectly preserved tissues of periderm were obtained by maceration in Schulze's Reagent (a mixture of concentric nitric acid and potassium chlorate). Good result can be obtained by allowing the coal powder in the solution for a week or ten days and then it is washed and treated again with ammonia. The residue is composed almost entirely of phelloderm or cork tissue which can be studied under the microscope.

Pl. II, Fig. 3 is a microphoto of the tissue separated from the Loping coal. It shows perfectly well preserved structures with rectangular formed cells of the following dimensions:

$64 \times 96\mu$ $48 \times 112\mu$ $48 \times 80\mu$

The tissue shows a deep brown to yellowish brown color and unlike in thin section it is isotropic under crossed nicols. The refractive index of the tissue as determined by immersion method lies approximately between 1.490-1.500.

The maceration product from the coal of Niuling, Chinhsien shows besides abundant periderm also some microspores, a few megaspores and several pieces of cuticle, Fig. 4, Pl. II shows one of the cuticle separated with stomatic opening distinctly preserved.

7. Comparison with Other Coals

Besides the coals from Loping, Yükan and Chinhsien there is a group of coal also exceptionally high in volatile matter, and low in moisture. The coal from Changhsing in Chekiang Province, constituets perhaps one of the most interesting types. The coal is compact and tough showing neither laminated nor sheeted structure, it is composed entirely of dull coal and in this way it looks very like cannel coal or boghead coal in macroscopic appearance. The streak is black while its sp. gr. is nearly 1.30. Its position in the triangular diagram is shown in fig. 2. from which we can see that the Changhsing coal also lies outside of the normal sequence but very close to it.

The microstructure of the Changhsing coal is quite different than those previously described. The thin section is composed essentially of a reddish colored transparent and homogeneous layers intercalated with layers or lines of opaque material, the latter when examined under reflected light proves to resemble fusain. The entire mass of the transparent and opaque layers are often folded or curved exhibiting a form not unlike the woody structure. From the coal-petrographical sense these transparent layers may be called vitrain, though their botanical nature remains still a question. In some sections true fusain occurring in lenticles or fragments are also present. Such constituents like spores, cuticles, xylon etc. which are so common in ordinary types are conspicuously absent in the Changhsing coal.

Cork tissue is abundantly present in certain seams of the Shenkungshan coal field in Anhui Province, but here the tissues are usually associated with other constituents such as micro- and macrospores, resinous bodies etc., or when occurring alone, they form only certain fractional part of the seam. Nothing like that observed in the coals of Loping, Yükan and Chinhsien can be found. In the triangular diagram, the coal of Shenkungshan occupies a position well inside the normal field, so it has no relation with the Loping coal.

8. Conditions of Formation

Cork tissue as well as other vegetal elements in the periderm have been frequently found in coal and more recently Wolfram Penseler[10] has found a great

10 Wolfram Penseler: The James Coal of New Zealand, Fuel, Vol. 12, No. 5, p. 166, 1933.

amount of cork tissue in the James coal of New Zealand. But the occurrence of this tissue in such a great amount as in Lopinite in Kiangsi Province is, so far as known to the writer, the first that has ever been described. The following is a short description of James coal quoted from Penseler.

The James coal occurs above a conglomerate bed with an intervening shaly band of about 6 in. thick and is below a sandstone formation; its age is Eocene. In thickness it may vary from 2-7 ft. but local thickening up to 20 feet is also found. The coal is dull, black and is peculiarly hard and tough, showing a conchoidal fracture. Chemically the coal is characterized by an unusually high content of volatile matter and hydrogen*, figures for which approach those for a cannel coal. It is rather high in sulphur. Under the microscope, the thin section shows a great amount of suberized tissue and cuticles together with fragments of xylon and disintegrated debris to form the ground mass. Sporic matter is conspicuously absent. In classification the James coal approaches that class of coal comprising cannels and bogheads. The extension of this special coal is however, rather limited, since mine working has shown its changing in character and becoming more like an ordinary bituminous coal within short distances.

From the above description, it is evident that Lopinite and James coal are closely related and may perhaps be classified under the same group. There are, however, several differences. The James coal is of Tertiary age and consequently it contains a great amount of perfectly preserved cork tissue while in the Lopinite, the periderm consists perhaps more of phellodern than the true cork cells. With the exception of the coal from Chinhsien, the Lopinite contains usually no or very little cuticle. As can be seen from fig. 1 our coal has moreover a greater surface extension than the James coal.

Concerning the particular nature of the Leping coal, Dr. Thissen in his letter to the writer, writes as follows: "It is an interesting coal to study, and never have I seen even thin layers of coal of that purity of one tissue.

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* Recent work by K. Y. King shows Lopinite containing also a high content of hydrogen amounting to 7%.

Recently we have been studying a bituminous coal from the Upper Cretaceous of Utah. In this coal are found certain layers composed largely of remains of the outer envelope of the stem, namely, of phloem, cortex and periderm, but never of such purity of one or two tissues as in your coal."

As to conditions for the formation of the James coal, Penseler has written the following:

"The attrital nature of the James coal, and the large amount of cuticle and cork fragments, combined with the geological and chemical evidence, suggest that the coal has been formed from forest offal, which was drifted into brakish water in a sheltered region of an estuary. The offal was probably derived from a forest growth which bordered this area of accumulation and protected it from the washing in of inorganic sedimentary material, and a gradual transition would therefore be found from this small patch of special vegetal material into a more normal type of coal derived from the fringing forest growth."

It is well known in geology that coal represents product of decay of vegetal material and consequently the most resistant parts of the plant as spores, cuticles, barks, etc. are more frequently preserved. Because of their intimate association and lack of chance to be separated, these tissues are usually found together in a coal though in widely different proportions. Any coal that is composed essentially of one kind or one part of the tissue must require therefore special condition for its formation. The cannel coal, for instance, a coal composed essentially of spore has been considered by many geologists to be formed under a sapropelic condition i.e. an open water to which the wind-blown spores are most easily to be accumulated and deposited. In the case of cork tissue, and phelloderm because of their fixed and non-flying nature, they can not be accumulated in this way. On the other hand, owing to the extraordinary resistant nature of the cork tissue, the latter can usually be preserved under the most advanced stage of decaying when other things were destroyed and removed. It is therefore suggested that for the formation of Lopinite, the following two conditions are necessary:

(1) The vegetal material must have suffered previously an excessive degree of decay so that most of tissues were destroyed, coalified, or removed except the resistant outer part including cork tissue, phelloderm, cuticles, and

some others. Such advanced stage of decomposition can perhaps be brought about by prolonged action of bacteria or under special climatic condition. The presence of a great amount of opaque matter in the coal may be taken as to represent the much coalified and macerated debris left over from the work of the bacterial action.

(2) This mass of vegetal material already decayed and somewhat macerated must then be subjected to a process of transportation, thereby to enable the removal of other resistant tissues like spores etc. and the final concentration and deposition of the cork and its allied tissues. The often crushed and fragmentary forms of the tissues so frequently observed in the coals of Yükan and Chinhsien may perhaps be cited as evidence in favor of this drifting theory.

In order to fulfill the above stated conditions, we must assume that lopinite and its associated strata were formed in brackish water of estuarine condition. The high sulphur content of the coal may be cited as an evidence of the brackish water origin, as in the later water sulphur bacteria was usually more active. It still lacks, however detailed stratigraphical evidence, but the occurrence of several layers of limestone, the abundance of marine fossils and the irregular nature of the coal seams in Yükan and Chinhsien are perhaps strong arguments indicating esturiane condition. In his excellent memior on the Permian formations of Southern China[11], Mr. T. K. Huang has rightly concluded that coal in the Liupakou series (Permian) may be of two types; the *in situ* type and the drifted type, the latter "occurs in regions outside the three provinces, (the coastal provinces where land flora as *Gigantopteris* etc. have been found) especially in those places where the marine Choutang series is well developed". Although Huang has given no definite localities for the occurrence of the allochthonus coal, a glance at his Palæogeographic maps (Pl. VI) will show at once the Loping coal basin in N. E. Kiangsi as one of them. From the same map we can see again that N. E. Kiangsi formed that time in all probability an estuary which bordered the old coastal land of the lower Yangtze Province. So on the whole the condition of formation for Lopinite is essentially similar to that of James coal i.e. an esturiane deposit formed from drifted forest offal from a nearby forest growth.

11 Huang T. K. Memoir Geol Serv. China, Series 4, No. 10, p.66 1932.

Although allochthonus theory for the explanation of coal formation has been recently rejected by most of the geologists, yet in our special type of coal like Lopinite and James coal, this theory seems to be still plausible.

9. Acknowledgement

I wish in this occasion to acknowledge my indebtness to Dr. Thissen for his kindness in examining the thin sections of Lopinite in order to verify certain results of my microscopical investigation. To Dr. W. H. Wong and Mr. K. Y. King, the writer is indebted for their coöperative discussion on the chemical composition of this particular kind of coal. The writer is also indebted to Prof. C. Y. Chang of the Botanical Department, National University of Peking for help in carrying out some microchemical tests.

Explanation of Plate I.

Explanation of Plate I

Fig. 1. Microphoto of a thin section of coal from Kwaninling, Yükan, Kiangsi province showing the rather distorted and contorted tissue of the periderm (gray) embedded in an opaque ground mass. Vertical section × 45.

Fig. 2. Microscopic structure of a coal from Niuling, Chinhsien district in Kiangsi Province. Here the opaque ground mass is more predominate while the transparent cork tissue is more thin as compared with the previous section. Vertical Section × 45.

Fig. 3. Horizontal section of the periderm showing the polygonal-shaped cork cells. Loping, Kiangsi. × 37.

Fig. 4. Same as Fig. 3 more enlarged. × 100.

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Explanation of Plate II.

Explanation of Plate II

Fig. 1. Vertical section of the periderm showing the laminated, brick-shaped cells. Loping, Kiangsi. × 143.

Fig. 2. More enlarged view of the cells, Loping, Kiangsi. × 190.

Fig. 3. A piece of periderm as separated by maceration—showing horizontal view of the cells. Loping, Kiangsi. × 135.

Fig. 4. A cuticle separated by maceration from the coal of Niuling, Chinhsien, Kiangsi Province. The Stomata are distinctly shown. × 140.

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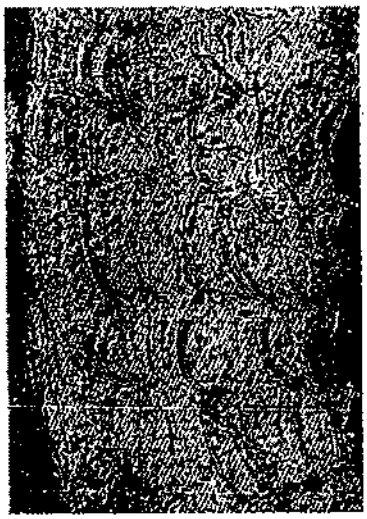

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