A PRELIMINARY PETROGRAPHICAL STUDY OF THE PEIPIAO COALS.

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(Contribution from the Sin Yuan Fuel Laboratory, No. 1.)

1. Introduction.

The Peipiao coal field is situated about 90 li North of the Chaoyang city, eastern Jehol and is connected with Chin Hsien, a station on the Peking-Mukden railway by a branch line of about 170 li. The region is characterized by a moderately dissected mountain range which runs roughly in a N. E.—S. W. direction.

Since 1921 the Peipiao coal field is being developed by the Peipiao Coal Mining Company. Under the able management of its first director Dr. V. K. Ting and its present director Mr. T. A. Yuan, this mine has been turned into a profitable enterprise and is now yielding a production of more than 360,000 tons annually.

The geology of the Peipiao coal field has been studied at first by Dr. V. K. Ting and afterwards detailedly mapped by Mr. H. C. Tan[1] and Dr. W. H. Wong[2]. To Dr. Wong we owed to his discovery of several overthrusts of considerable magnitude,—a discovery of prime importance to the well understanding of the Chinese tectonics. The geological interest of the region is further enhanced by the existence of two volcanic series between which the coal formation of Jurassic age is found. A petrographical study of the volcanic rocks collected by Mr. H. S. Wang[3] in this region has been recently made by P. C. Wang[4]. In regard to the mining condition and technical development of the mine, we have the report of Mr. P. H. Lay[5], mining engineer of the said company.

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1. T'an, H. C., Geology of the Peipiao coal field, Chaoyang district, Jehol, Bull. Geol. Surv. China No. 8, 1926.
2. Wong, W. H., Etude tectonique de la region de Peipiao et se environs, Bull. Geol. Surv. China No. 11, 1928.
3. Mr. Wang's report on the geology of the Peipiao region is in course of preparation.
4. Wang, P. C., The volcanic rocks in Peipiao region, Bull. Geol. Soc. China. Vol. 8, No. 4, 1929, p. 343.
5. Lay, P. H., Engineering report on Peipiao Colliery, Mining & Metallurgy (Chinese) Vol. 1, No. 1, p. 129, 1927.

It is interesting to note from the above mentioned that the Peipiao coal field, though its systematic development being dated from comparatively recent time, has furnished us a good deal of scientific informations and became now one of the best known coal fields in China. On the other hand, a petrographical knowledge of its coals produced, which from the genetic point of view is of fundamental importance, is unfortunately still lacking. With a view to fill up this gap of knowledge, the present work is intended.

The writer wishes to thank the authorities of the Peipiao Coal Mining Co. for the sending of specimens and various other informations.

2. THE COAL SEAMS.

According to Mr. Lay's report there are more than ten seams of coals encountered in the bore holes and underground but among which only eight are considered as workable. Among these seams, the seams No. 7 and No. 8, because of their high content in ashes are now not worked. Their average chemical composition[1] is listed below with notations[2] indicated:

No. of Seam	Moisture	Volatile matter	Fixed Carbon	Ash	$\frac{C}{M+V.}$	Notation
	%	%	%	%		
No. 3 (1st level)	2.31	29.60	53.20	14.84	1.66	Bl_4
No. 3 (2nd level)	2.65	27.35	52.45	17.54	1.74	Bm_4
No. 4 (1st level)	2.08	30.67	53.10	14.15	1.61	Bl_4
No. 4 (2nd level)	1.96	31.25	53.09	13.63	1.59	Bl_4
No. 4½	4.00	26.84	39.68	29.48	1.28	BC_5
No. 5 (1st level)	3.10	29.40	51.50	14.71	1.58	Bl_4
No. 5 (2nd level)	2.01	29.20	51.00	17.60	1.63	Bl_4
No. 6	1.50	26.50	51.00	21.00	1.82	Bm_5
No. 7	1.00	33.50	33.00	32.50	0.95	BC_6

3. MICROSCOPIC AND MACROSCOPIC CHARACTERS.

In the following description of the microscopic characters of coals, the writer has adopted the somewhat modified nomenclature of Stopes[3] proposed by the Prussian Geological Survey in Berlin. In this nomenclature the term Clarain is discarded, because it does not show much difference both chemically

1. Taken from Mr. Lay's unpublished report on the Coal Seams in Peipiao field.
2. Wong, W. H., Classification of Chinese Coals, Bull. Geol. Surv. China, N. 8, 1926, p. 33.
3. Stopes, M., On the four visible ingredients in banded bituminous coals, Proc. Roy. Soc. Ser. B. Vol. 90. No. 633, p. 483, 1919.

and microscopically from durain, the latter as we understand now is used to indicate all inhomogenous layers in the coal, no matter whether it is made up of spore exines or of cuticles or of any other constituents.

To describe the various degrees of humification of the woody materials in the coal, the writer is preferred to use the terms xylain and xylo-vitrain of Duparque[1] rather than the eu-vitrain and pro-vitrain of Potonie[2], the former nomenclature seems to give a much clearer understanding.

After having stated the defination of the terms used in this article, I may now proceed to describe the different coals studied.

Seam No. 3.

Macroscopic character: This is a finely laminated coal composed essentially of durian with thin intercalations of vitrain and several lenses of fusain. The coal is light, seems to contain little ash. It breaks easily to roughly parallelopiped fragments of various sizes.

Microscopic character: Under the microscope the vertical section of the coal is seen to be composed almost entirely of durain which is characterized by a great abundance of woody materials in the forms of fusain, xylain and xylo-vitrain. In some section practically no cuticle is observed while in others it is very abundant. Some resinous matter in rounded to lenticular fragments showing high relief and grayish color is present.

Fusain forms usually long lenticles of considerable sizes attaining sometimes one centimeter or more in length. It can be clearly recognized by the naked eyes from its high relief, dull appearance and fibrous form. Under the microscope fusain shows very well-preserved cellular structure, the cells are usually neatly preserved and have apparently suffered no or little compression. Both transverse and longitudinal section of the fusain is encountered in the vertical section. The cells are generally infiltrated by ashy matter which gives a dark and dull appearance under the microscope. It is perhaps due to this infiltration that most of the higher ash content of fusain is to be accounted for. Pyrite replacing the cells is also frequently observed.

Xylain has a lower relief, but brighter luster than fusain. It exhibits no well marked relief on the polished section when seen by naked eye or by a

1 Duparque, André, Le rôle des tissus lignifiés dans la formation de la houille, Extr. Ann. de la Soc. Geol. du Nord T. LI p. 51, 1926.

2 Potonie, R., Zur Kohlenpetrographie und Kohlenentstehung, Z. d. D. Geol. Ges Bd. 78, 1926.

lens as this is the case with fusain. Under the microscope, xylain shows also a well preserved cellular structure; in this respect it resembles fusain and can only be distinguished from its relief and luster; the former character is best to see by the use of a hand lens. In the sections examined, xylain forms usualy long or short lenses of various sizes. It is generally bordered by a structure-less zone of thin xylovitrain. Pieces of woody matter showing transition from xylain to xylo-vitrain are frequently observed.

The durain is composed essentially of a ground mass (pate fondamental of Duparque) in which are embedded numerous thin lenses, fragments or small grains of xylovitrain and fusain. Both groundmass and xylovitrain are homogenous and structureless, but they can be distinguished by the fact that xylovitrain is higher in relief, brighter in luster and distinctly yellow in color, while the groundmass assumes generally a gray to bluish tint.

In the section just described there exists very few cuticle or microspore exines. According to Duparque, a structure like this should be called clarain, instead of durain, but as we are not intended to make minor distinction of this kind the name durain is used throughout this paper.

In another section from the same specimen, the microscopic structure gives quite a different picture. The groundmass is characterized by the presence of numerous microspore exines, and in certain portion it is crowded with cuticles of immense sizes. This is the typical durain, using the definition of Duparque. Other woody material like fusain, xylain and xylovitrain are equally abundant, and the cellular structure in fusain and xylain is equally well preserved as in the other section.

The occurrence of cuticle is of special interest. It is usually crowded together to form a band of ½ cm or more in thickness, in which nothing but cuticles of various sizes are found. The thickness of the cuticle varies naturally with the orientation of the section; thus it varies from a mere fine line to as much as 10 microns. By naked eye the presence of cuticle band is already noticeable from its high relief and long-striated aspect of the polished section.

In the coals studied, the microspore exines are not so abundant as commonly seen in the coals of Palaeozoic age. They are extremely minute in size, being only a few microns in length and could hardly noticeable unless examined carefully and by the use of small aperture.

Microscopic characters of the horizontal section: The microscopic view of the horizontal section depends of course much upon the position along which

the section is cut. It shows in one case an homogenous groundmass embedded with numerous small fragments or fine grains of xylainic and fusainic material, the latter is generally higher in relief. In another case the section is crowded with abundant pieces of fusain or xylain with well preserved cellular structure. As a rule the cells seem to have suffered little compression. Infiltration of ashy matter in the cellular spaces is a common phenomenon, and it is perhaps due to this reason that the cells have been rendered hard and resistent so as to show little signs of mechanical strain.

Thin section: The study of thin section confirms the existence of numerous bands, lenses or chips of fusain which together with cuticles and small lenticular bodies of resin are embedded in a reddish brown vitrainic groundmass. The resin shows a brilliant reddish brown color and is very transparent in the thin section.

Seam No. 4.

This is a hard and compact coal like seam No. 3. It is heavier than seam No. 6. It breaks into an uneven fracture, this character being also somewhat similar to seam No. 3.

Under the microscope: The coal is seen to be composed essentially of durain with a few intercalations, of vitrain which is more developed here than in any other coals studied presently. The vitrain attains sometimes a thickness of 2 mm or more.

As usual, the durain is made up principally of woody materials with subordinate representation of microspore exines, cuticles and a few resinous bodies, the whole series of material being embedded in an homogenous groundmass. The woody material occurs mostly in the form of xylovitrain, i. e. a much transformed xylain with its cellular structure almost entirely obliterated. It can still be recognized as such from its high relief and not infrequently the presence of numerous cavities suggesting the original cellular spaces. Fusain is also present, but rather rare. Besides, there presents a fragmentary material with thick cell walls occurring either in single isolated cells or in one or two rows of a series of cells. Some of the cells assume a form very like bast fiber which has been produced by etching in the coal of Hokong and Chimenshan[1] while in others the cell walls of which are so thick that they may be called stone cells. Such cell generally shows a higher relief and distinct

1. Hsieh, C. Y., Ätzstrukturen in der Kohle, Arb. Institut f. Palläobotanik u. Petrographie der Brennsteine, Bd 2, Heft 1, pp. 25, 1930.

bright lustre than ordinary xylain. When examined by naked eye or by a lens it shows a sub-metallic lustre of gray color, so it can not be fusain.

Seam No. 4½.

Macroscopically, this is a compact and hard coal showing distinct banding of bright and dull layer, the latter is an ash-rich components weathered generally to yellow or brownish color, evidently due to the presence of iron. It breaks into regularly formed parallelpiped fragments.

Under the microscope,—Vertical section: This is composed essentially of durain intercalated here and there with extremely abundant lenticles of fusain showing distinct cellular structures. In the durain is present a great amount of xylainic debris or isolated rows of cells showing distinct relief and bright lustre of yellow color; also some cuticles and microspore exines, and a few resinous bodies. Most of the woody material here occurs in the forms of fusain and xylain; xylovitrain is present only in subordinate way. The cellular structure in both fusain and xylain has suffered some degree of compression, so that arc structure is common. It seems that well formed, uncrushed cells have not been observed; a feature similar to seam No. 6, but unlike seam No. 3. The more abundance in xylain than xylovitrain in this coal distinguishes it from seam No. 6.

Stone cells, bast fiber and other thick walled cells of indeterminate nature are very abundant in this coal occurring either in unburnt (xylain) or in burnt state (fusain); the latter form of preservation seems to be more common.

Another characteristic feature of this coal is the ash-rich beds which show under the microscope a great amount of woody debris embedded in a dark grey groundmass of inorganic origin. The debris is of different sizes and is composed of a great variety of tissues.

Horizontal Section: The horizontal section reveals a great abundance of fusain and xylain forming either large pieces of several mm. long or small irregular fragments embedded in a bright ground-mass. Cuticles of wrinkled or folded forms are found but they are only subordinately represented.

The ash-rich layer shows under the microscope to be an aggregete of xylainic and fusainic material embedded in a groundmass containing greyish spots or masses of ashy matter.

Seam No. 5.

The horizontal section of this coal shows a great abundance of leaves, often wrinkled and folded giving thus a most complicate appearance, being bounded in all cases by cuticles of irregular outlines. In some part of the section it seems to be made up essentially of large pieces of xylainic to xylo-vitrainic materials with cellular structure more or less clearly shown.

The vertical section shows also a great abundance of cuticles and spore exines embedded in a bright groundmass. The cuticles are often contorted and curved. The coal seems to have suffered some movement during or after its formation, as is evidenced by the displacement and discontinuity of the cuticle bearing layers. Crushing of the beds is also commonly seen. Both fusain and xylain are present, but they are not so abundant as in other coal. A richness in small lenticular fragments or grains of resin is very characteristic for this coal. It is more gray in color and higher in relief as compared with xylainic constituent. The recognation of resin can be best made by using polarized light[1] or still better under oil immersion; in this way the internal reflection color of brown or yellow is distinctly shown.

From the above description it seems clear that seam No. 5 is unique in its abundance in cuticles or sporic matter and in its great reduction in woody materials such as are the case with the other seams previously described.

Seam No. 6.

This is also a finely laminated coal, but less hard and compact as compared with seam No. 3. It is much crushed showing abundant slickensides and cleavages while bedding planes being only indistinctly shown.

Under the microscope the vertical section is seen to be composed almost entirely of durain with a few thin intercalations of vitrain, the thickness of which reaches only 20—40 microns. The durain is composed in the main of lenses or fragments of xylo-vitrain, in which cellular structure has been mostly obliterated, but can still be inferred from the form and distribution of cavities which occurs abundantly in it. Moreover, the xylovitrain has a distinctly higher relief than the ground mass or the common vitrain. Xylain and fusain showing distinct cellular structure are also present, but they are not so abundant as in coal of seam No. 3. In addition, the cells have generally

1. See the next article in this Bulletin by C. Y. Hsieh on "some new methods in coal petrography."

suffered some compression, so that arc structure is commonly observed. Transition from xylain to xylovitrain is also observed. In some pieces of fusain, especially those of large sizes, there occurs some well preserved, uncompressed cells together with intensely crushed ones; this suggests very likely the structure of annual ring, which the author has repeatedly seen among the Chinese coals of Jurassic or more younger ages.

In the durain there occurs some exines of microspores, small grains of detached fusain, xylain or xylovitrain and here and there rounded to irregular-shaped resinous bodies.

In some part of the section, cuticles are observed, but they are far less abundant and not so crowdly spaced as in the coal of seam No. 3. Bast fiber and bright, fragmentary cells are also present but are not very abundant.

In some other polished section made from the same specimen, there shows great development of an homogenous groundmass in which are embedded numerous fragments of xylovitrain (or vitrainic debris) some exines of microspores and cuticles and several lenticles or fragments of fusain, lenticles the latter show sometimes a well preserved and uncompressed cellular structure. The cell walls are often replaced by pyrite. Some beds of one or more mm. in thickness are exceptionally rich in small ash grains which make the coal to exhibit a dirty appearance.

The similarity of this coal with some of the previously described is very great, but some distinction is still noticeable. Firstly, the woody material is here found to be mostly in a state of more advanced transformatien; fusain and xylain with somewhat distinct cellular structure are certainly present, but they have generally suffered some compression and transformation, so that arc structure and xylo-vitrain are found to be more common. Moreover, cuticles are not so abundant in this coal; this character distinguishes it from the seam No. 3.

4. Maceration

In order to know more detail about the botanical constituents preserved in the coal, a study by maceration method is the best means. This method is now being used in a large extent by coal investigators and has yielded in some cases surprising results. The coal to be studied must be pulverized first; the fine powders are then immersed in a solution of concentric nitric acid (sp. gr. 1.40) and potassium chlorate. The time of treatment varies with

the nature of the coal and in the case of Peipiao coals, I have left them in the solution for about 4-5 days. The residues are then washed throughly, and treated again with ammonia for ten to twenty minutes. Practically all the humic substances are dissolved by ammonia while fusain, mineral grains and what is most important, the cutinized substances such as exines of spores, cuticles etc. can be picked out and studied under the microscope.

The maceration products from the seam No. 3 and No. 6 are very similar; they are composed in the main of isolated wood fibers showing sometimes distinct structures such as bordered pits, medullary rays etc; also some fusain and cuticles. Exines of microspores are only rarely found, though they are certainly present. Epidermal cells of the cuticle are generally well preserved, showing a long streatched, rectangular forms. The best preserved cuticles showing distinct cell structures and stomata are seen in the coal from seams No. 4 and 4½, of which an example is given in the illustration. Wood fibers and fusain are equally abundant in these coals while microspore exines are rare. The maceration product of seam No. 5 shows only some badly preserved cuticles and unidentifiable tissues.

From the above maceration study, it is concluded that the vegetable tissues forming the bulk of the Peipiao coals are composed in the main of the woody elements and cuticles, while sporic constituents are conspicuously rare. The forms of the epidermal cells in the cuticles as well as the structure of the wood fiber present some striking resemblance in all the coals studied, so that they afford no means by which to distinguish or to correlate the different coal seams from a maceration study alone.

5. Conclusion.

The present study is merely a petrographical description of six principal coal seams found in the Peipiao coal field. As the exact location [1] of the specimens studied are in most cases unknown, and systematic collection of coals from one place to another is not yet available, any discussion about the horizontal variation in microstructure and botanical constituents of the coals is therefore not the scope of the present work. A detailed study to show horizontal variation is, however, of fundamental importance, as it furnishes the only means to interpret the mode of conditions under which the coals in different parts were formed. It is hoped that such a study shall be taken up

1. The Peipiao authority has consented to send such a collection in the near future

by the Fuel Laboratory in the near future.

From the previous microscopical and maceration study, it is concluded that the Peipiao coals are made up principally by woody constituents and cuticles together with some fragmentary cells of bast fiber, some stone cells characterized by extraordinary thick cell walls especially abundant in Seam No. 4, whereas sporic matter, resins etc. are conspicuously rare (Only abundant in Seam No. 5). Among the woody materials, three different forms of preservation may be distinguished; namely fusain, a charred wood, xylain, a humified wood showing still distinct cellular structure and xylovitrain, a more advanced transformation of woody material with complete obliteration of most of the cellular structures.

Another important conclusion brought out by the previous microscopic study is the constant association of ashy matter in fusain, the former is almost always present occurring as infiltration in the cells of the latter. Therefore, if we can develop some means to separate out more or less completely the fusain particles from the coals, it will decrease the ash content and consequently improve the quality of the coal to a considerable extent. Perhaps the coking quality of the coal can also be improved in this way as is believed by most of the recent coal investigator.

Explanation of Plate I

EXPLANATION OF PLATE I.

Microphotographs of polished sections of coal.

Fig. 1. A transverse section of fusain showing well preserved cellular structure perhaps of a coniferous wood. Annual ring is here distinctly marked. (See the horizontal demarcation in the center). Seam No. 3. × 100.

Fig. 2. Pieces of fusain in coal seam No. 3 showing thin walled cells filled almost entirely by ash infiltration. The ash content of the coal is robably largely derived from this infiltration. × 90.

Fig. 3. Vertical section of coal from seam No. 4 showing its general microstructure. This coal is characterized by an abundance of xylovitrain which occurs generally in fragmentary state. White, xylovitrain; gray, groundmass or vitrain. × 100.

Fig. 4. Vertical section of coal from seam No. 4 showing a portion with abundant cuticles. The bands both above and below in the figure are xylovitrain with woody structure indistinctly shown. × 90.

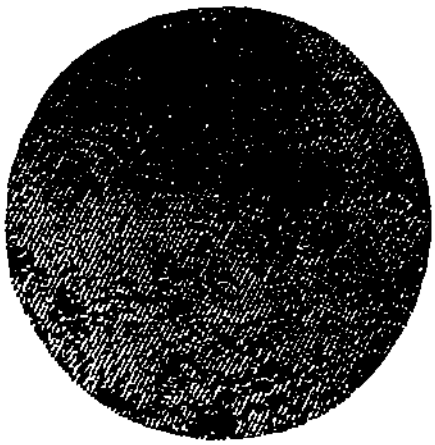

Fig. 1. Coal Seam. No. 3
x 100

Fig. 2. Coal Seam No. 3
x 90

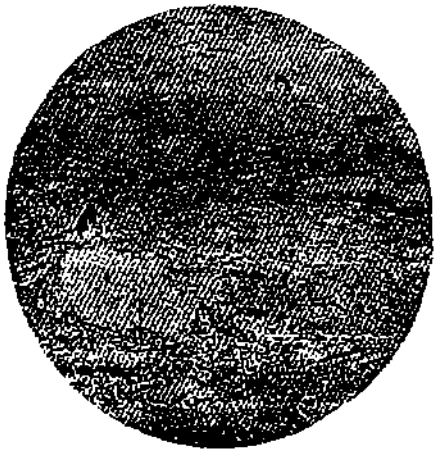

Fig. 3. Coal Seam No. 4
x 100

Fig. 4. Coal Seam No. 4
x 90

Explanation of

Plate II

EXPLANATION OF PLATE II.

Microphotographs of polished sections except Fig. 8 which is a maceration preparate.

Fig. 5. Vertical section of coal seam No. 4, showing several bands of xylain exhibiting a more bright lustre and higher relief than the ordinary one. × 100.

Fig. 6. Several bands of fusain embedded in a groundmass of vitrain. Seam No. 4½. × 100.

Fig. 7. Vertical section of coal of seam No. 5 showing an entirely different aspect from other seams. It is characterized by a richness in resinous matter and a durain with fairly abundant microspore exines. The exceptionally higher content of volatile matter in this coal is perhaps due to this reason. One of the large resinous fragments is shown in the upper left corner. × 100.

Fig. 8. A cuticle as isolated by maceration from coal seam No. 3. It shows a long stretched, rectangular epidermal cells. × 80.

Fig. 5. Coal Soam No. 4.
x 100

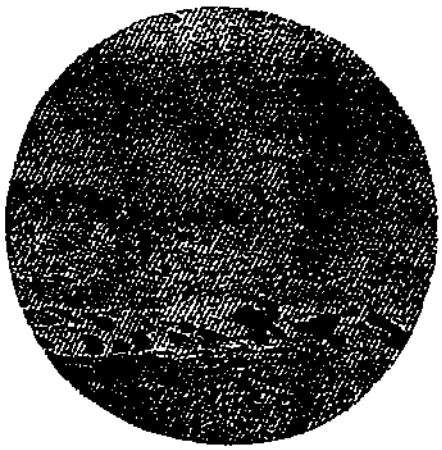

Fig. 6. Coal Seam No. 4½
x 100

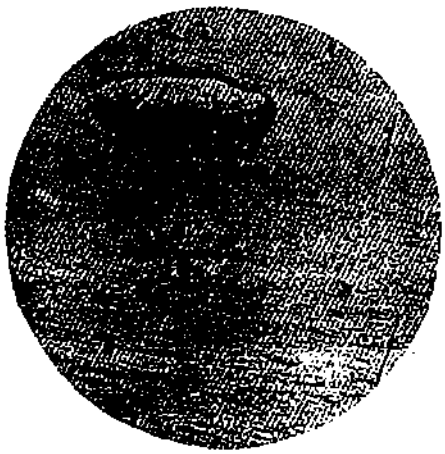

Fig. 7. Coal Seam No. 5.
x 100

Fig. 8. Coal Seam No. 3.
Maceration preparate, x 80.