PHYTERALS OF JURASSIC COALS OF TUVA

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ABSTRACT

Phyterals of the coals of two thick coal seams (vitrinitic for the most part) near the USSR Mongolia border are described here: the "Ulug" of the Ulugkhem basin and the "Chadan" of the Chadan deposit. A three-stage hierarchical classification of the studied phyterals has been worked out. Within this classification we distinguish groups (according to the plant organs), subgroups (on the basis of the plant tissues) and individual phyterals. One can draw a conclusion that the Jurassic coal-forming vegetation in Tuva was rather a shrubby (probably, an undershrub) or a herbaceous one, than an arboreal forest.

THOSE components of coal which are coalified plant remains are called "phyterals" in coal petrography (Cady, 1942). The term "anthracolemma", proposed by Schopf (1975), is similar as regards its sense, but it is more extensive. By this term Schopf meant any coalified organic remains (both phytogenous and of animal origin) which are found in the rocks.

At present there is no general classification of the phyterals of coals. Previously, it was pointed out that the phyteral is considered to be a definite one if the tissue of the original plant and its taxonomic belonging are determined (Lapo, 1973). These criteria are used while working out particular classifications of phyterals as well as the mode of preservation of the plant tissue: vitrinization and fusinization, etc. However, when we try to classify phyterals we are faced with a fundamental difficulty. The matter is that some coalified plant tissues can occur in coal in the form of isolated fragments and can also be part of the plant organs, including several tissues. This phenomenon can be illustrated by the ginkgophyte-conifer cork and its wood. They are found not only as isolated fragments in coal, but also form part of the axial organs of the plants — roots, branches and stems. In our opinion, we should consider cork and wood independent phyterals and should regard the abovementioned axial organs of which they are a part, as a combination of several phyterals forming a single anthracolemma.

Not very many publications are concerned with the description of phyterals in particular. As for the Carboniferous, we can point to the following papers: Hickling and Marshall (1933, 1934), Marshall (1955), Thiessen and Sprunk (1941) and the papers by some Soviet authors, such as Lapo (1968), Vyrvich and Lapo (1970), Drozdova *et al.* (1971), Uzijuk (1970); for the Mesozoic — Drath (1935) and Drozdova (1963, 1966, 1973); for the Cenozoic — Jurasky (1936), Navale (1968, 1973, 1974a, 1974b) and Mikhelis (1975). A brief account of the methods of phyteral analysis together with the description of the most characteristic phyterals of coals of different geological ages is given in the monograph by Ginzburg *et al.* (1976).

We have studied the phyterals of two coalfields of the Tuva, USSR (Southern Siberia, near the border of the USSR and Mongolia), i.e. the phyterals of the Ulugkhem basin and those of the Chadan deposit. In the Ulugkhem basin the coals of the major seam "Ulug" were studied. The thickness of this seam is about 7 m and is composed of the coals, containing great amount of vitrinite (up to 97%). The coals range from the gas flame ones in the north-east of the basin (the Kaakhem deposit, locality 1) to the short flame ones in the south-west (the Elegest deposit, locality 2). Fat coals of the "Chadan" seam in the Chadan deposit (locality 3) have been studied. The thickness of this seam is upto 13·4 m. In comparison with the coals of the "Ulug" seam of the Ulugkhem basin, these coals are characterized by a higher content of fusinite (up to 25% in type samples) and of micrinite (up to 25%). The content of macerals of the liptinite group in them is not high (up to 3%).

TABLE 1 — CLASSIFICATION OF PHYTERALS OF JURASSIC COALS OF TUVA

GROUPS	SUBGROUPS	PHYTERALS	COMBINED OCCURRENCE IN A SINGLE ANTHRACOLEMMA	CHARACTER OF THE PRESERVATION (END MEMBERS)
1. Phyterals of leaves	—	a) Lycopod phylloids	—	Vitrinized, fusinized
		b) Gymnosperm leaves	—	Vitrinized, fusinized
2. Phyterals of axial plant organs	A. Phyterals of protective plant tissues	c) Ginkgophyte-conifer cork	with wood	Vitrinized, semivitrinized
		d) Gymnosperm cortex	—	Vitrinized, fusinized
	B. Phyterals of conductive plant tissues	e) Ginkgophyte-conifer wood	with cork	Vitrinized, fusinized
		f) Osmundaceae petioles	—	The bundle is fusinized, the parenchyma is vitrinized
3. Phyterals of unestablished plant organs	C. Phyterals of mechanical plant tissues	g) Sclerenchyma component parts	—	Vitrinized, fusinized
		h) Gymnosperm sclereids	—	Vitrinized, fusinized

The investigation of the phyterals of the Tuva coals was carried out on the basis of the thin sections polished from both sides, in the common or polarized light. Apart from the vertical* thin sections, we paid great attention to the investigation of the horizontal ones since there the majority of phyterals is represented in the longitudinal sections, whereas in the vertical ones this can be observed for the most part in the oblique sections (Lapo, 1973). The phyterals were preliminarily distinguished with reference to their morphological characteristics, and then identified with this or the plant tissue and plant taxon with different degrees of accuracy. During this investigation we made use of botanical literature and also consulted some Leningrad botanists, such as I. N. Drozdova, V. G. Lepechina and N. S. Snigirevskaya, to whom the author is very grateful.

The phyterals which are described below are represented in Table 1. The individual phyterals are united into subgroups on the basis of the initial plant tissues (conductive, protective, mechanical tissues and parenchyma) and into groups, on the basis of the plant organs. Since we are faced with fundamental difficulties when we are to distinguish roots, small twigs and stems in coal thin sections, an undifferentiated group of phyterals of the axial plant organs is established.

On the other hand, two individual phyterals (sclerenchyma component parts and gymnosperm sclereids) cannot be positively referred to any definite plant organs. They are distinguished into a special group.

The mode of preservation of the plant tissues is reflected in the last column on the right of the Table 1 given above. Some plant organs are known in the form of both vitrinized and fusinized phyterals, as well as in the intermediate forms — semivitrinized and semifusinized ones. The gradual transition from vitrinite to fusinite can sometimes be observed within the single phyteral. Osmundaceae petioles represent a special case (see Table 1).

The association between the individual phyterals was calculated with the help of the statistical methods on the basis of their joint occurrence in thin sections. The coefficient of pair-association (Q) was calculated according to Yule and Kendall's formula (1953):

$$Q = \frac{(AB)(\alpha\beta)-(A\beta)(\alpha B)}{(AB)(\alpha\beta)+(A\beta)(\alpha B)}$$

*Thin sections of coal, prepared perpendicularly to the bedding plane, are conventionally called vertical thin sections, and the thin sections within the bedding plane are called horizontal ones.

In our case:

AB — the number of thin sections where both studied phyterals are found;

$\alpha\beta$ — the number of thin sections, where both phyterals are absent;

$A\beta$, αB — the number of thin sections, containing either only the first ($A\beta$), or only the second (αB) of the studied phyterals.

Limiting Values — 1 (the complete negative association) and +1 (the complete positive association). The first case means that the phyterals are not found in common (i.e. in the same thin sections), the second one means that they are encountered only together with each other.

The values, obtained for Q in the vitrinized phyterals are listed in Table 2 (with the exception of the Osmundaceae petiole which is found in rare instances). The presence of the close positive association between the phyterals can testify to the fact that the initial plants belonged to one and the same plant community (with coal matter accumulating in an autochthonous manner). In a more particular case these phyterals are the remains of one coal-forming plant.

I. PHYTERALS OF LEAVES

Two phyterals of this group are described which differ considerably as regards their characteristic features.

Lycopod Phylloids (Pl. 1, figs. 1-4) — Both vitrinized and fusinized lycopod phylloids have been found (Pl. 1, fig. 3). Vitrinized phylloids are composed of parenchymatous tissue (often very light); and in vertical thin sections they have the form of lenses with wavy contours. These lenses are for the most part (but not always) surrounded by a thin cuticle (Pl. 1, fig. 1).

The thickness of lenses is about 100 μ (80-160 μ) and the length varies greatly (from hundreds of microns to several millimetres) depending on the direction in which the section was made. The loose structure of the mesophyll is quite typical, as well as a great amount of intercellular ducts (Pl. 1, fig. 2). In some cases, the structure of the tissue is more ordered and the light epidermis cells are seen. In the central part of the phyteral we can usually observe almost a structureless part around which mesophyll cells are grouped. Apparently, this part corresponds to the bundle, which is unique in the lycopod phylloids. The considerable looseness of the mesophyll is rather well seen on the sagittal cuts in horizontal sections (Pl. 1, fig. 2). Vitrinized lycopod phylloids are part of the parenchinite paragenetic association of microcomponents (macerals) (Lapo, 1975b).

Fusinized and semi-fusinized phylloids have a similar structure, but their colour is different. They are usually concentrated in coal in the form of clusters together with vitrinized phylloids in definite microinterbeds (Pl. 1, fig. 3).

This phyteral in the Jurassic coals of Siberia was first determined by Drozdova (1973, pl. 16, figs. 1-7); its microphotos can also be found in a paper by Korzhenevskaja, Bogdanova and Lapo (1975, pl. 4, fig. 6; pl. 6, figs. 9, 14).

Gymnosperm Leaves (Pl. 1, figs. 5-6) — This phyteral is rather rare. Vitrinized phyterals are thin leaves, surrounded by cuticle and containing several vascular bundles or/and rounded bodies of poor preservation. The leaves are thinner than

TABLE 2 — COEFFICIENTS OF PAIR-ASSOCIATION (Q) BETWEEN VITRINIZED PHYTERALS*

Vitrinized phyterals	N	1	2	3	4	5	6	7
Lycopod phylloids	1		0	0	1	0	−1	−1
Gymnosperm leaves	2			−0·36	0·64	0·58	0	0
Ginkgophyte-conifer cork	3				0	0	0	0
Gymnosperm cortex	4					0	−1	0·64
Ginkgophyte-conifer wood	5						0	0
Sclerenchyma component parts	6							−0·25
Gymnosperm sclereids	7							

*Weak association with Q</0·25/ are designated by 0.

the vitrinized lycopod phylloids: 20-75 μ; their length is usually great (the prevailing length amounts to several millimetres). On the cross sections the form of the cut is close to a triangular one. The vascular bundles preserve their structure but seldom. They, for the most part, have the form of dark (in the translucent light) elliptical bodies which vary in number from 1 to 6. Sometimes resinous bodies are present in this type of leaves (Pl. 1, figs. 5-6). The tissue is not so loose as that of the phylloids and is composed of the cells of elliptical form. Sometimes the cell structure of the tissue cannot be distinguished.

The considerable length of these leaves, the presence of resinous bodies and a great number of bundles make it possible to identify the studied phyteral with the conifer leaves described by Drozdova (1973, pls. 12-13) in the Mesozoic coals of Siberia. Due to the investigation of the microstructure of leaves, composing the weathered paper coal, the presence of resin in ginkgophyte leaves has been proved. But the specific features of these leaves have not been revealed. Because of the absence of the diagnostic features on the basis of which the leaves of conifers, ginkgophytes and other gymnosperms can be distinguished in the coal thin section, the described phyteral is determined as the gymnosperm leaves which cannot be defined more exactly. Not only vitrinized, but also fusinized gymnosperm leaves are found in the Tuva coals. They have similar features, but are devoid of resinous inclusions.

Gymnosperm leaves are characterized by a clear positive association (see Table 2) with the gymnosperm cortex and the ginkgophyte-conifer wood. However, with the other phyteral of gymnosperms the ginkgophyte-conifer cork and their association is negative. Apparently, the cork producer is not the same one as the producer of this phyteral.

II. PHYTERALS OF AXIAL PLANT ORGANS

The axial plant organs (stems, twigs and roots) can sometimes be seen in thin sections in the form of the whole cuts, including protective and conductive plant tissues. They are for the most part small organs of ginkgophytes-conifers. The size of their cross sections is several hundreds of microns. However, more often the phyterals of protective and conductive tissues occur in the coal separately.

Phyterals of Protective Tissues

Two phyterals of this type have been described. Both of them refer to gymnosperms.

Ginkgophyte-Conifer Cork (Pl. 2, figs. 1-2) — Both vitrinized and semivitrinized cork have been found in the Jurassic coals of Tuva. In the vertical thin sections of coal it is represented by lenses of the following size: along the short axis: about 100 μ (from 70 to ...150 μ); along the long axis — from hundreds of microns up to 1-2 mm (sometimes, smaller ones). The characteristic form of this phyteral (a slightly curved ones — Pl. 2, fig. 1a), observed in vertical thin sections, is caused by the fact that this phyteral is composed of the cork scales which have come off; they are the fragments of a cylinder with a large diameter. The phyteral is more rarely represented by oblate rings in the vertical thin sections or forms part of the single organs (twigs, roots or stems) together with the conductive tissues.

The structure of the tissue is usually easily distinguished (Pl. 2, figs. 1a, 1b). The tissue is composed of tabular crescentiform convexo-concave cells. They are arranged either one over another or in less regular columns. In the complete sections of the small stemlets (?) or roots (?) the cells may be concave both inside and outside. And the boundaries between the rows are on the radius to the axis of the stem. In the isolated anthracolemma of the cork these radial cell columns are either vertical or inclined. Sometimes their outline is rather intricate. In tangential sections of the tissue (in horizontal thin sections) the cells have an elongated rectangular or a polygonal form (Pl. 2, fig. 2). The maceral, referring to the group of vitrinite, of which this phyteral is composed was named phellinite by Drozdova (1963). Later on, this name was introduced into the classification of macerals of brown coals which is accepted as the state standard of the USSR (Gost 12112-66).

The described phyteral is the characteristic of the Mesozoic coals in many basins and deposits of the USSR. Drozdova determined phellinite as vitrinized ginkgophyte-conifer cork (phellema) on the basis of the multilayered tissue structure and its occurrence in the reliably diagnosed ginkgophyte-conifer cork.

Vitrinized and semivitrinized ginkgophyte-conifer cork is one of the most widely spread phyterals of the Tuva coals. However, in the papers by Larishchev (1971, etc.) its coal-forming role is obviously exaggerated. Phellinite in the Tuva coals is found only in the form of small lenses. And it is not likely that it participates in the formation of the heterogeneous basis, as is proposed by Larishchev. During the statistical processing of the data of coal petrography it was established that there is either no positive association between the ginkgophyte-conifer cork and other vitrinized phyterals, or this association is negative. Larishchev considers vitrinized ginkgophyte-conifer cork to be the major coal-former. If it is so, how can we explain so obvious an antagonism which exists between the cork and all the other phyterals.

Gymnosperm Cortex (Pl. 2, figs. 3-5) — Both vitrinized and fusinized gymnosperm cortex are found in the Jurassic coals of Tuva; they differ greatly as regards their characteristic features.

Vitrinized cortex (Pl. 2, fig. 3) is a plant tissue of a complex structure. It is found in the form of bands (the thickness of which is 0·8 mm), extending through the whole of the thin section, and also in the form of lenses 100-200 μ thick and with the extension varying from 0·5 to 3·5 mm. The tissue is composed of three types of cells. The cells of the first type are the lightest; apparently they represent a periderm. They are of a tabular outline and form two- and three-layered rows of cells which are clearly distinguished in the thin sections (from the three-dimensional point of view they are plates); they subdivide the tissue into separate parts, the thickness of which is 80-150 μ. Apparently, it was just along these plates that the tissue disintegrated into separate scales.

Those parts of the tissue which are delimited by the periderm are in their turn composed of two types of cells. The cells of the first type are smaller and flattened out (their long axis is on the bedding or oblique to it); they form the "main background" of the plant tissue. Their cell cavities are strongly compressed and are usually filled by a semitranslucent matter. The cells of the second type are larger. They are of a sclerenchymatous outlook and form isolated groups which consist of approximately 10 cells, the long axes of which are parallel to one another and are perpendicular or oblique to the bedding plane. The cells are characterized by a rectangular outline and are tightly pressed to each other by the long sides of the rectangles. The cell cavity is usually completely closed, it is gaping but rarely. In those places where groups of sclerenchyma cells are found the parts limited by the periderm extend. Due to this phenomenon their form in the thin sections becomes undulated. Sometimes one can watch a gradual transition from vitrinite to fusinite within one anthracolemma.

This phyteral has not been described in literature. Its general structure reminds one of the scaly cortex of the living *Oak*. On the basis of this feature we referred it to the cortex. The complexity and the likeness of the tissue structure with that of the living plants made it possible to refer this phyteral presumably to the most progressive class of the Jurassic plants — gymnosperms. The close positive association of this phyteral with the vitrinized gymnosperm leaves is a certain indirect evidence of such an identification. Besides, the vitrinized gymnosperm cortex also reveals the positive close association with the gymnosperm sclereids. Among the Tuva coals this phyteral is found only in the Chadan ones. It is highly probable that it is characterized by a rather narrow stratigraphic or and regional distribution.

The fusinized gymnosperm cortex (Pl. 2, figs. 4-5) is found in the form of anthracolemma with a characteristic cell structure. It is rather a rare phyteral of the Tuva coals as well as the vitrinized cortex.

Phyterals of Conductive Tissues

Two phyterals of this subgroup are described.

Ginkgophyte-Conifer Wood (Pl. 3, figs. 1-3) — This phyteral can be encountered in two forms of preservation: the vitrinized and the fusinized one, the vitrinized phyteral being one of the most wide spread phyterals of the

Tuva coals. It is found for the most part in the form of lenses and the thickness of which is 200-400 and the length amounts to several millimetres. No case of ginkgophyte-conifer wood extending through the whole of the thin section has been observed.

The phyteral is characterized by a clear cell structure (Pl. 3, fig. 1). The strongly flattened tracheids are distinctly seen; their cell cavity is filled up by a substance which is darker than the cell walls (in the translucent light). Sometimes (rather rarely) uniseriate rays, consisting of 3-6 cells, can be observed. At one moment they are lighter (in the translucent light) than tracheids, at another moment — darker. On the basis of the strong predominance of tracheids in the composition of the phyteral we can identify it (following Drozdova, 1973, pl. 1) as vitrinized ginkgophyte-conifer wood. With the exception of gymnosperm leaves it does not reveal any positive association with the other phyterals.

Fusinized wood which is encountered more rarely than the vitrinized one is characterized by an excellent preservation of the plant structure (Pl. 3, figs. 2-3). In the horizontal thin sections cross fields can also be observed (Pl. 3, fig. 2).

Petioles of Osmundaceae (Pl. 2, fig. 6) — The phyteral was found in isolated cases in the form of a fragment with the length of 700 μ and the thickness of 110 μ. It is surrounded by a thin cuticle and includes a lenticle of fusinite which is the product of the preservation of the bundle and its sclerenchymatous sheath. The identification has been carried out on the basis of the resemblance between the phyteral structure and the cross section of the Mesozoic Osmundaceae (Kidston & Gwynne-Vaughan, 1907; Archangelsky & del la Sota, 1963; Gould, 1973).

III. PHYTERALS OF UNESTABLISHED PLANT ORGANS

Phyterals of this group are the remains of mechanical tissues. They are easily identified on the basis of their morphological characteristics. However, the problem of the taxonomic affinities of the initial plants has not been solved yet.

Sclerenchyma Component Parts (Pl. 3, fig. 4) — Small amounts of a vitrinized phyteral, which formed from the peculiar mechanical tissues, were found. The same tissues are present in the form of semifusinite (Pl. 3, fig. 4); one can observe a continuous series of transitions from vitrinized phyterals to semifusinized ones (sometimes within one and the same anthracolemma). The phyteral has a form of a flattened thick ring with the following dimensions: along the long axis — —1-2 mm, along the short axis — 0·3-0·5 mm. The inner cavity is not large and has an elliptical shape with a strong elongation along the horizontal axis. The thickness of the walls of the ring is about 0·1-0·2 mm. Sometimes we can distinguish two types of cells there. In the peripheral part of the ring the cells are larger, and the cell cavities are filled by mobilinite. In the central part the cells are smaller and flattened. In some cases there is an elliptical body (with the dimensions of $80\text{-}150 \times 350\text{-}500$ μ), characterized by the same tissue structure as the outer ring, inside the ring broken from one end. Both the fragments of the outer walls and those of the inner elliptical body can be found in an isolated form in the heterogeneous coal base.

This phyteral has been described in detail by Drozdova (1966, 1973) in the Mesozoic coals of Siberia; she defines it as the sclerenchymatous sheath of marrattiaceous ferns. But on the basis of the observations made by Drozdova we can draw a conclusion that sometimes a yellow (in the translucent light) substance from the liptinite group is found in the central part of the phyteral. This strange circumstance, and also the resemblance between the microscopic structure of this phyteral and the vitrinized seeds of some plants do not allow us at present to solve the problem of its origin exactly. That is why we make use of rather an indefinite term "sclerenchyma component parts", and do not go into any details as regards their nature.

In the course of the statistical treatment the positive association of the sclerenchyma component part with the vitrinized gymnosperm cortex has been revealed. They are characterized by a predominant confinement to the layers of coal seams, adjacent to rock interbeds (the same phenomenon is observed in the Lower Cretaceous coals of the Zyrjanka basin in Yakuta). Apparently, the period of accumulation of material in these interbeds was characterized by the conditions which were critical for coal formation, and in particular, by a great flowing of the environment.

Gymnosperm Sclereids (Pl. 3, figs. 5-6) — This vitrinized phyteral occurs in coal for the most part in the form of isolated fragments, the thickness of which is 100-250 μ and the length about several hundreds of microns. The phyteral is vitrinized plant tissue which is composed of sclereids pressed tightly to one another. They are rounded or rounded-angular. The cells are thick-walled, and the pores are present in the cell walls (Pl. 3, fig. 6). The cell cavity is clearly seen and is filled with mobilinite which is lighter (more rarely — darker) than the substance of the cell walls.

It is known that sclereids in the form of isolated cells and cell groups are a component part of different plant tissues and organs (Rao & Bhupal, 1973). In the Mesozoic coals of Siberia they are found in the form of isolated fragments both in the heterogeneous matter and in the composition of ginkgophyte-conifer cortex (Drozdova, 1963, fig. 3; Drozdova, 1973, pls. 7-8). In the Permian coals of India sclereids are also associated with the cortex tissues (Ganju, 1955, p. 85, pl. 2, figs. 1-3). We have observed that mechanical cells, which are similar to the described sclereids, are present both in vitrinized conifer branch wood (the Bogoslovsk deposit, in Northern Ural, Lower Mesozoic) and in vitrinized cortex (the Zyrjanka basin, Lower Cretaceous). That is why we leave the question open concerning the origin of this phyteral from the tissue of cortex and wood.

The statistical treatment showed that there is a close positive association between vitrinized gymnosperms sclereids with their vitrinized cortex (Table 2). The phyteral is a part of the composition of attrit-desmitvitrinite paragenetic association of microcomponents (macerals) (Lapo, 1975b).

While analysing statistically the frequency of occurrence of the described vitrinized phyterals we came across some interesting observations. For instance, a positive association between some vitrinized gymnosperm phyterals was revealed: their leaves and cortex, ginkgophytes-conifer leaves and wood. On the basis of the presence of these associations one can not naturally draw any unique conclusion as regards the fact that they were produced by a common coal former. The growth of different initial plants in one and the same plant community is also highly probable. As for the associations between the ginkgophyte-conifer cork, sclerenchyma component parts and gymnosperm sclereids, probably, there is direct evidence of the correlations of those plant tissues which turn out to be the most stable ones during the process of decomposition.

On the basis of the investigations it appears possible to answer the following question in a preliminary way: Was the Jurassic coal-forming vegetation of Tuva a forest one? This can be established through the following calculation:

$B = W + AF$, where

B — the whole of the biomass formed by one tree during its life;

W — once measured volume of the whole tree;

F — the volume of annual fall;

A — the age of a tree.

The volume of the trunk (T) of living trees amounts to about $0{\cdot}65W$ (Pozdnjakov, 1973). The fall (F) of the living *Thuja* is equal to $0{\cdot}21W$ (Reiners, 1974). The age of the Jurassic trees, established on the basis of counting of annual rings in the mineralized trunks from Chadan deposit, was about 50 years.

Consequently, had the Jurassic coal-forming plant associations been forest ones (similar to contemporary coniferous woods), the contents of trunks in the whole of their biomass could be calculated in the following way:

$B = W + A.F = W + 50.\ 0{\cdot}21W = 11{\cdot}5W$

$W = B{:}11{\cdot}5 = 0{\cdot}09.B$

$T = 0{\cdot}65.W = 0{\cdot}65.\ 0{\cdot}09.\ B = 0{\cdot}06.B$, or

$T = 6\%\ B$

Thus, if the Jurassic coal-forming plant communities were forest ones with a weakly developed under-growth, and the degree of decomposition of different plant tissues was more or less equal, then the general content of pycnoxylic trunks in coal would be approximately 6%*. However, in fact, the content of pycnoxylic vitrains in Tuva coals is many times less. This means that the Jurassic coal-forming vegetation of Tuva was not a forest one. Apparently, this vegetation was a shrubby (probably an

*In contemporaneous forest peats of the moderate zone, the contents of wood remains can be much greater: 40-50% and even more (Turemnov, 1949).

undershrub) or a herbaceous one. The phyteral analysis of coals has shown that it consisted of gymnosperms, lycopods and ferns.

The data cited above show that it is possible to determine a phyteral in the thin sections even in coals with high coalification degrees, such as fat and short flame ones. The phyteral composition of the Tuva coals turned out to be rather variegated. It seems to us that besides palaeobotanical reconstruction (Lapo, 1975c), the studies of the phyteral composition of coals can be used not only for some purposes of stratigraphy, but also for the prediction of the coal properties (Lapo, 1975a).

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EXPLANATION OF PLATES

Plate 1

1. Vitrinized lycopod phylloid, surrounded by a thin, dark cuticle. Locality 2, vertical thin section El-6. × 55.

2. Vitrinized lycopod phylloid in a sagittal section. Locality 2, horizontal thin section El-19b. × 80.

3. Vitrinized (a bit below the centre) and fusinized (in the upper and lower parts) lycopod phylloids. Locality 2, vertical thin section El-6. × 55.

4a. Vitrinized lycopod phylloid. Locality 2, vertical thin section El-78a. ×110.

4b. A detail of fig. 4a. × 440.

5. Vitrinized gymnosperm leaf with a resinous body (in the centre), surrounded by a thick, dark cuticle. Locality 2, vertical thin section El-5. × 185.

6. The complete section of a vitrinized gymnosperm leaf with two resinous bodies. Locality 2, vertical thin section El-5. × 130.

Plate 2

1a. Semivitrinized ginkgophyte or conifer cortex. The section is close to the cross sections. Locality 2, vertical thin section El-10. × 330.

1b. A detail of fig. 1a. × 1000.

*Sampling points are given on page 3. All microphotos are taken in double side polished thin sections in the polarized translucent light with the paralleled nicols.

2. A tangential section of vitrinized ginkgophyte or conifer cork. Locality 2, horizontal thin section. El-19b. × 330.

3. Vitrinized gymnosperm cortex. Locality 3, vertical thin section Cha-7a. × 250.

4. Fusinized gymnosperm cortex with the cell cavities filled by carbonates. Locality 2, horizontall thin section. El-55b. × 55.

5. Fusinized gymnosperm cortex with the ceil cavities filled by carbonates. Locality 2, hor-. zontal thin section. El-55b. × 40.

6. Vitrinized Osmundaceae petiole with a fusnized bundle and its sclerenchymatous sheathi Locality 3, vertical thin section. Cha-7a. × 100·

Plate 3

1. Longitudinal section of vitrinized ginkgophyte or conifer wood. Locality 3, horizontal thin section. Cha-24b. × 250.

2. Fusinized ginkgophyte or conifer wood in a tangential section. Locality 1, horizontal thin section. Ka-8b. × 55.

3. Fusinized Ginkgophyte or conifer wood in a longitudinal section. Locality 2, horizontal thin section El-55b. X 55.

4. Semifusinized sclerenchyma component part. Locality 3, vertical thin section. Cha-29. × 80.

5. A nest of vitrinized sclereids. Cell cavities are filled by light mobilinite. Locality 2, vertical thin section. El-43. × 130.

6. A nest of vitrinized sclereids. Pores are seen on the cell walls. Locality 3, vertical thin section. Cha-21. × 330.

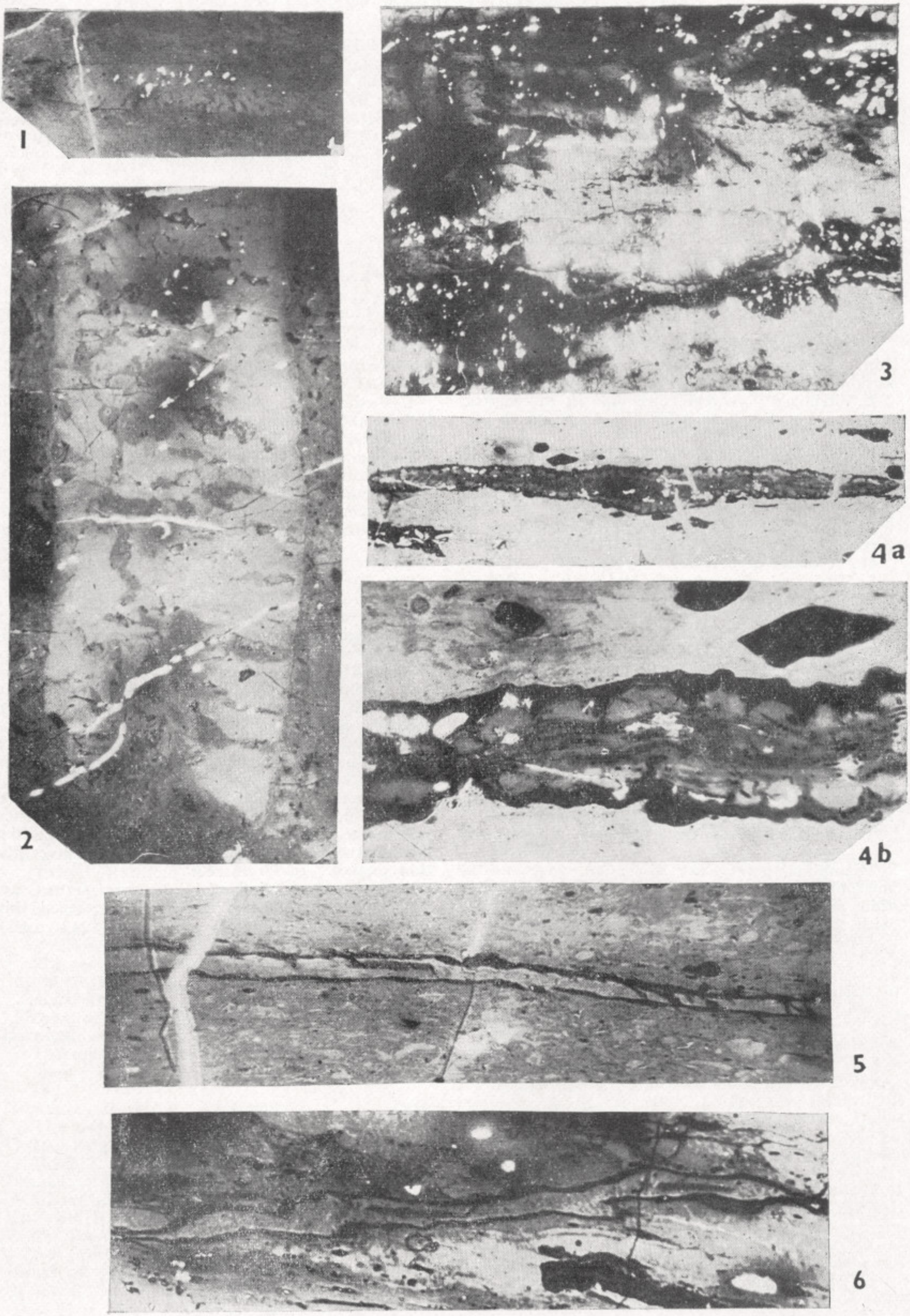

PLATE 1

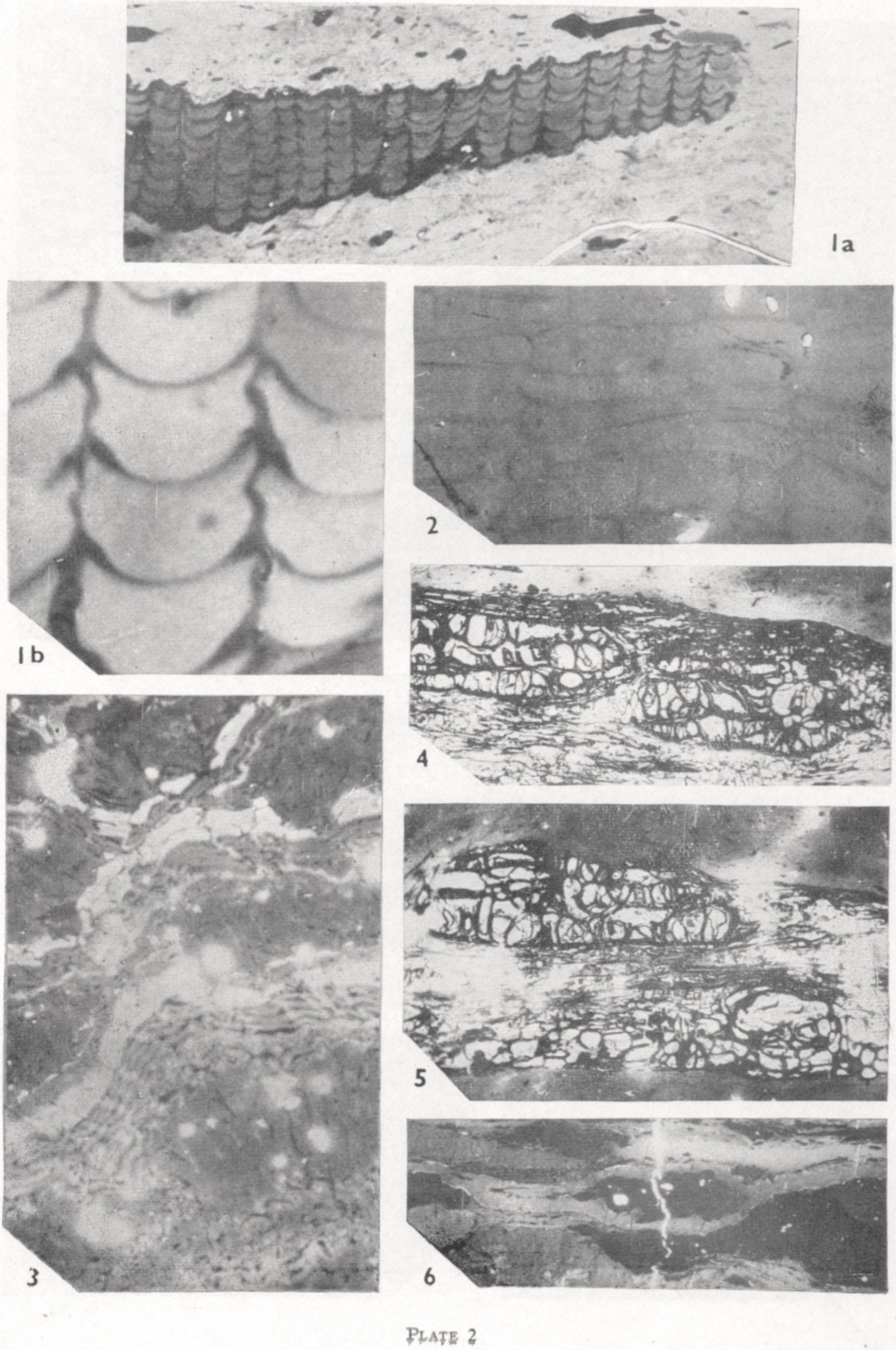

PLATE 2

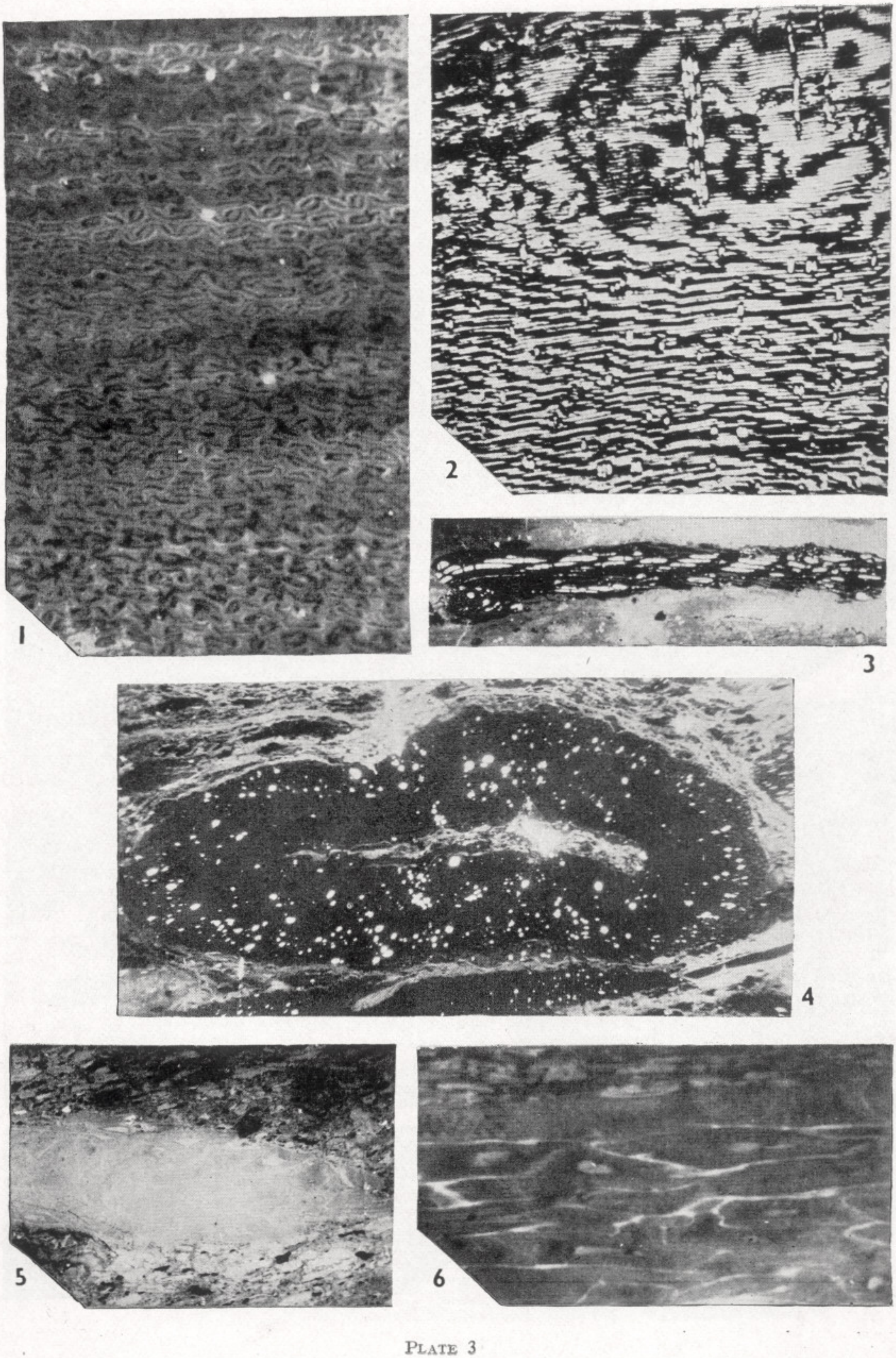

PLATE 3