STRATIGRAPHY AND FLORA OF CRETACEOUS VOLCANOGENIC SERIES IN NORTHEASTERN RUSSIA

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ABSTRACT

Modern problems of the paleofloristic method in stratigraphic analysis of Cretaceous non-marine sediments are presented. The peculiarities of formation of volcanogenic series and fossil plant burials are analyzed. Representatives of relict forms that are not observed in coal-bearing series, are found among the plant remains of coeval volcanogenic series. There is suggested a hypothesis on the two types development of flora: (i) in the calm environment of coastal plains and (ii) in the critical environment of terrestrial volcanism.

INTRODUCTION

Late Mesozoic non-marine sediments are wide-spread in northeastern Russia. They are represented by terrigenous coal-bearing, volcano-sedimentary, and volcanogenic series. Only plant leaf impressions occur as representatives of organic remains, both in coal-bearing and volcanogenic rocks. At the end of the 1960's, the paleofloristic method for subdivision and correlation of continental sediments at the regional and local levels was put into geological practice. By this time, Samylina (1974) had established the stage-line (stratoflorae) of ancient flora development from the Late Jurassic to Turonian, inclusive. Sedimentary layers representing every stage were distinguished as horizons (Decisions..., 1978). Subsequently, phytostratigraphic charts for the Okhotsk-Chukchi Volcanic Belt (OCVB) and the Anadyr-Koryak folded region were constructed by Lebedev (1987), Herman (1993), and Golovnyova (1990). Based on the history of geologic development during Cretaceous time and the composition of the sections, we distinguish three subregions in northeastern Russia: (1) the Verkhoyansk-Chukchi subregion - a terrigenous, coal-bearing series; (2) the Okhotsk-Chukchi subregion - composed of terrigenous, coal-bearing, volcanogenic-sedimentary deposits and predominantly volcanogenic rocks in the OCVB; and (3) the Anadyr-Koryak subregion - a terrigenous, coal-bearing series and marine sediments (Herman, 1993).

Analysis of all data obtained by the beginning of the 1990s, resulted in the use of the paleofloristic method as the major analytical tool to determine the age and correlation of late Mesozoic continental sediments in the region. Other methods of correlation and dating are not as commonly used in the region. However, problems of age and position in the evolutionary sequence of some stages of flora development (Samylina, 1986, 1988; Filippova, 1991) are not solved. Recently obtained data (Belyi, 1994; Herman, Shchepetov, 1994; Markevich, 1990; Shchepetov, 1991 a,b; 1994; Shchepetov et al., 1992) extend the limits of traditional ideas on biostratigraphy of non-marine sediments. These data make it possible to propose the coexistence of florae of various types that are usually considered to be developmental stages of different ages. The author has elaborated and suggested for discussion the basis for the new regional stratigraphic chart of the continental Cretaceous of northeastern Russia. It is generalized in Figure 1.

SHORT DESCRIPTION OF NEW PALEOFLORISTIC AND STRATIGRAPHIC DATA

During the time since publication of the stratoflorae concept (Samylina, 1974) and its public recognition (Decisions..., 1978), a great amount of geological work and special paleofloristic and stratigraphic investigation was carried out. The analyses of their results show the following:

(1) According to paleobotanic data, the following evolutionary line of paleoflorae of late Mesozoic age is recognized in the region: *pezhenka - ozhogin - silyap - buor-kemiuss - toptan - arman - grebionka - penzhina - kajvayam - barykov - gornorechensk - koryak*. The systematic composition of *arkagala* flora does not help to define the succession or share any similarity with this succession of flora. After determining the time of existence of *grebionka* flora (Shchepetov et al., 1992), a generally sharp change in paleoecological environment that might have interrupted the process of normal evolution and resulted in the appearance of *arkagala* flora, becomes unimportant. This phenomenon did not manifest itself in the florae of the Anadyr-Koryak subregion. It was assumed that *arkagala* flora existed before the beginning of continental sedimentation in the Anadyr-Koryak subregion (i.e., earlier than *grebionka* flora). However, now this suggestion is not considered probable due to the analyses of both paleobotanic and geological data.

(2) Several local-florae are recognized by the consistency of their plant remain complexes of similar general composition (the most studied are *teukich* and *palyavaam* florae). These florae contain abundant representatives of relict genera that predominate in burials and characterize these burials as belonging to the Jurassic and Early

Cretaceous, but not the second half of Cretaceous period. However, these florae representatives contain needle and angiosperms with evolutionary young appearance. It is an established fact that the stratigraphic position of *palyavaam* flora burials is higher than layers with the *qereuxia* and *metasequoia* (Shchepetov, 1991a,b).

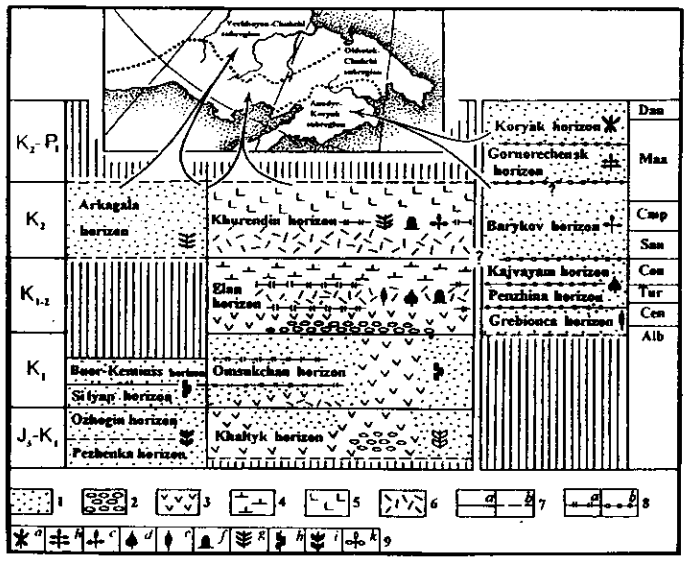

Fig. 1. Correlation of stratigraphic units of non-marine deposits of the Verkhoyansk-Chukchi, Okhotsk-Chukchi and Anadyr-Koryak subregions. Predominate rocks: 1 - sedimentary, 2 - volcanic and sedimentary undivided, 3 - intermediate volcanic (without making more precise), 4 - mainly two-pyroxene intermediate volcanic, 5 - mainly olivine intermediate and basic volcanic, 6 - felsic volcanic; 7 - location of boundaries of main stratigraphic units (horizons): a - ascertained, b - suggested; 8 - location of boundaries of other stratigraphic units: a - additional units (sub-horizons), b - special units (phytohorizons); 9 - symbols of fossil plant assemblages attributed to following states of flora development: a - Koryak (Rarytkin), b - Gornorchensk, c - Barykov, d - Penzhina, e - Grebionka and Arman, f - Chauna, g - Arkagala, h - Toptan, Buor-Kemiuss and Silyap, i - Pezhenka and Ozhogin, k - open symbols are possible analogues of these fossil plant assemblages.

(3) Recently collected data (Belyi, 1994; Lebedev, 1987; Markevich, 1990; Shchepetov, 1991a,b; 1994; Shchepetov et al., 1992), and the results of paleo-magnetic, palynologic, and geochronologic investigations, show the layers containing the *delokachan* and *ust-emuneret* floristic plant remain complexes (typical plant complexes of the *arkagala* stage of flora development and the *barykov* complex), are coeval. Not all dates are similar and equivalent, but the fact that they are coeval is proven by each independent method. This coincidence is not occasional. Thus, by separate methods, the stratigraphic level that in the Okhotsk-Chukchi subregion corresponds to the geological boundary between the "upper" series (Fig. 1) of felsic volcanics and the olivine basalt sheets, has been recognized. At this stratigraphic level, there were florae of two types - *arkagala* (burials of ola suite) and *barykov* (*delokachan* and *ust-emuneret* plant remain complexes), and probably also flora of *chauna* type (burial in the layers of Yana plateau suite). By systematic composition, they have a different age.

FORMATION OF VOLCANOGENIC SERIES AND PLANT BURIALS

The taphocoenosis composition within the Mid-Cretaceous terrestrial volcanics of the Okhotsk-Chukchi subregion is due both to its age and other factors, (i.e., ecologic environment and burial conditions). This information can be obtained from the lithologic characteristics of flora-bearing rocks. But, usually this information is not taken into account, because there is a common viewpoint that it is sufficient to have only a detailed palynologic sampling.

By analogy with the modern processes in the Vostochny Range on the Kamchatka Peninsula (Melekestsev et al., 1974), we can assume that the Late Albian - Late Cretaceous volcanogenic series of the Okhotsk-Chukchi subregion fixed the periods of equilibrium processes of volcanic accumulation, denudation, and tectonic movements. Persistence along strike of the series forms when the accumulation rate of volcanic material is higher than its removal. At a certain point in time, there is an abrupt slow-down of the fluvial processes due to disappearance or attenuation of the localized run-off in the upper relief stage. This, in turn, hampers slope denudation. As a result, volcanic plateaus or vast plains form. These plateaus may have existed a long time, especially if they were protected by overlying lava sheets. The vegetation of these plateaus are fixed by the burials of *arkagala*-type flora or plant complexes that are considered to be transitional florae between *arkagala* and *arman* types. These burials are usually confined to basal volcanic and volcano-sedimentary strata of the volcanogenic series, where the plants formed during a disequilibrium period at the beginning of the deposition of a new series.

Essentially *Filices taphocoenoses* of the *chauna* flora and *teukich* plant remain complexes are confined to tuff bands. The character of burial impressions makes it possible to propose that they are the pioneer plants, which occupied a surface without a humic layer during a break before the deposition of subsequent ash material.

In addition to the two burial types under consideration (symbolically "a," and "b"), there are often burials in the terrigenous coal-bearing series and volcano-sedimentary deposits of pre-volcanogenic molasses ("c"). It is interesting to note, that plant remain complexes from burials of one type and from different stratigraphic levels, are sometimes more similar than the complexes from one stratigraphic level and of different burial types.

Thus, plant remain complexes of the *chauna* type (burials "b") were recognized in rocks that replace one another along the section of *alkakvun, kalenmuvaam, pykarvaam, voronyin* and *koekvun* suites (Shchepetov, 1991 b; 1994); plant remain complexes of *aliki* flora (burials "a"), were recognized in the layers of *gidra, yum* and *kanayga* suites (Shchepetov, 1991a). In the Viliga and Tumany interfluve (Shchepetov, 1991a), at the base of the lower series of intermediate volcanics and just above the washed-out surface of *verkhoyansk* complex, the following complexes are recognized; (1) within the Mongke River - one of the *aliki* flora plant remain complexes (burial "a"); (2) within Teukich Creek - a unique plant complex of the same name with a contrasting combination of ancient and young forms, and abundant new species that have no analogues in the region (burial "b").

TWO TYPES OF FLORA DEVELOPMENT

The characteristics under consideration and the differences in systematic composition of coeval floristic complexes in the Anadyr-Koryak and Okhotsk-Chukotsk subregions (Fig. 2), cannot be explained by traditional ideas of Mid-Cretaceous flora development. It has been proposed that this is a case of the manifestation of two evolutionary types; the coherent and the noncoherent (Krasilov, 1986; 1992). We identify the first type in the terrigenous coal-bearing series of the Verkhoyansk-Chukchi and Anadyr-Koryak subregions, where plants of the structurally stable ecological community are represented in burials. The noncoherent-development type is observed in the burials of volcanogenic series, where taphocoenoses convey information on the composition of plant communities during disruption of the ecological system, caused periodically by an increase in volcanic activity.

Horizons of Verkhoyan-Chukchi Subregion	1 2 3 4 5 6	Horizons of Okhotsk-Chukchi subregion	1 2 3 4 5 6	Phyto-gorizons of Anadyr-Koryak subregion	1 2 3 4 5 6
				Koryak	+ + +
				Gornorechensk	+ + +
Arkagala	+ + + +	Khurendin	+ + + + + + +	Barykov	+ + +
		Elan	+ + + + + +	Kajvayam	+ + +
			+ + + + + +	Penzhina	+
				Grebionka	+ + +
Buor-Kemuss	+ +	Omsukchan	+ + +		
Silyap	+ + +		+ + +		
Ozhogin	+ + +	Khaltyk	+ + +		
Pezhenka	+ + +				

Fig. 2. Distribution of some characteristic elements of Mesophyticum (1-3) and Cainophyticum (4-6) in stratigraphic and biostratigraphic units of continental Cretaceous of the Russian North-East
1 - Phoenicopsis, 2 - Heilungia, 3 - Podoxamites, 4 - Metasequoia, 5 - Trochodendroides, 6 - Quereuzia.

Each stage of volcanism that formed the particular rock series was probably a catastrophe for the vegetable kingdom or a crisis of regional or subregional scale. The open ecological niches were first occupied by poorly specialized species, exhibiting pioneer features (probably representatives of *Czekanowskiales*, several kinds of *Felicales, Cycadophita*, and *Ginkgoales* plants had such features). These species provided the regeneration of plant communities. The plant remain complexes of *chauna* type were probably due to the same plant groups. These complexes fix the initial stage of the noncoherent development type. Other burials characterize the later stages of plant community regeneration where, together with the pioneer forms, abundant species and genera occurred, predominating in the ripe communities, particularly in the stable environment of the nearby Anadyr-Koryak subregion. With the exception of *chingandzha* flora of the Viliga and Tumany interfluve, there are no well documented illustrations of the complete regeneration in the Late Cretaceous of the Okhotsk-Chukchi subregion when relict forms rarely occur and are not preserved in the burials (Shchepetov, 1991a). *Chingandzha* flora of the Viliga and Tumany interfluve probably appeared in the relatively stable period of the final accumulation of pre-volcanogenic molasses before the first volcanogenic series formed.

CONCLUSIONS

According to two types of flora development during the Mid-Cretaceous period in the region, we agree with the viewpoint of Lebedev (1987) that while determining the age of plant remain complexes from a volcanogenic

series, it is necessary to pay attention not to the relict plant form, but to young, specialized ones. However, the presence of the latter in burials, testifies to not only the age, but the degree of surface development after the usual volcanic eruptions. Thus, there is a need to correct paleofloristic correlations of sediments of the Anadyr-Koryak and Okhotsk-Chukotsk subregions.

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