

FOREST FERNS OF THE CAUCASUS, ITS SYSTEMATIC
 AND ECO-GEOGRAPHICAL ANALYSIS

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Abstract. The forests of the Caucasus are one of the most important regions of the taxonomic diversity of ferns. Here are 70 species and 29 genera, or 64% of genera and 44% of species of ferns of Eastern Europe as given by Cherepanov, with exception of hybrid and adventive ferns [Cherepanov, 1995]. Critical revision of the forest ferns of the Caucasus made possible to identify two new genera in the flora of the region (*Cyrtomium*, *Onoclea*). In general, as a result of taxonomic revision of the number of fern families of the Caucasus increased from 4 to 20, and the number of genera - from 23 to 31. New for the flora of Eastern European were 20 species and hybrids of the species range, 5 subspecies: *Pteris vittata*, *Adiantum cuneatum*, *Cyrtomium falcatum*, *Dryopteris remota*, *D.caucasica*, *D.atrata*, *D.ambroseae* and others. For the first time in the Caucasus were found *Botrychium virginianum*, *Onocle sensibilis*, *Cystopteris dickieana* and *Dryopteris expansa*. The most favorable for the development and dispersal of ferns in the Caucasus were forest areas with moderately warm and humid climate. At the same time, along with the humidity, the most important factors that influence the spread of ferns were the degree of rocky and stony habitats and the nature of slope exposures.

Key words: Ferns, Taxonomy, Ecology, Rare species, Pteridoflora

Introduction. The fern being one of the most ancient groups of high plants take its beginning from Devon geological period (300 million years BC). More than 10000 samples belonging to 300 genera are spread around the world. The most of its species diversity and the forms of life (biomorphs) is in the tropical countries. The fern species is one of the main phyto-components among the plant cover, especially in forest plants. There is much kind of medicines, food, technical and decorative species among the ferns. We were researched the ferns before on the flora of Thalish and then on the flora of whole Caucasus since 1970. I was published the monograph "The ferns of Caucasus" in 1984. When I was doing these scientific researches the well-known researchers-professors of Caucasus A.A. Kolakovsky and A.G. Doluchanov gave me valuable advices about this.

Ecological groups of ferns – mesophytes,

xerophytes, mezoxerophytes, hydrophytes and geophiles were identified. Over 70% of the ferns of the region were mesophytes, typical for wooded ravines, riverside habitats and rocky - forest complexes. The main regularities in the distribution of ferns along vertical zones were determined. The richest in number of species were foothills and lower mountain (50 species, or 52% pteridophlora) and middle mountain (49 species, or 51.5%) zones. In the highlands, the number of species decreased. Of all types 8 were not typical for the forest zone. From forest ecotypes were particularly rich forest ravine (51 species), river valley (34 species). Lithophilous group includes 57 species, out of which 13 were calcephilous; epiphytes - 13 species, 23 species of forest ferns were found in secondary coenoses. This distribution of species probably was due to the peculiarities of climatic, orographic and other factors, as well as the main natural ecosystems

of the Caucasus Isthmus. Analysis of the distribution of fern species in botanical and geographical areas of the Caucasus showed that for the abundance of fern populations were allocated two provinces - Evksinski (Colchis) and Hirkanian, but for the number of species Colchis exceeded Talysh by more than 2 times (respectively 67 and 36 species). Colchis for the number of species followed by the rest of the Greater Caucasus (51 species) and forest areas of the North Caucasus (36 to 42 species). Respectively less ferns were in Ciscaucasia, Gobustan, Absheron, Nakhchivan (2 - 10 species). Thus, in the Caucasian isthmus number of species of ferns decreased with distance from the forest regions in the direction of semi-deserts and steppes. Arealogical and florogenetical analyzes established a connection with the forest ferns of the Caucasus and flora of the tropics and subtropics of Eastern Asia and South Paleartic on the one hand and South - West Asia and South Africa - on the other hand.

Materials and methods. The materials for research were herbarium materials and ecologic-botanic information collected by author from whole regions of Caucasus. As well as the herbarium fund materials which were kept the botanic institutes of Sankt-Petersburg Caucasus have been critically analyzed. Mostly were used from the classic- morphological and geographical methods in this work. Also were used from critical taxonomies comparative-morphological-anatomic, polynological, karyological and experimental methods. As well as there were used from areological, paleobotanic and florogenetical methods in the work.

Result and discussion. The main researcher of ferns was acad. A. Fomin [Fomin, 1913] in the former Soviet Union. He published the monograph "Pteridoflora of Caucasus" in 1911 and described 6 new species which is special for the forests of Caucasus: *Dryopteris raddeana*, *D. alexeenkoana*, *D. oreades*, *Polystichum woronowii*, *Asplenium pseudolanceolatum*, *A. hermannii-christii*. We meet some interesting information about ferns of Caucasus on the works of A. Qrossheym, A. Kolakovsky, I. Safarov, L. Piriipko [Kolakovsky

and Asgarov, 1981].

The taxonomic analyze of Caucasus ferns. 96 species of ferns belonging to 20 family and 31 genera have been found at the results of our researches in Caucasus. The 51 species from these is special for the forest phytosenoz. Numerous new genus and species have been found for the science and flora by the expeditions and researches keeping materials in the Herbaria funds. 8 new species and 2 species diversity have been described by us: *Polystichum kadyrovii*, *Polypodium issaevii*, *Polystichum x fominii*, *P. xsafarovii*, *P. xdmitrievae*, *D.x. doluchanovii*, *D.x. schorapanensis*, *D. xkolakovskiyi*, *Dryopteris raddeana* var. *talyschensis*, *Polypodium vulgare* var. *zuvandicum*.

The number of ferns families of Caucasus Flora increased from 5 to 20 and the genera from 23 to 31 compared to the current "flora" and "modifier". 2 genera have been new for Caucasus: *Cyrtomium* C. Presl., *Onoclea* L. But 20 new species and 2 half-species have been found for the past Soviet Union: *Pteris vittata*, *Adiantum cuneatum*, *Cyrtomium falcatum*, *Dryopteris remota*, *D. caucasica*, *D. atrata*, *D. ambroseae*, *D. x deweveri*, *D. x euxinensis*, *D. x initialis*, *D. x mantoniae*, *D. x sarvelae*, *Polypodium x mantoniae*, *P. x shivasiae*, *Polystichum x illiricum*, *P. x bicknellii*, *P. x luerssenii*, *P. x wirtgenii*, *Asplenium x ticinense*, *A. x centovallense*, *A. septentrionale* ssp. *coriacea* and ssp. *persica* [Asgarov, 1977]. A lot of new species and new spreading fields have been found for South and North Caucasus as well [Asgarov, 2001].

The rare and endangered species. Generally, the ferns were considered the group of relict plant and have to protect. There are many species among them which is tagged in category prepared by the Union Environmental Protection, especially being critically endangered species. This species has been researched by us and were published in the large scale article named "The rare ferns of Caucasus" on the journal of "Botanic" 25 species analyzed on this article. For example, *Osmunda regalis* (Abkhasia), *Hymenophyllum tundbrigense* (Adjariya), *Anogramma leptophylla* (Talış, Adjariya), *Botrychium antemoides* (Azerbaijan,

Daghestan), *Ophioglossum lusitanicum* (Azerbaijan, Abkhazia) and others [Asgarov, 1983].

Ecological analyze. The ferns more reflective to ecological factors, especially against the factors of humidity. This is related with its reproduction. The forest regions having temperate and humid climate is more suitable for developing of ferns in the Caucasus. As well as there are a lot of places in mountainous areas, humid stony and rocky biotopes where the ferns develop intensive.

The ferns vertically conform to the legality on spreading in mountain slopes in Caucasus. From this point of view the alp, sub alp and forest slopes clearly chosen on its spreading. Let's talk shortly about the spreading of ferns in the forest slopes. The ferns spreading easy and larger at the deep valleys of forests, banks of the rivers and humid slopes cause of having constant humidity background. Humid climate was stayed basically unchanged during the millenniums in these forms of relief. The species of fern (for example, very reflective changes in humidity, having thin anatomical structure – *Hymenophyllum tunbrigense*) in those areas were stayed at least from 3rd geological period.

Ecological factors are special in forests and humid stony and rocky biotopes. There are about 57 species (approximately 65% of forest ferns) at this kind of places. One of the important bimorphs of ferns is epiphyte. The epiphytes give the special beauties to our forests (table 1).

A lot of species of fern are met in the formation of specific forest: for example, *Dryopteris raddeana*, *Polystichum woronowii* is typical for Hirkan and Kolkhida forests. There is decrease of species in spreading from lowland to mountain areas at the spreading period by the forest slopes. *Polypodium vulgare* L (shrubby place above the humid rocks in hornbeam forest) (pic.).

Areologic analyze. There 21 botanical-geographical regions are determined [Asgarov, 2001] at the following diagram paying attention the spreading features of pteridophytes in Caucasus (diag.).

The spreading of ferns has seen easily in this scheme on those regions. Actually, there

are 2 regions in Caucasus - Kolkhida and Talish are chose on the normal progress and compactness of ferns population. According to number of species compared with Talish there are 2 times more species in Kolkhida. This is related with humid climate of areas and with other climate - the factors of soil. The regions of North Caucasus with forests have much more species after Kolkhida region (51 species) and 40 species in South Caucasus. The Gobustan, Nakhchivan and Absheron regions have less species. Thus, the number of species were observed gradually reduce from regions with forests to semi-desert and steppe.

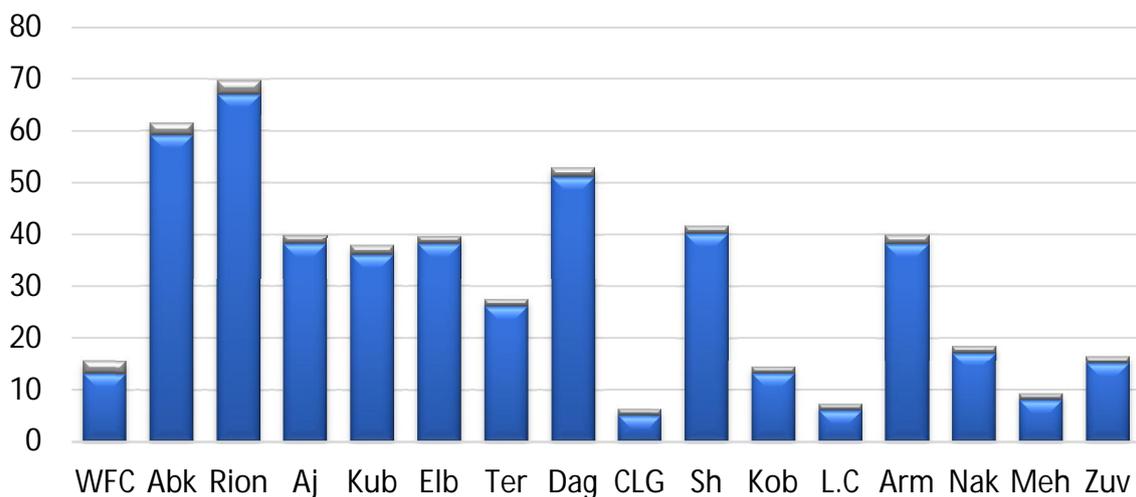
TABLE 1. The epiphytes of Caucasus and its substratum (growing above bodies) trees.

Species	Substratum
<i>Polypodium australe</i>	<i>Quercus iberica</i> , <i>Carpinus caucasica</i>
<i>P. issaevii</i>	<i>Carpinus caucasica</i> <i>Alnus subcordata</i> <i>Pterocarya pterocarpa</i> <i>Junglans regia</i> <i>Tilia begonifolia</i>
<i>P. vulgare</i>	<i>Zelkova carpinifolia</i>
<i>P. x mantoniae</i>	<i>Carpinus caucasica</i> <i>Pterocarya pterocarpa</i> <i>Junglans regia</i>
<i>P. x schivasiae</i>	<i>Acer velutium</i> <i>Pterocarya pterocarpa</i> <i>Junglans regia</i>
<i>Hymenophyllum tunbrigense</i>	<i>Lauroserasus officinalis</i>
<i>Phyllitiss colopendrium</i>	<i>Parrotia persica</i> <i>Acer velutium</i> <i>Alnus barbata</i> <i>Pterocarya pterocarpa</i> <i>Zelkova carpinifolia</i>
<i>Asplenium adiantum -nigrum</i>	<i>Parrotia persica</i> <i>Acer velutium</i>
<i>A. trichomanes</i>	<i>Parrotia persica</i>
<i>Polystichum aculeatum</i>	<i>Parrotia persica</i> <i>Quercus castaneifolia</i>
<i>Dryopteris filix - mas</i>	<i>Carpinus caucasica</i> <i>Pterocarya pterocarpa</i>
<i>D. raddeana</i>	<i>Fagus orientalis</i> <i>Pterocarya pterocarpa</i>

PICTURE. *Polypodium vulgare*L.



DIAGRAM 1. The spreading scheme of fern species in botanical-geographical regions of Caucasus. 1-Western Front Caucasus, 2-Abkhazia, 3-Rion, 4-Ajaria, 5-Kuban, 6-Elbrus, 7-Ter, 8-Dagestan, 9-Caspian Littoral-Guba, 10-Shamakhi, 11-Gobustan, 12-Lesser Caucasus, 13-Armenia, 14-Nakhchivan, 15-Mehri, 16-Zuvand, 17-Talish, 18-Northern Caucasus, 19-Absheron, 20-Estern Front Caucasus, 21-Cherquez.



Chorological analyze. The forest ferns species of Caucasus belong 10 type of geographic areas: Kolkhid, Hirkan, Hirkan – Kolkhid, Eucaucasus, Daghestan, wholeCaucasus, Europe – Caucasus, Holarktık, Palearktık, Pluriregional. The relict species most related with

the refugiums of Kolkhida and Talish and have 7 species: *Dryopteris alexeenkoana* Fomin, *D. liliana* Golits., *D. aemula* (Arit.) O.Kuntze, *D. raddeana* Fomin, *Polystichum woronowii* Fomin, *Asplenium woronowii* Christ, *Polypodium subuntegrum* (Fomin) A. Askerov. We are

meet species belonging to the types of geographic areas - Holarktık (26 species), Palearktık (13 species) and Europe – Caucasus (11 species). The event of endemism is weak at the pterydoflora of Caucasus (total 8 species): *Hymenocystis fragilis*, *Polystichum kadyrovii*, *Asplenium woronowii*, *A. hermannii-christii*, *A. daghestanicum* and *Polypodium issaevii*.

About the genesis of pterydoflora of Caucasus. For the researching of genesis and ways of formation of Caucasus forest ferns and all of pterydoflora have been used a lot of paleobotanical materials. The paleobotanical materials

of Caucasus ferns – part of leaves and spores have been known from paleozoic millennium (Carbon period) but main finds begin from mesozoic (Cretaceous period) (table 2.). There are a lot of tropical and subtropical ferns and tree forms (*Dicksonia*, *Cyathea*). The ferns were spread much more in Cenozoic, especially in oligocene (the species of 12 genera), in miocene (11 genera). The leaves vestige of 24 species and the spores of 41 species have been found on Caucasus ferns. The species of 24 genera are met in modern flora.

TABLE 2. The geochronologic of modern ferns genera of Caucasus in Cenozoic (macro sediments - with intermittently lines, spores - with intact lines).

Genera	PALEOGEN			NEOGEN					ANTROPOGEN										
	Paleosen	Eosen	Oligosen	Karagan	Konk	Tarkhan	Chokrak	* Sarmat	* Meotis	Pont	Kimmeriya	Kuyalnik	Guriya	Chauda	Ari-riantavksin	The longs	Karangat	New evksin	Holosen
<i>Adiantum</i>								*	*										
<i>Anogramma</i>									*	*	*	*	*						
<i>Asplenium</i>		*	*	*			*	*					*				*	*	*
<i>Athyrium</i>												*	*		*				
<i>Blechnum</i>		*																	
<i>Botrychium</i>								*		*	*	*	*	*	*	*	*	*	*
<i>Cystopteris</i>				*	*		*	*		*	*	*							
<i>Cryptogramma</i>							*	*		*	*	*	*	*	*	*	*	*	*
<i>Dryopteris</i>			*										*						
<i>Gymnocarpium</i>												*	*						
<i>Hymenocystis</i>																			
<i>Hymenophyllum</i>							*	*		*	*								
<i>Matteuccia</i>										*									
<i>Onoclea</i>							*												
<i>Ophioglossum</i>								*	*	*	*	*							
<i>Oreopteris</i>													*						
<i>Osmunda</i>			*	*	*		*	*		*	*	*	*	*	*	*	*	*	*
<i>Polypodium</i>			*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*
<i>Polystichum</i>								*					*						
<i>Pteridium</i>				*	*		*	*	*	*	*	*	*	*	*	*	*	*	*
<i>Pteris</i>						*			*										
<i>Salvinia</i>											*			*	*	*	*	*	*
<i>Thelypteris</i>							*			*		*	*						
<i>Woodsia</i>																			

Conclusions. The present fern flora of Caucasus consists of 96 species [Kudryashova, 2003], 21 of them hybridogenous from 31 genera and 20 families, 20 species and hybrids were newly described. There are 21 interspecific hybrids, 9 of them are new. The species richness of the various parts of the Caucasus is discussed. As to the general distribution of the taxa, 10 geo-elements can be distinguished; the holarctic is predominant. 15 species are endemic or almost endemic and are mostly confined to certain, limited parts of the area.

A lot of tropical and subtropical fern species were destructed in Pliosen and the pterydoflora was getting its modern situation in pleystosen. The chronological and paleobotanical analyze show that the pterydoflora of Caucasus has florogenetic connection with the tropical and subtropical floras of Eastern Asia and Southern Paleoarctic. The florogenesis of some groups is close to the floras of Southwestern Asia and Southern Africa.

Then under our leadership, from 2016 to 2018 the species of ferns in different regionsof the Caucasus were studied by different Phd students (U.Akchay and L.N.Verdieva).

As a result of the monographic processing of Caucasian ferns by A.M.Asgarov, as well as the monograph of the genus by Fraser-Jenkins, the composition of the genus [Asgarov and Akchay, 2016]. *Dryopteris* was supplemented by 6 more species: *D. assimilis* S. Walker, *D. remota* (A. Br. ex Döll.) Druce, *D. pseudorigida* (Christ) Askerov, *D. caucasica* (A. Br.) Fr. – Jenk., *D. schorapanensis* Asgarov, *D. iranica* Fr. – Jenk. In addition, 5 more hybrid species of ferns were found (Asgarov, 2013): *D. x sarvelae* Fr. – Jenk. et Jermy (*D. expansa* x *D. carthusiana*); *D. x euxinensis* Fr. – Jenk. et Corley (*D. caucasica* x *D. filix-mas*); *D. x initialis* Fr. – Jenk. et Corley (*D. oreades* x *D. caucasica*); *D. x mantoniae* Fr. – Jenk. et Corley (*D. filix-mas* x *D. oreades*); *D. x tavelli* Rothm. (*D. filix-mas* x *D. borrieri*).

Also, during the expeditions in the north-eastern part of the Lesser Caucasus between 2014-2016 and based on the results analysis of the collected herbarium and descriptor informations three species (*Polypodium interjectum*

Shivas, *Polystichum illyricum* (Borb), Hahne, *Cystopteris anthriscifolia* Fomin), one botanical variety (*Polystichum aculeatum* var. *aristatum* (Christ) A.Askerov) and one new ecotype (*Adiantum capillus - veneris* L., "Dwarf plant - Ganja") has been identified [Verdieva and Asgarov, 2018].

Fam: *Ophioglossaceae* (*Ophioglossum - O.lusitanicum, O.vulgatum; Botrychium - B.lunaria; Botrypus - B.anthemoides*);

Fam: *Osmundaceae* (*Osmunda, O.regalis*);

Fam: *Salviniaceae* (*Azolla, A.filiculoides, S.natans*);

Fam: *Marsileaceae* (*Marsilea, M.quadrifolia, M.strigosa*);

Fam: *Pteridaceae* (*Cryptogramma, C.crispa; Anogramma, A.leptophylla* (L.); *Pteris, P.cretica; Adiantum, A.capillus - veneris; Oeosporangium, O.persica, O.pteridioides; Paragymnopteris, P.marantae*);

Fam: *Dennstaedtiaceae* (*Pteridium, P.aquilinum*);

Fam: *Cystopteridaceae* (*Cystopteris, C.fragilis, C.dickieana; Gymnocarpium, G.dryopteris, G.robertianum*);

Fam: *Aspleniaceae* (*Asplenium, A.adiantum-nigrum, A.ceterach, A.scolopendrium, A.ruta-murari, A.septentrionale, A.trichomanes, A.viride, A.woronowii*);

Fam: *Woodsiaceae* (*Pseudathyrium, P.alpestre; Woodsia, W.alpina, W.fragilis, W.glabella*);

Fam: *Onocleaceae* (*Onoclea, O.struthiopteris*);

Fam: *Athyriaceae* (*Athyrium, A.filix-femina, A.multidentatum*);

Fam: *Thelypteridaceae* (*Phegopteris, P.connectilis; Oreopteris, O.limbosperma; Thelypteris, T.palustris*);

Fam: *Dryopteridaceae* (*Dryopteris Adans, D.borrieri, D.carthusiana, D.caucasica, D.expansa, D.filix-mas, D.oreades, D.raddeana, D.talyschensis; Polystichum, P.aculeatum, P.braunii, P.kadyrovii, P.lonchitis, P.setiferum, P.woronowii*);

Fam: *Polypodiaceae* (*Polypodium, P.cambricum, P.vulgare*).

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