Relicts of the forest cenoflora in the eastern Russian Caucasus

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Abstract. The article is devoted to the analysis of relics of the forest cenoflora occurred in the eastern part of the North Caucasus. Using the methods of morphological-ecological-geographical, florogenetic analysis and synthesis, etc., we analyzed the results of field observations and herbarium funds available in the region, and also scientific publications. The species composition of relics was revealed, their territorial distribution in forest communities, their origin, and florogenetic relationships were determined. The purpose of the analysis is to establish the geographical origin of relic species. In the studied flora, two types of relics were identified - tertiary and glacial, their importance for solving florogenetic issues is noted. The presence of relics of different geographic origin in forest cenoflora is explained by the consequences of migration processes that have taken place since the middle of the Tertiary period, which led to the movement of floristic complexes from the northern territories, from Transcaucasia and the adjacent parts of Asia Minor and Western Asia. Many relic species (Huperzia selago (L.) Bernh., Lycopodium annotinum L., Selaginella helvetica (L.) Spring, Equisetum hyemale L., Polypodium vulgare L., Phyllitis scolopendrium (L.) Newman, Polystichum braunii (Spenn.) Fee, Taxus baccata L., Actaea spicata L) have rather extensive ranges in the Caucasus, and in general, their relictness is determined by the insular position of forests in this area.

1. Introduction
The relict species that are part of modern flora are botanical documents testifying to the historical formation of flora and the paths of ancient migrations of species and floristic complexes.

The results of the analysis of their ranges are extremely important for florogenetic constructions, which make it possible to reconstruct the changes in flora on a geological time scale. The methodology of this study is based on the fact that the ongoing global climate changes on the globe caused periodic alternation of cold snaps and warming, which led to the migration of mesophilic floras during the ice ages and xerophilic floras during the xerothermal ones. Changes in these periods led to the extinction of the corresponding floras (with the onset of the ice age, the xerothermal flora died out, during the interglacial period, the mesophilic flora). But the remains of these floras could be preserved in separate areas with a corresponding ecological situation, especially in areas with rugged mountainous terrain with different heights and slopes of different steepness and exposure. These are the so-called refugia, where xerophytes are preserved on the southern, well-warmed slopes, and mesophilic species are preserved on the northern ones with a lower temperature and a different water regime. That is, the relict species includes the remains of the ancient flora, which in the modern flora...
have a relict area (once more extensive), occupied by them from the moment they entered the flora, which determines the age of the species [1].

The originality of the forest flora is given by endemic and relict species, which are indicators of florogenetic changes occurring within any physical-geographical unit, in this case, in the eastern part of the Russian Caucasus. Analysis of data on this group of species allows obtaining material for correcting the model of phlorogenesis within the study area and adjacent ones.

Isolation of forest phytocenoses in certain types of landscape leads to the formation of heterogeneous floristic forest complexes, which makes it possible to carry out florocenotic zoning of the territory and make adjustments to the existing botanical and geographical schemes. The relevance of the study is also determined by the need to address the issues of protecting certain species of forest plants and justify the allocation of specially protected natural areas (SPNA), maintaining regional Red Data Books, accumulating material for their reprint. In the applied aspect, an inventory of the gene pool of useful plants is important.

The mechanism of the transition of widespread species to relict ones is associated with historical climate changes, when, with its warming and drying, xerothermal species penetrate from arid regions, which usually die out during a cold snap and remain only in those places where the habitat conditions correspond to their ecology, and vice versa, in periods of cooling, mesophilic species penetrate, which persist during periods of warming in places corresponding to their ecology. Such territories with preserved relics are refugia (shelters), where there is a possibility of more or less long-term preservation of isolated areas of the range of relict species. This mechanism can be implemented only in areas with a rugged relief, which allows the formation of a large number of ecological niches associated with the exposure of the slope, altitude, the nature of the substrate, moisture regime, etc. Historical climate change associated with the course of the history of the globe, to a greater extent with Tertiary-Quaternary changes, led to a global geographical displacement of floras and floristic complexes - waves of migration. The remnants of these waves are relict species. Therefore, the presence of relict species in the flora is one of its most important characteristics, which makes it possible to draw conclusions of a florogenetic nature.

Fanerophytes are among the most ancient representatives of the forest flora, this opinion was expressed by the famous researcher of the flora of the North Caucasus A.I. Galushko [2]. This is confirmed by the finds of spores in the Chokrak deposits (Dagestan), dating back to the Middle Miocene. Here, the pollen of species of such genera as Pinus, Carpinus, Corylus, Betula, Alnus, Fagus, Quercus, Ulmus, Celtis, Ilex, Acer, Tilia, Cornus and others have been identified [3] that are part of the modern flora? The species of these genera are widespread throughout Eurasia and are dominants of modern forest ecosystems.

Based on the above, the goal was set - to analyze the areas of relict species of forest cenoflora in the Eastern part of the Russian Caucasus. The main task of the study was to identify the species composition of relict species and their localization in forest phytocenoses.

2. Materials and Method

The objects of research are forest flora and spatial localization of certain forest species in the territory of the Eastern part of the Russian Caucasus. The material for research was obtained as a result of observations in nature during expeditionary research from 2010 to 2019. As a result of the research, xxx specimens of plants were collected, stored in the herbarium of the Chechen State Pedagogical University. The herbarium funds of the North Caucasus Federal University (SPI), the Stavropol State Museum-Reserve named after G.N. Prozritteleva and G.K. Prave (SMRS), Stavropol Botanical Garden (SBG), Mountain Botanical Garden of the Dagestan Scientific Center of the Russian Academy of Sciences (DAG), Dagestan State University (LENUD).

One of the unresolved problems is the history of the formation of forest flora in this territory of the Russian Caucasus.

To solve this problem, the objects of study were the spatial localization of relict species of the flora of the Russian Caucasus, and the establishment of their geographical connections.
The main research method is the analysis of modern ranges of forest species in order to identify relict localities, determination of the position of the main range in order to establish the possible direction and time of migration flows.

3. Result and Discussion

The studied forest flora includes 460 species, which are included in 241 genera and 95 families. In this flora, 38 relict species have been identified, which is 8.3% of the species composition. They represent the remains of the flora that was characteristic of this territory in the past geological epochs.

The systematic structure of forest relics is presented in Table 1. It shows that the largest number of species are angiosperms (5.7% of the total flora and 68.4% of the number of relict species). Spore plants account for 2.4% and 28.9%, respectively. The vast majority of relics belong to different families and genera. Two species are represented by the genus *Pilystichum* and *Sorbus*, three species are represented by the genus *Acer*. The rest of the genus contain one species each.

Table 1. Systematic structure of relict species of forest flora of the eastern part of the Russian Caucasus.

| Taxon            | Number of species | % of the total | % of the number of relics |
|------------------|-------------------|----------------|--------------------------|
| Lycopodiophyta   | 3                 | 0.7            | 7.9                      |
| Equisetophyta    | 1                 | 0.2            | 2.6                      |
| Polypodiophyta   | 7                 | 1.5            | 18.4                     |
| Pinophyta        | 1                 | 0.2            | 2.6                      |
| Magnoliophyta    | 26                | 5.7            | 68.4                     |

The presence of relict species in the studied flora (along with endemics) is an indicator of its originality. Forest phytocenoses of this territory do not have continuous distribution and are fragmented into separate, more or less large forest tracts with the character of refugia, where the ecological conditions of existence are close to those that developed during the Cenozoic. This fragmentation contributes to the manifestation of the island effect, expressed in the fact that the populations of some species are significantly reduced and in the modern forest flora they have a limited distribution and are on the verge of extinction. These are types such as:

- *Cypripedium calceolus* L. - localized in three places - Khobi-Shaudan heights in the lower reaches of the river. Gudermes [4] and the adjacent territory of Dagestan - the vicinity of the villages of Akhar and Kapir-Kazmalyar [5]. Perhaps this species has disappeared because from the moment A.A. Grossheim [6] there is no confirmation of the finding of this species in nature, and L.V. Averyanov [7] does not indicate it for the territory of the North Caucasus.

- *Helleborus caucasicus* A.Br. - a rare species, the finding of which is known from the lower reaches of the Argun and Sunzha rivers [4], also in Dagestan, in the Tsuntsinsky region, in the vicinity of the village. Kidero [8]. The main area is in the Western Caucasus.

- *Ilex hyrcana* Pojark. – unique location: s. Gurkhun Tabasaran region: [9]. The main range of the species is located in the south of Azerbaijan, in Talysy.

- *Botrichium virginianum* (L.) Sw. - with. Murego. Known only from the collections of A.D. Raji and A.M. Askerov [9]. The main area is located in Central Europe, on the Russian Plain, in Western and Eastern Siberia.

- *Majanthemum bifolium* (L.) F.W.Schmidt - surroundings with. Suetl of the Tlyaratinsky district [8]. General distribution - Europe, Northeast Asia.

- *Potentilla sterilis* (L.) Garcke - in the forests of the vicinity of the village Alcun [10]. The main range of the species is in Europe.

The studied forest flora includes two groups of relics - tertiary and glacial. Considering the complex history of the flora of the Caucasus and migration processes, many species attributed to
Tertiary relics could have entered the composition of the modern flora as a result of glacial migrations, and their relict character is of a double nature: in terms of age they are Tertiary, in terms of migration they are glacial. We include *Polystichum braunii* (Spenn.) Fee, *Taxus baccata* L., *Acer ibericum* Bieb., *A. hyrcanum* Fisch. et C. A. Mey., *Ilex hyrcana*.

By the location of the main habitat, relict forest species are divided into two groups. The first includes species that are currently common in the forest zone of the Palaearctic. These species include such tertiary relics as *Hyperzia selago* (L.) Bernh. ex Schrank et C. Mart., *Lycopodium annotinum* L., *Selaginella helvetica* (L.) Spring, *Equisetum hyemale* L., *Polypodium vulgare* L., *Phyllitis scolopendrium* (L.) Newm., *Polystichym braunii* (Spenn.) Fee, *Ophioglossum vulgatum* L., *Taxus baccata* L., *Actaea spicata* L. .. Of the glacial relics, this group should include *Rhizomatopteris sudetica* (A. Br. Et Milde) A. Khokhr., *Botrichium virginianum*, *Carex depauperata* Curt. ex With., *Majanthemum bifolium*, *Cypripedium calceolus*, *Sorbus torminalis* (L.) Crantz, *Potentilla sterilis*, *Pyrola rotundifolia* L., *Orthilia secunda* (L.) House, *Hyopithys monotropa* Crantz, *Lysimachia nummularoxia* L., *Linnacea mostellina* borealis L., *Arctium nemorosum* Lej.

The second group includes species common in the Transcaucasus and the adjacent territories of Asia Minor, Western Asia, as well as in the Mediterranean. The most ancient representatives of this group are Tertiary relics *Polystichym aculeatum* (L.) Roth, *Helleborus caucasicus* A.Br. (Mediterranean), *Oberna multifida* (Adams) Ikonn., *Ilex hyrcana*, *Acer laetum* C.A. Mey., *Acer hyrcanum* Fisch. et C. A. Mey., *Hedera pastuchovii* Woronow, *Pterocarya pterocarpa* (Michx.) Kunth ex Iljinsk. (Caucasus). Of the glacial relics, the Mediterranean include *Anemonoides blanda*, *Pteridium aquilinum*, *Polystichum aculeatum*, the Caucasian ones *Corydalis angustifolia* (Bieb.) DC., *The Near East Nectaroscordum tripedale* (Trautv.) Grossh., *Sorbus hajastana* Gabr..

Table 2 shows information about the groups of relics and the territories of their main range. It follows from it that the most of relics have main areas in the Palaearctic, much less relics with main areas in the Mediterranean (Euxin and Crimean-Novorossiysk provinces) and in the Caucasus and adjacent territories of Asia Minor and Western Asia (sub-Caucasian species).

It should be noted that the attribution of glacial relics of boreal and European origin to glacial migrants is questioned by some researchers. The classical representation of this process is the hypothesis that during the maximum phases of glaciation there was a direct exchange between the northern and Caucasian floras. In the integracials, a break in the ranges of boreal species into the northern and Caucasian floras. In the integracials, a break in the ranges of boreal species into the e forest zone of the Palaearctic. These species include

| Tertiary Relics | Main Territories |
|----------------|-----------------|
| *Polystichum braunii* | Transcaucasus, Adjacent Territories |
| *Taxus baccata* | Northern Flora |
| *Acer ibericum* | Mediterranean |
| *A. hyrcanum* | Caucasian Flora |

Concerning the boreal and European species, we support the point of view of the second group of researchers. As for the Mediterranean, Caucasian and Sub-Caucasian species, these relics have become isolated as a result of glacial migrations within the territory of the Caucasus.
Table 2. Relict species of forest cenoflora in the eastern part of the Russian Caucasus and localization of their main range.

| Main area                              | Tertiary relics                           | Glacial relics                          |
|----------------------------------------|------------------------------------------|----------------------------------------|
| Boreal region (without European part)  | *Huperzia selago* (L.) Bernh. ex Schrank et Mart.] | *Botrichium virginianum* (L.) Sw.       |
|                                        | *Lycopodium annotinum* L.                | *Majanthemum bifolium* L.              |
|                                        | *Selaginella helvetica* (L.) Spring      | *Cypripedium calceolus* L.             |
|                                        | *Equisetum hyemale* L.                   | *Hypopithys monotropa* Grantz           |
|                                        | *Polystichym braunii* (Spenn.) Fee        | *Linnaea borealis* L.                  |
|                                        | *Pyrola rotundifolia* L.                 | *Adoxa moschatellina* L.               |
|                                        | *Orthylia secunda* L.                    |                                        |
| Europe                                 | *Phyllitis scolopendrium* (L.) Newman     | *Rhizomatopteris sudetica* (A. Br. et Milde) A. Khokhr. |
|                                        | *Taxus baccata* L.                       | *Carex depaupera* Curtis ex With.      |
|                                        | *Actaea spicata* L.                      | *Sorbus terminalis* (L.) Crantz        |
|                                        | *Ophioglossum vulgatum* L.               | *Potentilla sterilis* (L.) Garcke      |
| Mediterranean                          | *Polystichym aculeatum* (L.) Roth        | *Lysimachia nummularia* L.             |
|                                        | *Helleborus caucasicus* A. Braun         | *Arctium nemorosum* Lej.               |
| Caucasus and adjacent territories of Asia | *Oberna multifida* (Adams) Ikonnn.       | *Pteridium tauricum* V.I. Krecz.       |
| Minor and Western Asia                 | *Ilex hyrcana* Pojark.                   | *Anemonoides blanda* Schott & Kotschy  |
|                                        | *Acer laetum* Gled.                      |                                        |
|                                        | *Acer hyrcanum* Fisch. & C.A. Mey.       | *Corydalis angustifolia* (M. Bieb.) DC.|
|                                        | *Acer ibericum* Bieb.                    | *Nectaroscordum tripedale* (Trautv.) Grossh. |
|                                        | *Hedera pastuchovii* Woronow             | *Sorbus hajastana* Gabhr.              |
|                                        | *Pterocarya pterocarpa* (Michx.)         |                                        |
|                                        | *Kunth ex Iljinsk.*                      |                                        |

4. Conclusion
Based on the foregoing, it should be concluded that more than half of the relict forest species are remnants of the Tertiary flora, the enrichment of which occurred due to the glacial epochs of the Holocene. Postglacial warming contributed to the fragmentation of forests in the study area and the formation of refugia with relict species. The geographic connections of these species testify to their relict nature and confirm the presence of paleomigration processes that have taken place since the middle of the Tertiary period, which led to the movement of floristic complexes both from the northern territories and from the Transcaucasus and the adjacent parts of Asia Minor and Western Asia. The island effect has led to a significant reduction in the ranges of some species currently known from 1-2 geographic points.

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