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THE VALUE OF BOTANY AS INDICATOR OF UNGLACIATED AREAS

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In his paper on the " Persistence of Plants in Unglaciated Areas of Boreal America " (1) Fernald states : " In studying the occurrence of the arctic species which reach western Newfoundland or Gaspé . . . the striking fact comes out that these species, likewise, are found on the unglaciated Torngat Mountains, *but not elsewhere in Labrador*, that they are generally distributed over the Arctic Archipelage . . . "

A little further he asserts : " *The Arctic plants which prior to the development of the Labrador ice sheet had pushed south to Gaspé* and Newfoundland or the Torngat Mountains are, then, in the Arctic Archipelage likewise confined to-day to a region which escaped Pleistocene glaciation."

Further on he continues : " . . . and it is certainly a fact of great significance that *many of the Arctic species which, prior to the Labrador glaciation, followed south* in western America and to western Newfoundland or Gaspé have, like the cordilleran species isolated in the latter region, given rise to many localized endemics."

Even to a convinced follower of Fernald's hypothesis on unglaciated areas in some sectors of north-eastern America the italicized portions in the preceding statements seem somewhat *a priori*. As there had been no botanical survey in the interior of Ungava (" Labrador " in Fernald's statements as well as in those of the majority of European writers includes Ungava) it would be an exaggeration to claim that these arctic plants did not grow " *elsewhere in Labrador*."

St. Lawrence Estuary, Bic, St. Urbain, and Matapedia

Since the publication of the Fernald work quoted above, field-work of mine carried out in connection with the *Astragalus*(2) of Quebec, the regional floras of St. Urbain(3), of Matapedia(4), and of Bic(5) (province of Quebec) already permitted to justify the persistence of a number of relics, in the immediate vicinity of the gulf and estuary of the St. Lawrence, by the hypothesis of " subarctic outposts " (we might even to-day say " Arctic outposts ") in this district. This postulate, more in harmony with pre-Fernald theories, could be summarized as follows : At the foot of the quaternary glacier there was a wide zone covered by the tundra. At a time which has been named the " presylvatic period "(6) the St. Lawrence valley was without any doubt in the tundra. Then, with the glacier's recession and the invasion of the valley by the forest, some limited habitats remained where floristic conditions continued to be of an Arctic or subarctic nature because of some adverse microclimatic or physiographic peculiarities which prevented the more aggressive meridional plants from invading these restricted areas. While the majority of plants typical of Temperate Zones cannot survive in the Arctic because of the brevity of the growing season, Arctic plants, on the other hand, easily thrive in Temperate Zones, even serving as excellent rock-garden plants provided there is no competition. The Arctic plants are essentially of short-season growth, requiring open light and long days of insolation. On the exposed cliffs and cornices

of Bic (Rimouski County) and Cap des Rosiers (Gaspé County), on the steep banks of many rivers for one part, and for the other part, in the beds of certain torrential rivers where great sandy and gravelly flats are exposed for a good part of the summer (rivers on Anticosti Island, the Restigouche and Matapedia Rivers, for example) the exposure to severe weather conditions in the first case, the short period of immersion in the second case, will not permit a temperate flora to establish itself permanently, leaving a gap for Arctic and subarctic plants, far better organized to cope with such conditions, to fill.

Modifying the third citation quoted from Fernald, one could conclude: " . . . and it is certainly a fact of great significance that many of the Arctic species *have established themselves around the Gulf of St. Lawrence only in such habitats where an adverse microclimate and physiography have prevented plants from the Temperate Zone to establish themselves, leaving such areas to Arctic plants, which, on account of their constitution, could adapt themselves more easily to the adverse conditions.*"

Nevertheless, I did not dare—because of the lack of more impressive elements, and mainly because I was won over by the poetry of the persistance of a pre-glacial flora in the Gaspé Peninsula—extend my theory on the " subarctic outposts " to include the so-called pre-glacial Gaspé plants and speak more openly of " Arctic outposts." The " persistence of post-glacial relicts in Arctic outposts " could certainly be considered as a plausible hypothesis and on even the same level perhaps as Fernald's theory on the " persistence of plants on unglaciated areas." The least that could be said is that the views expressed in the second and third of the quotations reproduced above were certainly too absolute.

Centre of Anticosti

The doubts exposed above suggested fields of survey entirely new. Two surveys were performed in the unexplored centre of huge Anticosti Island, in the Gulf of St. Lawrence, in 1940 and 1942(7). According to Professor Marie-Victorin, who devoted many years to the study of the shores of Anticosti Island, and Mingan Islands, the allogenous flora of these areas revealed the existence there of an unglaciated area(8). According to Professor Marie-Victorin's hypothesis, there should in the centre of the island be a more elevated terrain which, having escaped Pleistocene submergence, could harbour this flora through the quaternary glaciation and later during the champlain sea submergence. Following the 1940 and 1942 surveys, this hypothetical " relicts preserve " no longer held true. The persistence of the relicts' flora of Anticosti and Mingan Islands, as well as the other relicts of the lowlands areas of the Gulf of St. Lawrence could be better explained by the theory of " persistence of post-glacial reliects in Arctic outposts "(7). The study of the flora of Anticosti as well as that of Bic, St. Urbain, Matapedia, the St. Lawrence Estuary, and some other localities in eastern Quebec tended to lessen the theory of the persistence of plants in unglaciated areas, but were not sufficient, nevertheless, to definitely put it to a test and, even less, to overthrow it.

Lake Mistassini

From 1944 to 1947 my field of activity was centered on Lake Mistassini, in the pre-Cambrian shield, midway between Lake St. John and James Bay, a limestone " island " lost in a " sea " of granite and gneiss. André Michaux(9) and later Macoun(10) first revealed some of the important floristic features. Lepage and Dutilly(11), after a hurried trip in 1943, brought back other very interesting elements. Wynne-Edwards(12), in a criticism of the Fernald theory, pretended that the so-called pre-Glacial relicts were for the most part merely calcicolous species, the distribution of which could be explained through their ecological requirements. Lake Mistassini, being close to the centre of the Labradorian Glacier, was no doubt in the path of the different phases of this glaciation. If the Wynne-Edwards theory were well founded, a great number of the Anticosti, Mingan, and Gaspé relicts would have been found there. Such, however, is not the case. There are many Arctic relicts in the immediate vicinity of the latter, but the number is far less numerous than that found in the granitic districts visited subsequently. The Mistassini surveys, nevertheless, call for the removal of a few elements included in the lists of plants classified as indicators of unglaciated areas(13).

George River, Eastern Ungava

An exhaustive survey of the whole Ungava territory, in my opinion, would possibly give the key of the problem of glaciation in north-eastern America, considered purely from the standpoint of vegetation. In 1944 Lepage and Dutilly crossed from Hudson Bay to Ungava Bay, via Richmond Gulf, and the Larch and Koksoak Rivers(14). In 1947 I surveyed George River from its source to the mouth, traversing half of the Ungava Peninsula(15). The whole district is granitic and gneissic and starts nearly from the presumed centre of the Labradorian Glacier. All phases of this glaciation necessarily affected this area—that is, unless we wholly reject the notion of a quaternary Labradorian glaciation. The physiography of the whole district from the source to the mouth of the river is pronouncedly glacial not even the smallest part is not covered by moraines nor glacial striæ. The river has never been surveyed by any scientist. It had been travelled its whole length only forty-two years previous to the author's trip by Mrs. Leonidas Hubbard in 1905, followed a few weeks later by Dillon Wallace(16). The George River flora, like that of the territory surveyed by Lepage and Dutilly, from Richmond Gulf to Fort Chimo, includes a fair number of the elements mentioned by Fernald in his lists, discussed later in the present paper. One of the conclusions of the George River survey is that the Arctic territory in Quebec is far more extensive than usually believed, and leads the author to the definition of a new climatic and biological zone, the *hemiarctic zone*. This point, without direct bearing on the present paper, will be discussed elsewhere.

North-eastern Ungava

In the summer of 1948 I made another traverse of Ungava, this time north of the absolute limit of trees, between Hudson Bay and Ungava Bay, via the Kogaluk and the Payne Rivers(17). No similar undertaking had ever been carried out either by Eskimo, as far as oral relation may be relied upon, or by white man, since only the lowest parts of the two

rivers have received visits of geologists and zoologists (Low, Flaherty, Todd, and Doutt)(16). Furthermore, half of this territory has never been mapped, while the remainder has only been done very fragmentarily by means of aerial photography. This botanical survey as well as the preceding, each covering a strip of land of about 350 miles long, includes a florula having a direct bearing on the Fernald nunatak theory.

We could hardly pretend as yet that we fully know the flora of the interior of Ungava (the Labrador Peninsula of the majority of authors), but what is already known allows us now to draw some conclusions.

Fernald's Preglacial Arctic Plants

Fernald divides into four groups the plants considered in the definitions of nunataks in the vicinity of the Gulf of St. Lawrence and in the mountainous districts of New England(1).

The first list, entitled " Arctic Species of New England, Chiefly on Alpine or Subalpine Areas," includes 93 species and varieties. Of these, 56 species were found in the material collected during the Mistassini surveys and the 1947 and 1948 expeditions to the Ungava and identified to date. I can already predict that the list of 56 species will be increased by at least another ten elements, once the material has been completely identified and the Lepage and Dutilly's list duly studied. Consequently, at least two-thirds of the plants listed in the first group of Fernald's Arctic plants are known to grow in this territory, which has surely undergone glaciation.

The second list of Fernald, " Arctic Species Centering South-eastward on the Gulf of St. Lawrence," comprises 78 species. Of these, 28 were discovered in the Mistassini flora and in the plants from George River which have so far been identified. The Payne-Kogaluk survey, the remainder of the George River plants and those from the Lepage-Dutilly's survey, will hoist the number to 40 at least, as I am led to believe after a preliminary investigation. As will be assumed, about one-half of the species in the second list grow in regions undoubtedly glaciated.

Sixty-five species comprise Fernald's third list, " Boreal or European Species Centering on the Gulf of St. Lawrence." Twenty-two of these are also found around Lake Mistassini or in the George River district, a number that may be further enriched by ten other elements or so when, as I have stated previously, the compilation will be complete. Therefore, nearly half of the plants of this list are known from glaciated areas as well.

If we combine the three first lists given by Fernald, including all the arctic plants growing in supposedly unglaciated areas, we note that out of the 236 plants listed a preliminary investigation allows us to attribute at least 135 to the interior of Ungava. It is logical to believe that the future surveys in other sectors of the interior of Ungava(18) will continue furthermore to fill the gaps, because the flora, as I have noticed, varies greatly from one sector to another. Without waiting for further corroboration, we can unhesitatingly conclude that the 135 elements found in undoubtedly *glaciated* areas may not be used as indicators of *unglaciated* areas. However, since the remaining hundred plants or so will easily find in Arctic territories the same requirements as the 135 species found on the location of the Labrador Glacier, there is a strong possibility that they, likewise, are of little value as nunatak

indicators. Consequently, the three first lists of Fernald are of little proof of the theory of the presence of nunataks in the Gaspé Peninsula and in other parts of north-eastern America.

Cordilleran Relicts

The fourth list given by Fernald, the most important by virtue of number and the value of elements listed, the " Western and Endemic Species Centering on the Gulf of St Lawrence," totals 293 species and varieties altogether. We can readily, for various taxonomical and phytogeographical reasons with which the majority of botanists, including Fernald himself, will agree, reduce it by about 40 elements. Of the remainder, the Lake Mistassini and George River floras have yielded 68 species, a number which, eventually, may be increased to about 80, judging from a preliminary investigation of the Payne-Kogaluk material and Lepage-Dutilly list. Consequently, even in granting the Fernald hypothesis the benefit of the doubt, we must recognize that at least 120 elements, approximately one-third of the list, have to be dropped.

In combining all four lists, we may note that about one-half of the plants we discovered in parts of Ungava have, according to the opinion of all scientists, been covered by the Labrador Glacier in one or more of its different stages. I feel, nevertheless, that we must treat as distinct units the Arctic species of the three first lists—even eliminate them from the discussions—and the so-called cordilleran plants. The latter are not necessarily Arctic in type. Some, apparently, are even delicate plants which require special protection, and it would be surely an *a priori* statement to pretend that they adopt alpine habitats because they are equipped to resist severe climatic conditions. Some of these elements, apparently, are merely alpine and would not survive in Arctic regions.

The problem of Arctic and alpine plants cannot be easily discussed before considering certain theoretical facts. Some plants grow in the Arctic Zone not only because they have a short growing season and they require full light, but because they need the long daylight summer period. Such are the true Arctic plants. Other plants live on high elevations farther south, in close proximity to permanent snow areas but do not occur in the Arctic ; if, like Arctic plants, they have a short growing season and like full light, unlike Arctic plants they will not tolerate a prolonged period of daylight during summer-time. Such plants would be the true alpine plants. The various alpine plants seem to categorically respond to different daylight lengths. One does not expect to find the true alpine plants of Gaspé Mountains, where daylight in the growing season covers a span of sixteen to eighteen hours every day, in the alpine zones of Mexico or Peru, where the maximum length of daylight for the same period will be twelve hours only. All those who have sought to acclimatize plants from Peru at a latitude similar to that of the cultivated lands in Canada know how problematic such an undertaking is. Those who have seen the Popocatepetl flora, near the permanent snow, know that this flora is neither that of the Canadian Rocky Mountains nor the Gaspé Mountains. Finally, outside of the categories of Arctic plants and true alpine plants, there could exist apparently indifferent Arctic-alpine species.

We may assume, at least, as a working hypothesis that a part of the so-called cordilleran plants of Gaspé are true alpine plants, fully adapted, let us say, to latitudes 45° to 50° N. If such is the case, a

part of the Gaspé Mountains flora could constitute a sort of " alpine island " unrelated whatever to the flora of a nunatak. To explain the establishment of this Cordilleran flora in Gaspé we can infer with reasonable foundation that, when the quaternary glaciers receded, such plants migrated along the Arctic " corridor " bordering the glacier because they found the necessary requisites : (1) full light due to the tundra habitat, similar to an alpine formation because of the absence of trees ; (2) a short growing season ; (3) the equivalent period of daylight ; (4) the hydrographic conditions which are practically the same in the Arctic tundra and in alpine formations.

For the time being this is simply an hypothesis ; but to explain the occurrence of cordilleran relicts in Gaspé it is surely just as verisimilar as motivating the " unglaciated areas."

Conclusions

The opinions expressed here are not in opposition to the actual fact of the persistence of plants on quaternary nunataks. Adversaries of the theory of non-glaciation in the centre of the Gaspé Peninsula argue that a flora could not survive on nunataks. There are proofs to the contrary. Nunataks completely surrounded by ice exist at present : the Antarctic Continent, where a lichen formation covers them, in Greenland where the flora contains phanerogams as well as lichens and bryophytes, and in the Alps, where the vegetation is at times quite luxuriant. If present-day nunataks harbour a flora, the same thing could well have occurred during the Glacial period and relicts would easily persist in the " refuges " which saved them during the glacial invasion.

Although the facts discussed in this paper may have a wider implication, they have not been extended here to other nunataks of the Glacial period, as, for instance, those of Scandinavia, which I have not studied. The problem involved was the following : could the plants, which Fernald mentions in his four lists, serve as indicators of non-glaciation in given parts of north-eastern America ?

The conclusions drawn from the preceding discussion may be summed up as follows :—

(1) Of the four lists of plants given by Fernald, the first three contain only Arctic and subarctic species which cannot be used as indicators of non-glaciation. Furthermore, all evidence seems to point to the fact that their present distribution is due to immediate post-Glacial migration. From what is known at present, we may safely conclude that the habitats where these plants grow around the Gulf of St. Lawrence and in New England are merely Arctic and subarctic outposts. Even if the limited areas to which these plants are confined were actually nunataks, the plants could just as easily have migrated there after the glacier's recession. The Arctic plants found in the interior of Ungava could not serve at all as indicators of non-glaciation. As a great number of these Arctic plants are circumboreal in distribution, their discovery in an area which was the centre of the Labradorian glaciation may well have a direct bearing on the study of the same phenomenon in Europe and Asia.

(2) The list of cordilleran plants prepared by Fernald must be reduced by a third of its elements at least. As for those in the remaining two-thirds, their occurrence in Gaspé may be explained in three different ways : (*a*) Some plants could be indifferent Arctic alpine plants, now absent from the Arctic proper through elimination by various historical

factors. The case of the distribution of these plants is that mentioned above in conclusion. (*b*) The remaining species after this elimination could be considered, at least hypothetically, as pre-glacial plants, though this is not the only probable explanation. (*c*) The remaining species could, as well, be considered as simply alpine species, living on alpine formations constituted after the recess of the glacier. The plants could have taken shelter there during the " pre-sylvatic period," after having travelled from the Canadian Rockies to the Gaspé Peninsula, along the " Arctic corridor " bordering the receding continential glacier. During glaciation these plants in the Rockies could have sought refuge either south of the glacier or on nunataks. The relicts would then be pre-glacial in the Rockies and post-glacial in Gaspé. (If point (*b*) were accepted, it would be a simple matter to consider the Gaspé relicts as cordilleran, because some relicts could have been saved during glaciation on Gaspé nunataks and have migrated to the Rockies via the " Arctic corridor." If such were the case, some of the western mountain relicts would be gaspesian and not cordilleran relicts.)

(3) Since the Arctic species may not be considered as indicators of the absence of glaciation and since the presence of cordilleran alpine plants in Gaspé can be explained by my hypothesis of " post-Glacial alpine colonization," it seems that the flora, in the present state of our knowledge, cannot be considered in north-eastern America as a sound proof of the non-glaciation of some parts of the territory.

(4) In the actual state of our knowledge geology alone can decide whether the heart of the Gaspé Peninsula was glaciated or not. The majority of glacial geologists are of the opinion to-day, Coleman notwithstanding, that the Gaspé Peninsula did not escape glaciation. To many scientists the only proof opposing the quaternary glaciation of Gaspé was the botanical evidence, which, in my opinion, may now be seriously questioned.

(5) Nevertheless, in the problem of the persistence of a pre-glacial flora on old nunataks, the geological proof should be seriously scrutinized. The quaternary glaciation has many phases. Admitting, for the purpose of discussion, that the Gaspé Peninsula was not glaciated during the Wisconsin period (the last phase of the glacier in North America), the occurrence of the immediate pre-Glacial glacier would be sufficient to leave traces of glaciation in Gaspé. The inter-Glacial period between the Wisconsin and the pre-Wisconsin would have been sufficiently long to permit migration of a cordilleran flora to the Gaspé. Later, during the Wisconsin phase, the centre of the peninsula remaining a nunatak, a relict flora could have persisted there. For the geologist, generally, there is no nunatak if a spot were glaciated at an early phase of the quaternary glaciation. For a phytogeographer it is sufficient that a nunatak existed at the final phase, to create the problem of persistence of plants in unglaciated areas.

(6) For the time being it seems that we may retain the hypothesis of " persistence of plants on unglaciated areas of north-eastern America " merely as a working hypothesis, even if a relatively weak one. Each survey in the Ungava Peninsula brings new facts to the contrary ; it seems that it may not be upheld for long and that the hypothesis of " post-glacial colonization of alpine areas," as described above, will constitute a better explanation of the Gaspé and other north-eastern co-called cordilleran relicts.

Bibliography and Notes

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(13) The results of the 1944–1947 expeditions to Lake Mistassini are still unpublished.

(14) Results to be published shortly in *Le Naturaliste canadien*. The authors have kindly loaned me their manuscript.

(15) Results unpublished. For a first account of the expedition and general aspects see Rousseau, Jacques. The vegetation and life zones of George River, Eastern Ungava, and the welfare of the natives. A preliminary note. *Arctic*, Vol. 1, No. 2, pp. 93–96, 1948. Also A travers l'Ungava, *l'Actualité économique*, 25, 83–131. Montréal, 1949. Reprinted in *Mémoires du Jardin botanique de Montréal* (Memoirs of the Montreal Botanical Garden), No. 4, 1949.

(16) For the bibliography of the non-botanical surveys of Ungava, see Rousseau, Jacques, " A travers l'Ungava," quoted above.

(17) Results unpublished. For a preliminary account see Rousseau, Jacques, " By Canoe Across the Ungava Peninsula via the Kogaluk and Payne Rivers." *Arctic*, Vol. 1, No. 2, 1948. Also, by the same, " A travers l'Ungava," quoted above.

(18) Since this paper was presented to the Pacific Congress a survey to Otish Mountains in central Ungava, by the author, has furnished important elements. However, I do not find it practical to change the figures given in the text. The least I can say is that they were not overestimated.

R. E. Owen, Government Printer, Wellington.—1953