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# *MINUARTIA GROENLANDICA* (CARYOPHYLLACEAE) IN NOVA SCOTIA

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The history of the discovery of *Minuartia groenlandica* in Nova Scotia is reviewed and 3 new localities, in Queens, Halifax, and Lunenburg Co., are reported bringing the recorded number of sites to 6. The habitat at the Kidston Lake barren is described and the persistence of the species at the site is ascribed to the presence of a very shallow soil on an impervious rock pavement which prevents the establishment of competing species. Although an arctic-alpine, *M. groenlandica* is not associated in its Nova Scotian habitats with any other arctic-alpine plants and the same applies to its other lowland sites in eastern United States. Its occurrence in these lowland sites is apparently determined by its ability to survive summer drought by means of the seed phase, an ability not commonly found among arctic-alpines. The intermediate nature of the Nova Scotian plants between the southern populations (var. *glabra*) and the arctic-alpine form is explained as a local adaptation to our intermediate and unpredictable summer weather.

## Introduction

*Minuartia*** *groenlandica* (Retz.) Ostenf. the Greenland sandwort, is one of the rarer plants in the Nova Scotian flora. It is a small (2-10 cm high), white-flowered herb belonging to the chickweed family and for 60 years was known in Nova Scotia from only a single collection which could not be confirmed since the locality given on the label proved to be misleading. Recent discoveries and a study of its habitat indicate that it may be much more common than hitherto suspected and the purpose of this paper is to describe its distribution, habitat and life cycle.

### *History of Discovery in Nova Scotia*

John Macoun, the Dominion Geologist, was the first person to report the species in Nova Scotia (Macoun 1886). He distributed specimens to several herbaria and the sheet at BM (herbarium acronyms follow Holmgren and Keuken 1974) has written on the label 'No. 287, *Arenaria Groenlandica,* Spreng. On rocky ground North West Arm, Halifax, N.S. Macoun, 5/19/83'. The 2 specimens on this sheet are quite typical of the Nova Scotian populations and appear to represent plants derived from seeds which had germinated early in the previous autumn.

It was not until 1943, 60 years after Macoun's report, that Eville Gorham found the species on the Kidston Lake barren near Halifax (UTM map reference ME512377) ending speculation that Macoun had not found the plant in Nova Scotia at all but had mixed up his collections with plants from farther north. Then in 1947 R.G.S. Bidwell and S.M. Mason found another colony only 8.5 km NW of Kidston Lake on

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***In North America often put into* Arenaria *sensu lato following Fernald (1919). Modern authors (e.g. Komarov 1934-1964, Tutin et al. 1964- ), however, have split* Arenaria *into a number of smaller genera and the species discussed in this paper falls into* Minuartia. *The latter name has now been adopted for Flora North America (Shetler & Skog 1978) and seems likely to be used generally in future.*

'Flagmast Hill, west of Geizer Hill'; this refers to the area of barrens south of Susie Lake and although the name 'Flagmast Hill' does not appear on the National Topographic 1:50,000 series of maps, the reference is to a small hill of about 130 m altitude (ME 458442). Following that, P.A. Bentley in 1956 discovered a more remote population (but still in Halifax Co.) on climbing to the top of Gibraltar Rock in the Musquodoboit Valley some 46 km NE of Kidston Lake (ME 805705). After a lapse of a further 20 years a colony of plants was discovered quite by accident north of Big Tupper Lake in Queens County (LE 393245) by W.A. Silver in October 1975. This is some 110 km west of the two populations near Halifax, but consists of a granite barren with much the same general appearance. This led to the suspicion that there may be patches of the plants on many more of the barrens of Nova Scotia. On being alerted, P.A. and C.J. Keddy found yet another population, this time in Lunenburg Co. near Blue Rocks east of Lunenburg in 1977 on a coastal barren (ME 105126), not many meters above sea level. In spring 1978 M.J. Harvey found several small, scattered populations near Quarry Lake (ME 453462) just 2 km north of the Flagmast Hill site; this is not separated from the latter in Figure 1 which shows the known Nova Scotian sites. It seems obvious that more populations remain to be discovered.

Except for the Macoun record where material was examined at BM, the above information is taken from herbarium specimens deposited in DAL. The records up to 1956 have been reported in Roland and Smith (1969), and all known localities are shown in Figure 1.

*Distribution Outside Nova Scotia*

The distribution and habitats of *M. groenlandica* outside Nova Scotia should be mentioned since they have ecological and taxonomic implications which have to be taken into account when making decisions about the status of the Nova Scotian material. However, it is not the intention to discuss anomalies of distribution or the taxonomic situation in this paper; suffice it to say for the taxonomy that two varieties, var. *groenlandica* and var. *glabra*, often regarded as species (e.g. Weaver 1970), have traditionally been distinguished. For the purpose of this paper, we regard both forms as belonging to one species—*M. groenlandica* sensu lato.

In North America the distribution may be regarded as having two components: first, eastern arctic-alpine distribution from Greenland, Newfoundland, and Quebec down the Appalchian peaks as far as North Carolina and Tennessee; second, a coastal plain-piedmont distribution from Nova Scotia to Tennessee, Georgia, and Alabama (Seymour 1969; Radford et al. 1968; Weaver 1970). Hulten (1964) presents a world map and draws attention to the curious occurrence of the species in southern Brazil.

## Materials and Methods

Vegetation analysis was carried out using a series of permanent strip transects 10 cm wide and of varying lengths laid out across the lichen and shrub zones in 4 separate areas. Plant species and soil depth were recorded in each 10 cm section of the transect. Lines painted on the adjacent rock surface enabled the transects to be relocated, thus enabling the appearance and disappearance of *Minuartia* seedlings in the various zones to be recorded; although the detailed results of this are not presented, they are referred to briefly in the discussion.

Soil samples were collected from a series of 4 standard stations at intervals throughout the summer of 1975, sealing each immediately in a 'Whirl-Pak' polyethylene bag to prevent loss of moisture. Moisture content was determined by drying weighed samples in an oven at 70°C and organic matter by burning samples of the dried soil in a muffle furnace. In turn the ash and a sample of ash from similarly burnt *Minuartia* plants was subjected to qualitative spectrographic

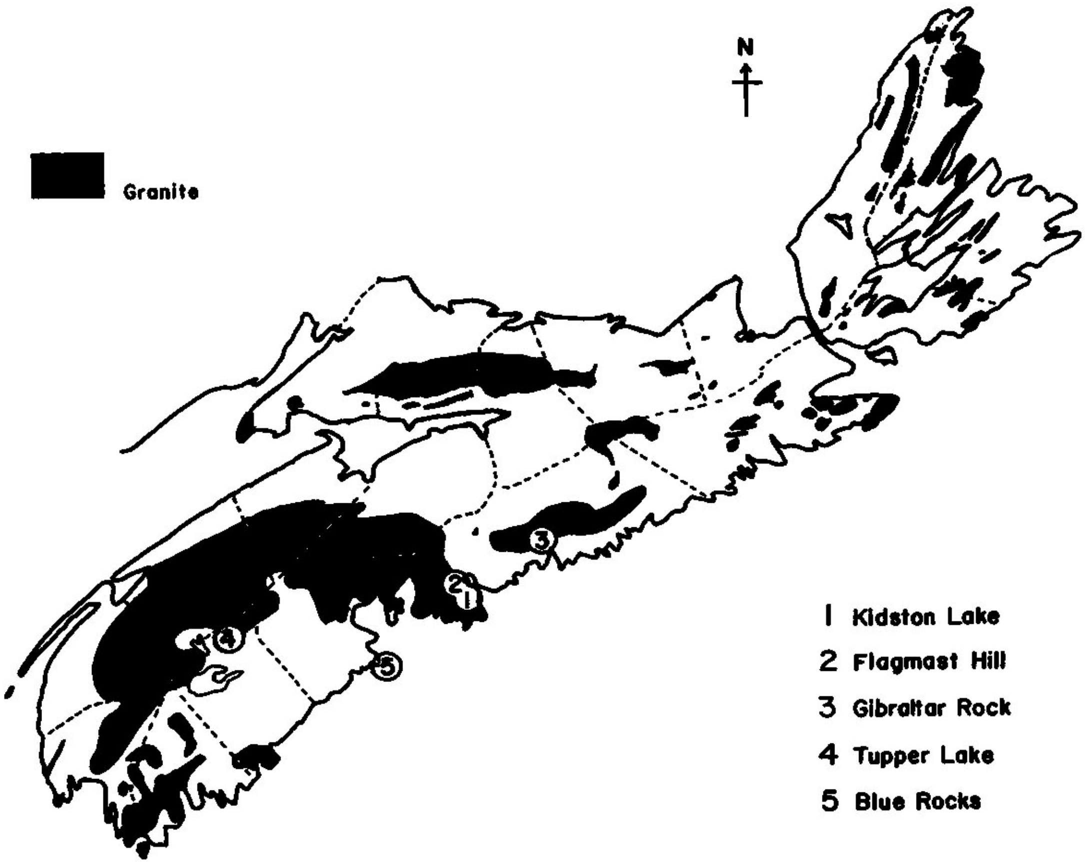


Fig 1. Map of Nova Scotia showing a) sites from which *Minuartia groenlandica* has been collected to 1977. b) distribution of granite (from the Geological Map of Nova Scotia, N.S. Department of Mines).

analysis in a Baird Atomic RDRS Spectrometer Model GX-3, as was a soil sample from the Tupper Lake site.

In addition to the above analyses, a number of samples of soil and various species of lichen in a fresh, apparently active, moist state as tested for the presence of nitrogen-fixing ability using the acetylene-reduction technique. No activity was detected and the subject was not followed further.

## Results

Figure 2 shows in diagrammatic form the general results obtained from the vegetation transects. The vegetation has been divided into a series of 6 zones according to soil depth, and we have adopted the numbering system used in a similar survey by Oostings and Anderson (1939).

Zone 0 lacks any soil or vascular plants and consists of the exposed rock surface with a variety of crustose and thallose lichens and mosses, the lichens include *Parmelia centrifuga* and *Stereocaulon* spp among the more conspicuous.

Zone 1 has soil up to about 2 cm deep, averaging 1 cm, with often a conspicuous growth of the lichen *Cladonia papillaria* where Zones 0 and 1 meet. *Cladonia boryi* is the dominant lichen and probably contributes the majority of the about 8% black, fiberless humus in the soil. *M. groenlandica* is the only vascular plant to occur in this zone.

Zone 2 has soils 2 to 4 cm deep with about 12% organic matter, is dominated by the same lichens as Zone 1, but supports a sparse vascular flora of *Danthonia spicata, Carex umbellata* (*C. tonsa*), *Panicum subvillosum*, and *Potentilla tridentata* — the latter being the more abundant. No mature *Minuartia* plants are found in this zone.

Zone 3 has soils from about 4 cm to as much as 20 or 30 cm but averages 10 cm. Lichens again dominate with abundant growth of the sub-shrub *Corema conradii*, lesser amounts of *Vaccinium angustifolium*, and occasional small plants of other shrublets such as *Epigaea repens* and *Gaultheria procumbens*. These soils contain about 15% organic matter.

Zone 4 has soils of 20 cm or more deep, with a humus composed of a greater proportion of fibrous material derived from the dense shrub growth. A few tree seedlings of *Picea mariana* are found, but grow in a very stunted manner probably because the soil is underlain by impervious granite and becomes dried out in occasional droughts thus sapping the growth of trees. Shrubs dominate with *Kalmia angustifolia* and *Gaylussacia baccata* abundant and lesser amounts of *Nemopanthus mucronata, Vaccinium angustifolium, Ilex glabra, Amerlanchier* spp, *Aronia prunifolia* and *Rhododendron canadense* occurring throughout the region.

Zone 5 is the scrub forest and is developed on the more broken areas of granite where the depth of humus is sufficiently deep or the rock is sufficiently cracked to allow for an adequate supply of moisture to support tree growth. The soil has nearly 90% organic matter. *Picea mariana, Acer rubrum* and *Betula papyrifera* are abundant but several other trees such as *Pinus strobus, P. banksiana*, and *Populus grandidentata* are present as is a rich shrub and herb layer. The microclimate of Zone 1 was obviously different from the adjacent shrub and woodland habitats. Lacking instruments to measure factors such as surface wind velocity, surface temperature, insolation, humidity, dew, and mist collection, we decided to follow soil moisture content over the 1975 growing season since it seemed that this would act as an integrator for the microclimatic regime in the different zones.

The first soil samples were taken in May after the beginning of the growing season for *Minuartia* when the soils had a high water content and at intervals until the onset of cool, wet weather in September. From October to April there is unlikely to be any drought. The results are presented in Figure 3.

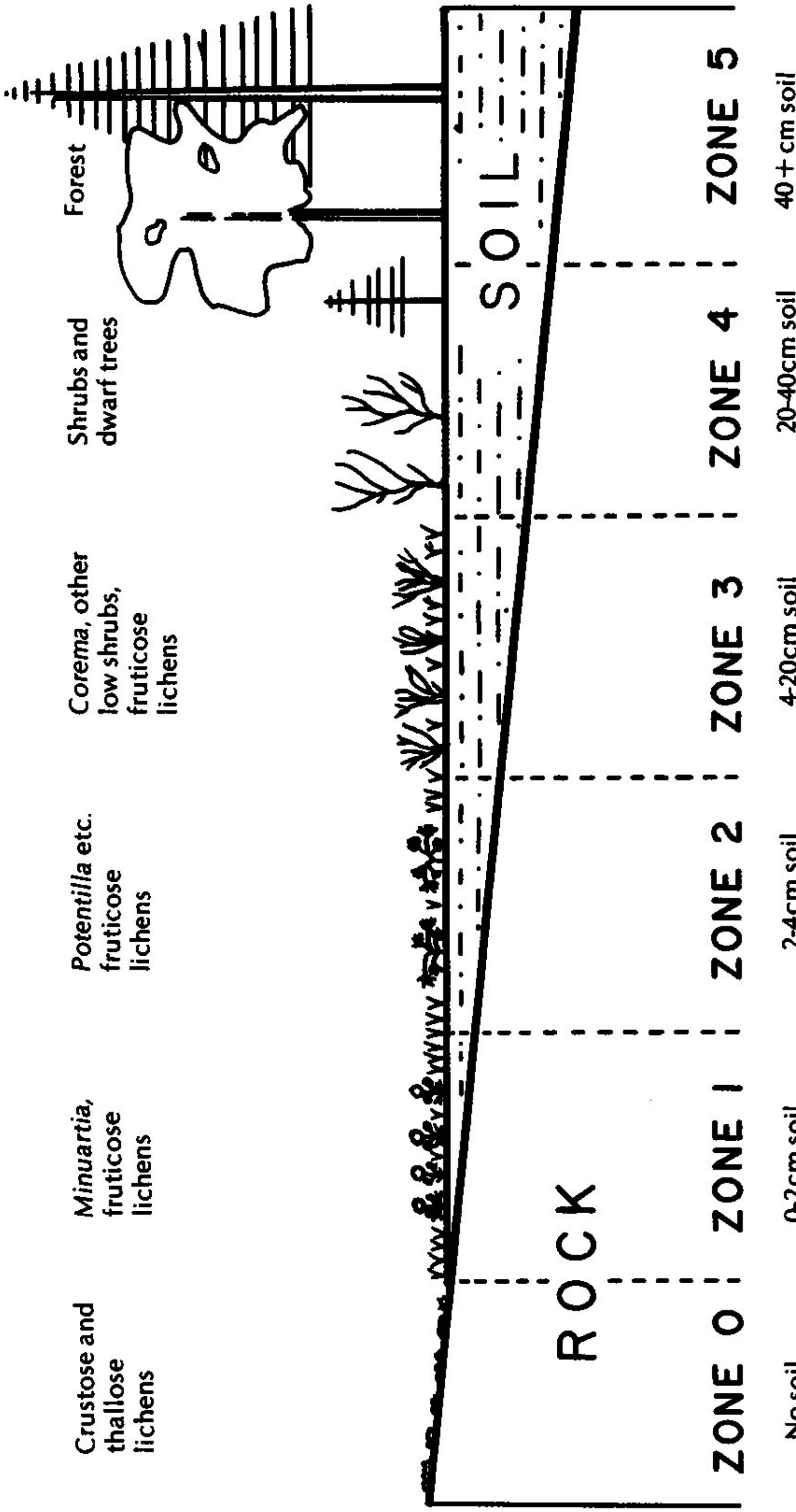


Fig 2. Diagram of soil-plant zones on the Kidston Lake barrens.

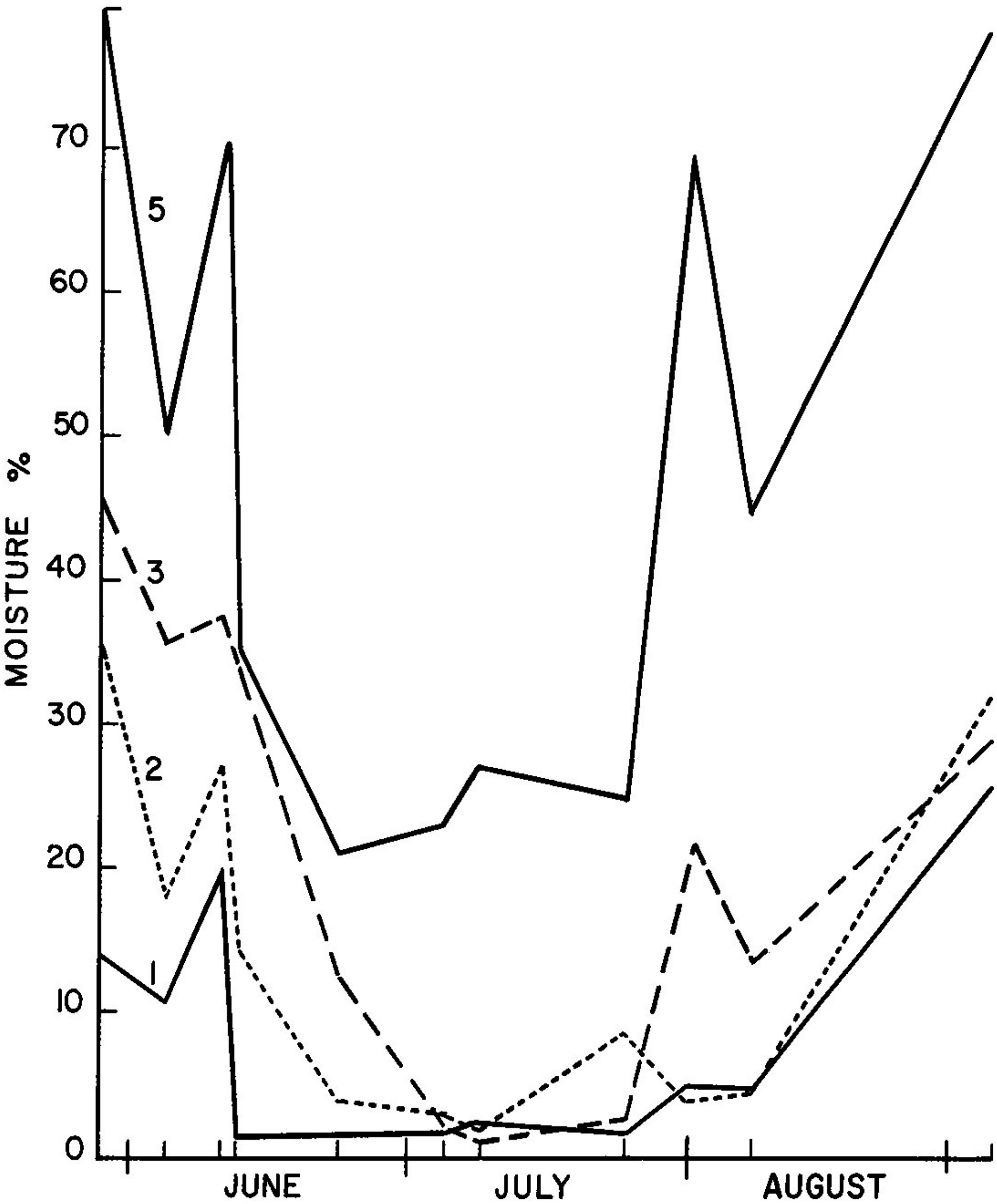


Fig 3. Soil moisture in soil-plant zones 1, 2, 3 and 5 during summer 1975.

## Discussion

It seems clear that *Minuartia* grows on the Kidston and other barrens because these are 'open', low-competition habitats and, as in the case of other arctic-alpines, competition from other plants, especially by shading, eliminates individuals. Observations on small seedlings for a few weeks following germination confirm this. There was abundant germination in September and October 1975 in Zones 1, 2, and 3 but most seedlings among the taller lichens and herbs grew weakly and etiolated and the majority died within a few weeks. This extreme intolerance of shading would appear to be the mechanism which keeps the sandwort confined to Zone 1.

At one time we were considering whether some peculiarities of the chemical composition of the coarse, grey granite (a biotite-granodiorite) on which the *Minuartia* grows might be responsible for its restriction to barrens in the same way that some species are confined to serpentine or calamine outcrops. However, while there is really no published data commenting on granite composition and associated floras, the analyses in Table 1 do not show any obvious peculiarities and the idea was dropped in favor of other interpretations.

The topography is probably more significant than the chemical nature of the rock in permitting the survival of *Minuartia*. The barren is formed on an undulating, glacially planed surface with areas of smooth uncracked granite exposed between more broken, blocky areas and hollows. There are a few glacial erratics lying on this granite pavement but till deposits are absent. The *Minuartia* grows on the smooth, uncracked pavement while the valleys and more broken areas support bushes and trees. The topography controls the soil depth and this in turn controls the type of vegetation; the islands of exposed, smooth granite support the *Minuartia* populations. Surrounding these are more or less level areas of granite supporting a bush vegetation mainly of huckleberry (*Gaylussacia baccata*) and lambkill (*Kalmia angustifolia*), while the hollows and broken areas of rock provide rooting opportunities for trees and a low-grade red maple, birch, black spruce woodland covers these areas.

The exposed rock is never perfectly level and slight depressions accumulate a soil of up to a few centimetres in depth. The soil is composed of coarse quartz crystals which have been weathered out of the granite surface and washed into the depressions, together with a black, amorphous humus presumably largely derived from the decay of the abundant lichens. This thin soil has too shallow a rooting depth to allow the growth of many vascular plants, but a thick mat of lichens, especially *Cladonia boryi*, dominates the areas. *Minuartia*, a very few other herbs and dwarf specimens of shrubs such as *Corema* and blueberry (*Vaccinium angustifolium*) can survive on these shallow soils but not larger bushes or trees. The soil zones and associated vegetation are shown in diagrammatic form in Figure 2.

While the original glacially formed topography was responsible for setting up the mosaic of smooth, raised granite areas interspersed with more broken rock and depressions there has to be some mechanism which has prevented the ecological succession from establishing a spruce-maple forest over the whole barren and thus wiping out the *Minuartia*. Fire and drought are the presumed agents and our thinking at the moment tends to give the greater role to drought. Observations in previous years had indicated that the shallow soils of Zones 1 and 2 dried out rapidly during dry periods both because their shallowness prevented any appreciable water storage in the humus and because they were exposed to the full sun and wind. This is confirmed by the results of moisture measurements shown in Figure 3 which shows that the soil in Zone 1 dried out very rapidly with the onset of drought conditions in May and remained at a low moisture level through the summer. Zones 2 and 3 dried out less rapidly and suffered a shorter period of low moisture content, while soil containing a high humus content shaded by trees did not dry out sufficiently to really subject Zone 5 vegetation to a severe water stress. The capacity of Zones 1, 2, and

**Table I:** Soil, plant ash and rock analyses (soil and plant ash analysed by qualitative emission spectrograph, rock data from T.E. Smith, 1970)

| Kidston barren soil | Big Tupper barren soil | *Minuartia*, Kidston plant ash | Biotite-granodiorite Spryfield | |
|---|---|---|---|---|
| | | 1% | % | |
| Aluminium | Aluminium | Aluminium | $SiO_2$ | 69.47 |
| Potassium | Potassium | Calcium | $TiO_2$ | 0.59 |
| Silica | Silica | Potassium | $Al_2O_3$ | 15.35 |
| Sodium | Sodium | Silica | $Fe_2O_3$ | 2.89 |
| | | Sodium | MnO | 0.09 |
| | | 100 ppm - 1% | | |
| Calcium | Calcium | Cobalt | MgO | 1.06 |
| Cobalt | Cobalt | Copper | CaO | 2.21 |
| Iron | Iron | Iron | $Na_2O$ | 3.17 |
| Magnesium | Magnesium | Lead | $K_2O$ | 4.04 |
| Manganese | Manganese | Magnesium | $P_2O_5$ | 0.19 |
| Strontium | Strontium | Manganese | $H_2O$ | 0.32 |
| Titanium | Titanium | Nickel | | |
| Vanadium | Vanadium | Strontium | | |
| | | Titanium | | |
| | | Vanadium | | |
| | | Zinc | | |
| | | 100ppm | | |
| Beryllium | Chromium | Chromium | | |
| Chromium | Copper | Silver | | |
| Copper | Lead | Tin | | |
| Lead | Nickel | Zirconium | | |
| Nickel | Silver | | | |
| Silver | Tin | | | |
| Tin | Zirconium | | | |
| Zirconium | | | | |

3 to hold water is additionally lessened by the presence of coarse quartz crystals weathered from the granite; Zone 1 soil contains about 90% quartz dryweight. It should be pointed out, however, that 1975, the year during which soil moisture levels were measured, did not have anywhere near average summer weather, this can be seen by referring to Table II showing the April-September precipitation, mean maximum monthly temperature, and insolation. Rainfall was far below normal levels, average temperatures were near normal with a few very hot days, and there was much more sun in June than usual. The effect of this on the vegetation

was quite dramatic. By midsummer all the *Minuartia* plants were dead in contrast to the previous few years when the larger plants had survived as rosettes over the summer and bloomed again in the autumn and the following spring. In addition the plants of *Corema, Danthonia, Potentilla, Carex,* and *Picea* in Zones 2 and 3 were either killed or severely damagaed.

The 1975 drought affected the *Minuartia* population in a genetic sense since every individual in 1976 was recruited from seed (which germinated abundantly August-October 1975). More usually the spring population consists of a mixture of older plants which have survived for 1 or more years and seedlings which have over-wintered from the previous autumn. The more southern plant *M. groenlandica* var. *glabra* is characterized, by its winter annual habit, recruitment being entirely from seed each year. The arctic-alpine var. *groenlandica* is a moderately long-lived perennial. Weaver (1970) uses length of life cycle as the prime separating factor in his key to distinguish the 2 plants, but it can be seen that the Kidston Barren plants possess a flexible life style intermediate between the 2 currently recognized taxa.

The drought had the effect of lessening competition in Zone 2 and some of the *Minuartia* seedlings which had germinated in Zone 2 sites in late 1975 were observed to flower in spring of 1976. This is quite contrary to observations of other years. Thus, drought has the effect of preventing the normal ecologic succession by killing herbs, shrubs, and tree seedlings and we consider this the prime cause of the persistence of the barrens and the suitable habitat for *Minuartia*.

Fire swept over part of the barren in spring 1977 and it was interesting to observe the contrasting ecological effect of this compared to drought. The fire destroyed the above-ground parts of shrubs and trees in Zones 4 and 5 but was unable to spread over Zones 1, 2 and 3 and apparently had no effect on them. The *Minuartia* bloomed as normal but was not able to spread any further as a result of the fire. Regeneration from stumps and underground shoots led to a vigorous regrowth in the burnt zones by the end of the growing season. Thus, fire does not create open areas available to *Minuartia* although it does alter the species composition of the scrub and forest. Fire is now frequent in the area because of its proximity to the suburb at Spryfield. It is difficult to assess the role of naturally occurring fire in the area, but the Kidston Lake Barren is in the foggy Atlantic Coast region where the high rainfall and humidity and low incidence at lightning strikes leads to a low level of natural fires. Thus, we consider that the Kidston Barren is an ancient and very stable topographic-edaphic unit arising as a result of the geological accident of massive rock left uncovered by glacial debris and hence not accessible to tree growth. We regarded the area as a rock barren. Although it is now regularly burnt as a result of human action

**Table II:** Rainfall, Temperature, and Insolation records abstracted from Annual Meteorological Summary 1975, Shearwater A Station (Environment Canada, 1976).

| | Monthly Mean | | | | | |
|---|---|---|---|---|---|---|
| | Precipitation mm | | Max Temperature | | Insolation hours | |
| | 1975 | Normal | 1975 | Normal | 1975 | Normal |
| April | 86.7 | 105.4 | 6.6 | 8.1 | 138.1 | 176.0 |
| May | 66.3 | 109.5 | 13.2 | 13.6 | 222.3 | 217.1 |
| June | 65.3 | 85.1 | 19.4 | 18.3 | 276.6 | 216.7 |
| July | 36.2 | 96.0 | 22.8 | 21.9 | 208.8 | 219.8 |
| August | 47.1 | 97.0 | 21.6 | 22.0 | 213.8 | 214.2 |
| September | 73.3 | 94.2 | 19.1 | 18.9 | 170.4 | 170.9 |

and is hence called a fire barren we regard the term as misleading from the point of view of the ecology of the *Minuartia*.

The habitat of *Minuartia* in Nova Scotia bears a striking physical resemblance to the granite barrens on the fall line between the piedmont and the coastal plain in North Carolina described by Oostings and Anderson (1939). Their description of more or less level areas of exposed granite with depressions accumulating a shallow soil in which species are zoned according to soil depth is exactly parallel to the Nova Scotian situation, although the mechanism producing the exposed granite is different since North Carolina was not glaciated. However, almost no species, apart from *Minuartia* (of which there are two species in North Carolina, see comment by Weaver 1970), are common to the 2 areas. It seems that similar topographic conditions, usually but not always exposed granite, from Nova Scotia to Georgia have acted as refugia for the shorter-lived, more southern-oriented series of populations. The maintenance of these conditions is obviously vital to the persistence of the species.

It is possible to give a conjectural reconstruction of the history of *M. groenlandica* in Nova Scotia from what is known of general postglacial history and the species habitat requirements. Because Nova Scotia was entirely covered by ice at the peak of the last glaciation, we can presume that *Minuartia* survived somewhere to the south or possibly on the offshore banks exposed by the lowered sea level. Ogden (1959) records *Caryophyllaceous* pollen at several levels in a late-glacial pollen sequence from Martha's Vineyard, Massachusetts. This pollen cannot be positively identified to species but in the context of the associated flora is probably derived from *M. groenlandica* since the earlier parts of the sequence probably represent tundra vegetation.

With the retreat of ice from Nova Scotia, a tundra vegetation invaded and *Minuartia groenlandica* was presumably an abundant plant during this period. This seems a safe assumption although no *Minuartia* pollen has been reported from palynological research in the province. With the rapid spread after about 9000 BP of spruce, birch, other trees and shrubs into the province, the open, low-competition habitats necessary for a heliophilous plant would become restricted in area and the quantity of *Minuartia* would have fallen drastically. Eventually only certain rock areas with very shallow soils and sufficiently uncracked that tree roots could not penetrate, would support the species. These areas, the *Minuartia* refugia, have probably been stable for the greater part of the time since trees arrived — maybe the past 9000 years or more. It seems unlikely that there has been any genetic interchange between these populations since the arrival of trees. During this time of isolation, the possibly genetically variable immigrant population would have become closely adapted to the climatic-edaphic conditions of each site resulting in the annual-perennial form of the species so exquisitely tuned to the Nova Scotian climate but so puzzling to herbarium taxonomists familiar with plants from more reliable climates to the north or south of the province.

Our observations indicate that the presence of *Minuartia* in the province is the product of its life cycle, the presence of unusual topographic conditions, and the migrations which occurred following the end of the last glaciation. The ability to produce a large crop of seeds every year and, under certain conditions, maintain its populations entirely from seeds, immediately marks it as having a different life cycle from all the other Nova Scotian arctic-alpines and indeed from most arctic plants, in which the annual habit is much less common than the perennial strategy. The germination of seeds over a period of months is undoubtedly of survival value. Recently germinated seedlings have been observed in August, September, October, and May — this spread of emergence allows the species to survive even if the plants from one particular month are wiped out by some climatic viscissitude. Growth can be rapid and some seedlings which had germinated in late August or early

September 1975 were found to have an open flower on 1 October. There is thus an approach to an ephemeral growth pattern, although the seedlings produce the majority of their flowers in the spring hence being more correctly regarded as winter annuals.

Not all plants necessarily die after the spring flowering, their fate depends on the succeeding summer which in Nova Scotia can vary radically from year to year. More often there is sufficient rain during the summer to allow some of the plants well established in the deeper soils of Zone 1 to survive and flower again, possibly for several years in succession. These plants are readily recognized in the spring by the presence of dead inflorescences and a better developed cushion of basal vegetative shoots. It is the presence of these semi-perennial plants and various metric characteristics which caused Fernald (1919) to write about Macoun's specimens: "the plant in stature and habit is perplexingly transitional to the boreal *Arenaria groenlandica,* being usually more tufted and lower than in *A. glabra* but with the very bushy habit of the latter and with pedicels intermediate in length, and petals shorter than in most arctic-alpine plants." The point to make here is not so much that the Nova Scotian plants are "perplexingly transitional" between two extremes, because these two extreme 'species' can be regarded as mere constructs of the human mind; what we wish to draw attention to is that the Nova Scotian plants are physiologically and genetically adapted to the climatic conditions prevailing at the site. The Nova Scotian climate is intermediate between the certain dampness of the arctic and the certain summer drought of the southern United States, and the flexible life cycle and intermediate morphology of the Nova Scotian plants is clearly adaptive for the uncertainties of the local summers. The populations clearly fall into the concept of ecotype originated by Turesson and the chain of populations from cool-damp to hot-dry conditions could well turn out to be a cline.

Now that we know more about the habitat requirements of *Minuartia groenlandica*, we can sensibly search other parts of Nova Scotia for it. Looking back on the history of its discovery in Nova Scotia we can see that Macoun's cryptic 'Rocky ground, North West Arm' must have misled people since it carries the implication that the plants grew on rocks alongside the seashore. This, and the low state of botany in the province was responsible for the 60-year gap between the first two collections. We are now of the opinion that Macoun was most likely on the Kidston Lake barrens when he and Burgess discovered the *Minuartia*. The Northwest Arm is visible from the site, it is certainly rocky and nearby is the Rocking Stone, a large granite, glacial erratic which is a local curiosity and would certainly be an obligatory trip for any visiting geologist of that era. The barrens are only a few hundred meters from the Rocking Stone.

Since there are extensive areas of rock barren in Nova Scotia, it seems highly probable that more populations of *Minuartia* remain to be discovered. The species is unfamiliar to the majority of people, and being small is easily overlooked or confused with other plants, e.g. *Sagina nodosa*. The areas marked as granite on Figure 1 give an exaggerated indication of the distribution of potential sites, although not all granite outcrops are topographically suitable. However, it is obvious that there is great potential, particularly in SW Nova Scotia although Cape Breton cannot be dismissed since there are many lichen barrens, especially in the Cape Breton Highlands. Even the distribution of granite does not define the potential sites since the locality near Blue Rocks is non-granitic.

## Conclusions

*Minuartia groenlandica* is adapted by its annual or perennial life cycle to survive in either arctic-alpine or lowland habitats, but only the latter occur in Nova Scotia. It migrated into the province during the tundra phase following the last glaciation and has since become confined to a limited number of open habitats. These are mainly on granite exposures, where the essential open habitat has been available continuously since trees migrated into the province. It differs from the other arctic-alpines of the province in its ability to survive drought by means of the seed phase, and may be much more common than our present information indicates.

## Acknowledgements

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## References

**Environment Canada.** 1976. *Atmospheric Environment, Annual Meteorological Summary 1975: Halifax-Dartmouth, N.S. (Shearwater 'A').* Information Canada.

**Fernald, M.L.** 1919. The unity of the genus *Arenaria, Rhodora,* 21: 1-22.

**Holmgren, P.K.** and **Keuken, W.** 1974. *Index Herbariorum.* Part I. *The Herbaria of the World.* Utrecht, Netherlands.

**Hulten, E.** 1964. Remarkable range extension for *Minuartia groenlandica* (Retz.) Ostenf. *Sven. Bot. Tidskr.* 58: 432-435.

**Komarov, V.L.** et al. (ed.) 1934-1964. *Flora S.S.S.R.* Leningrad and Moscow.

**Macoun, J.** 1886. *Catalogue of Canadian Plants.* Part III. Dawson Brothers, Montreal.

**Ogden, J.G.** 1959. A late-glacial pollen sequence from Martha's Vineyard, Massachusetts. *Am. J. Sci.* 257: 366-381.

**Oostings, H.J.** and **Anderson, L.E.** 1939. Plant succession on granite rocks in eastern North Carolina. *Bot. Gaz.* 100: 750-768.

**Radford, A.E., Ahles, H.E.,** and **Bell, C.R.** 1968. *Manual of the Vascular Flora of the Carolinas.* University of North Carolina Press, Chapel Hill.

**Roland, A.E.** and **Smith, E.C.** 1969. The flora of Nova Scotia. Part II. The dicotyledons. *Proc. N.S. Inst. Sci.* 26: 277-743.

**Shetler, S.G.** and **Skog, L.E.** 1978. *A Provisional Checklist for Flora North America (revised).* Monographs in Systematic Botany, 1. Missouri Botanical Garden.

**Smith, T.E.** 1970. The geochemistry of the granitic rocks of Halifax County, Nova Scotia. *Can. J. Earth Sci.* 11: 650-657.

**Tutin, T.G.** et al. (ed.) 1964-. *Flora Europaea.* Cambridge Univeristy Press, London.

**Weaver, R.E. Jr.** 1970. The Arenarias of the Southeastern granitic flat-rocks. *Bul. Torrey Bot. Club,* 97: 40-52.