# A Late Permian flora of Pechora affinity in North Greenland

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Late Permian plant impressions comprising six taxa have been obtained from the North Greenland fold belt. *Rhipidopsis,* a probable ginkgophyte, occurs together with the ferns *Prynadaeopteris venusta* Radczenko and *Pecopteris (Asterotheca?)* cf. *P. (A?) helenaeana* Zalessky, the sphenophyte *Sphenophyllum* cf. *S. biarnicum* Zalessky the cordaitean *Cordaites* cf. *C. sylovaensis* (Neuburg) Meyen and a possible conifer branch fragment. The assemblage invites comparison with the Pechora flora of the northern Pre-Urals, and also with that of Mongolia and north-eastern China. These may be warm temperate floras on approximately the same palaeolatitude.

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During the 1979 and 1980 field seasons, several outcrops of post-metamorphic cover rocks were discovered in the North Greenland fold belt in eastern North Greenland (fig. 1). These increase considerably the known extent of the Wandel Sea Basin succession, i.e. the Carboniferous-Palaeogene sediments of eastern North Greenland which post-date the deformation in the North Greenland fold belt and the East Greenland Caledonian fold belt. The new occurrences are in two areas and are both preserved due to post-Palaeozoic tectonic features (fig. 1). One is in north-west Johannes V. Jensen Land and is associated with the Kap Cannon thrust zone. Quartzites and limestones with a marine fauna were found in 1979 on north-west Lockwood Ø (Soper *et al.,* 1980). E. Hakansson (personal communication) associated this fauna with that of Lower Permian strata of the Wandel Sea Basin. In 1980 the Lockwood Ø sequences proved to rest unconformably on Lower Palaeozoic flysch of the fold belt and to be overlain by shales below the Kap Washington volcanic succession. Similar fossiliferous Permian strata were also found as a thrust slice on the Kap Kane peninsula to the east of Lockwood Ø.

Several outliers of cover rocks are associated with the Harder Fjord fault zone (fig. 1). This is a major fault zone which traverses the fold belt in an E–W direction and which throws down to the south. In its eastern development, along Frederick E. Hyde Fjord, the fault zone is expressed as a narrow graben, in which Tertiary strata are preserved (Croxton *et al.,* 1980)

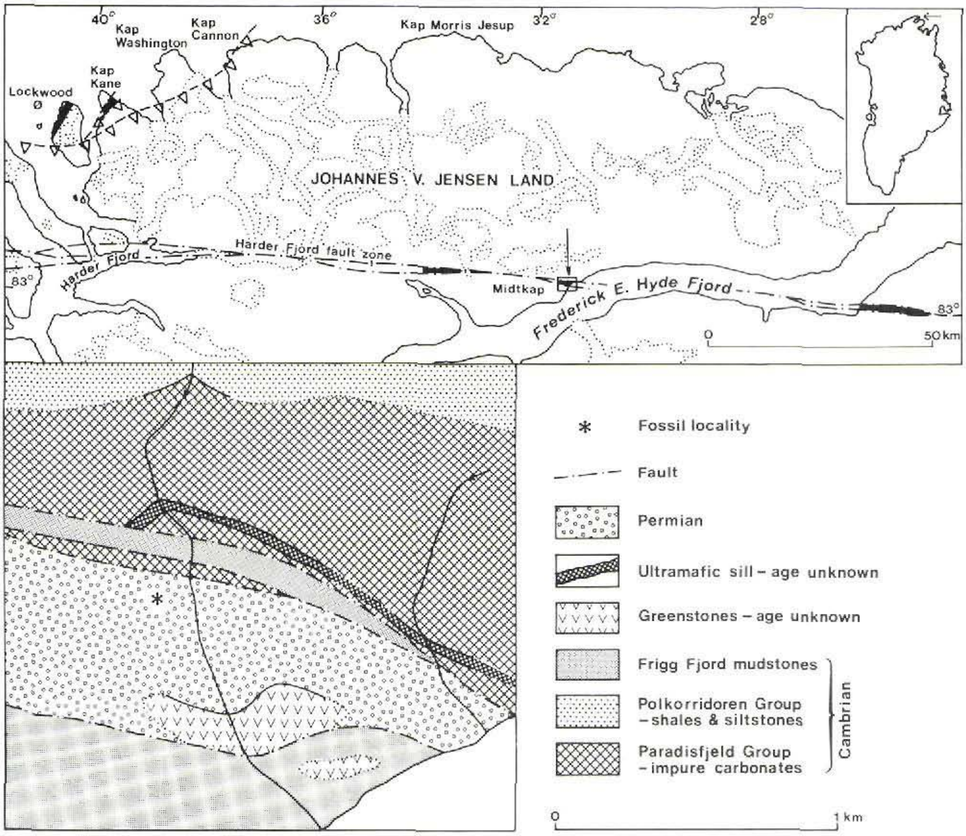


Fig. 1. Location Map. Outcrops of Wandel Sea Basin sediments in central North Greenland are indicated in black. The location of the geological map around the fossil locality is arrowed.

as well as Cretaceous and Permian. This Permian occurrence was found in 1979 and contains the floral remains reported in the present paper. The initial collection proved interesting and further material was collected in 1980, providing one additional taxon.

The plant bearing strata crop out in a stream section which crosses the northern branch of the Harder Fjord fault zone, north of Frederick E. Hyde Fjord, a few kilometres north-east of Midtkap (fig. 1). Exposure is limited, but the Permian sediments appear to be faulted against calcareous flysch deposits of the Paradisfjeld Group to the north and against greenstones and Frigg Fjord mudstones to the south. A few hundred metres of steeply dipping conglomeratic sandstones are exposed west of the stream. These contain partings of siltstones and shales from which the floral remains were collected. To the east there is an extensive slope of carbonaceous shale debris. The latter proved barren of plant remains, and also of pollen and spores.

## Description of floral remains

The plant fossils occur in dark grey, silty mudstones which are blocky in places due to the presence of sideritic ironstone. Fissility is variable and may be related in part to silty streaks which show a hint of cross-lamination. This indication of current activity agrees with the presence of abundant small carbonaceous debris at certain horizons. On the other hand, the identifiable plant fossils consist of large frond fragments of two ferns, a pecopterid and a sphenopterid, together with fairly cohesive large palmate leaves of the probable ginkgophyte *Rhipidopsis,* and sizeable fragments of cordaitean leaves. Two other taxa are present with only single fragments. The identifiable plant remains occur on certain bedding planes which represent the deposition of finer grained mudrock. The large size of a number of specimens (one fragment measures about 25 cm and extends to the edge of a broken slab) precludes transport over a long distance.

*Rhipidopsis* sp. (fig. 2) is represented by petiolate, palmate leaves subdivided into long, cuneate segments, twice cleft at the apex. The segments differ in length depending on their position within the leaf, and are 5 to 10 cm long and 1 to 2 cm wide. The veins are subparallel and dichotomising, and the vein density is about 28 per centimetre across the width of the segment. These leaves are most similar to that figured as *Rhipidopsis* aff. *R. palmata* Zalessky by Durante (1976, pl. LII, fig. 2) from Mongolia. They may also be compared with *Rhipidopsis baieroides* Kawasaki & Kon'no as figured from north-eastern China (Kon'no 1968, pl. 23–24). However, it is noted that the type *R. baieroides,* from the Kobosan Beds of Korea, shows a more highly dissected leaf with a very marked variation in the size of leaf segments. Both the Mongolian and north-eastern Chinese specimens came from Upper Permian strata.

*Pecopteris (Asterotheca?)* cf. *P. (A?) helenaeana* Zalessky (fig. 3) occurs with many large sterile frond fragments as well as a few small remains showing poorly preserved sori. The species is characterised by closely adpressed pinnules, confluent at the base in the more distal parts of pinnae but slightly constricted at the base in the much more elongate pinnules in the lower parts of pinnae. Fragments of pinnae up to the penultimate order have been found. Pinnule insertion is characteristically subperpendicular and the size is very variable, ranging from some 4 to 15 mm in length in non-lobing pinnules. Their width is more constant and ranges from 2 to 3 mm. Gradually lobing, even more elongate pinnules seem to effect a gradual transition to pinnae of the last order. The venation consists of a well marked midvein and strongly developed, oblique laterals. These are generally forked only once but are more rarely three-pronged. Vein density is about 12 per cm on the pinnule margin. The smallest individualised pinnules show simple veins (fig. 3 D). Poorly preserved sori (*Asterotheca?*) fill the spaces between the midvein and the pinnule margin in a few specimens.

The comparison with *Pecopteris helenaeana* Zalessky, suggested by S. V. Meyen (personal communication), is supported by the fact that this species is also characterised by large pinnules with a wide venation consisting of a strong midvein and mainly once forked laterals oblique to the pinnule margin. Zalessky & Tchirkova (1937, p. 29) describe this species as possessing a strongly marked nervation which is also an obvious feature of the present specimens. *P. helenaeana* also shows gradual lobing with a nervuary development of the *Lobatopteris* kind, a development which has also been observed in the material from North Greenland. The shape of the pinnules also appears to be similar, as is the insertion and the tendency for a confluent base to be present in the smaller pinnules. However, the pinnules of

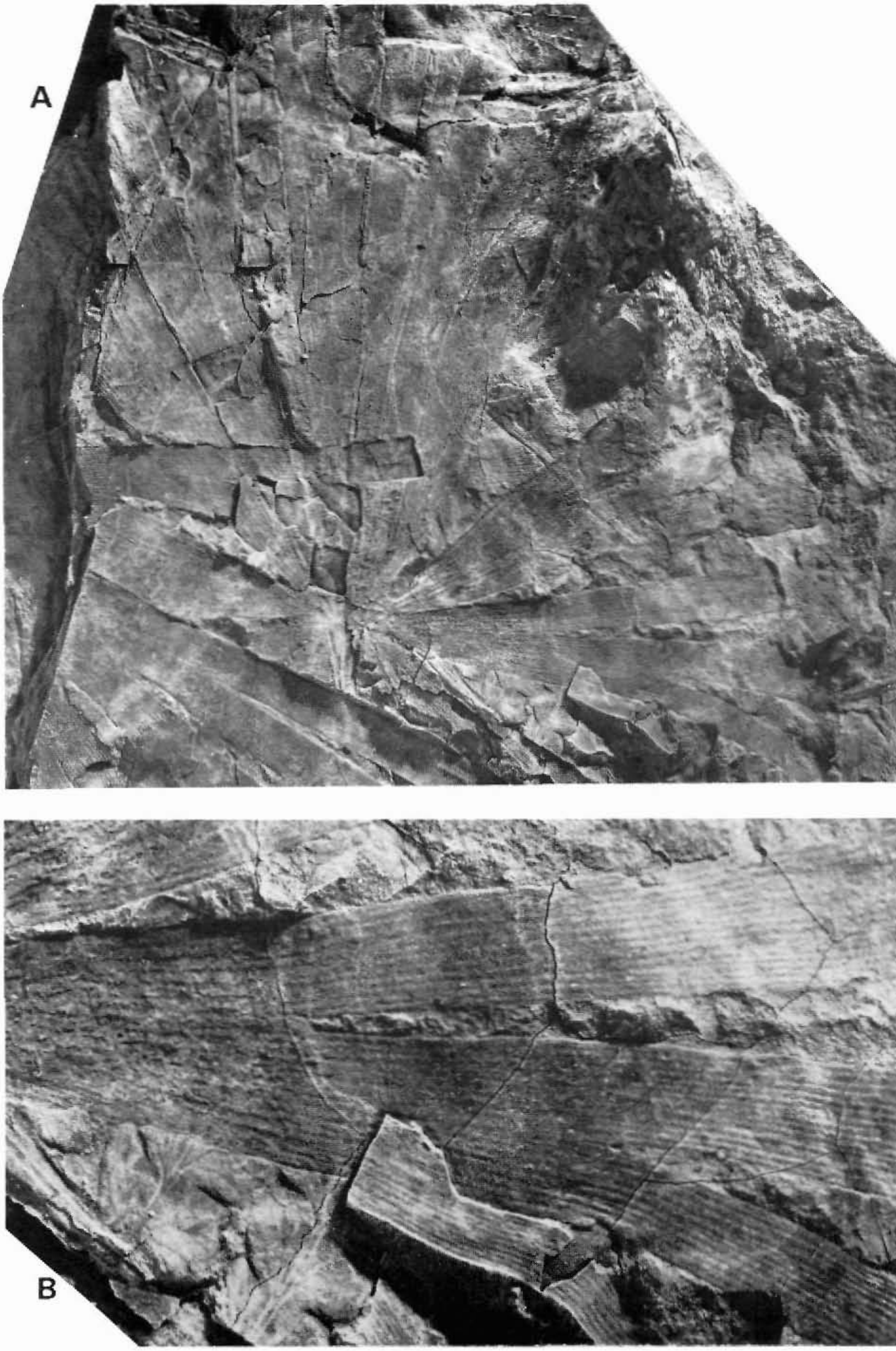


Fig. 2A. *Rhipidopsis* sp., × 1. MGUH 15.965 from GGU 255770.
2B. Detail of the same specimen showing venation of a leaf segment cleft twice at the distal end × 3.

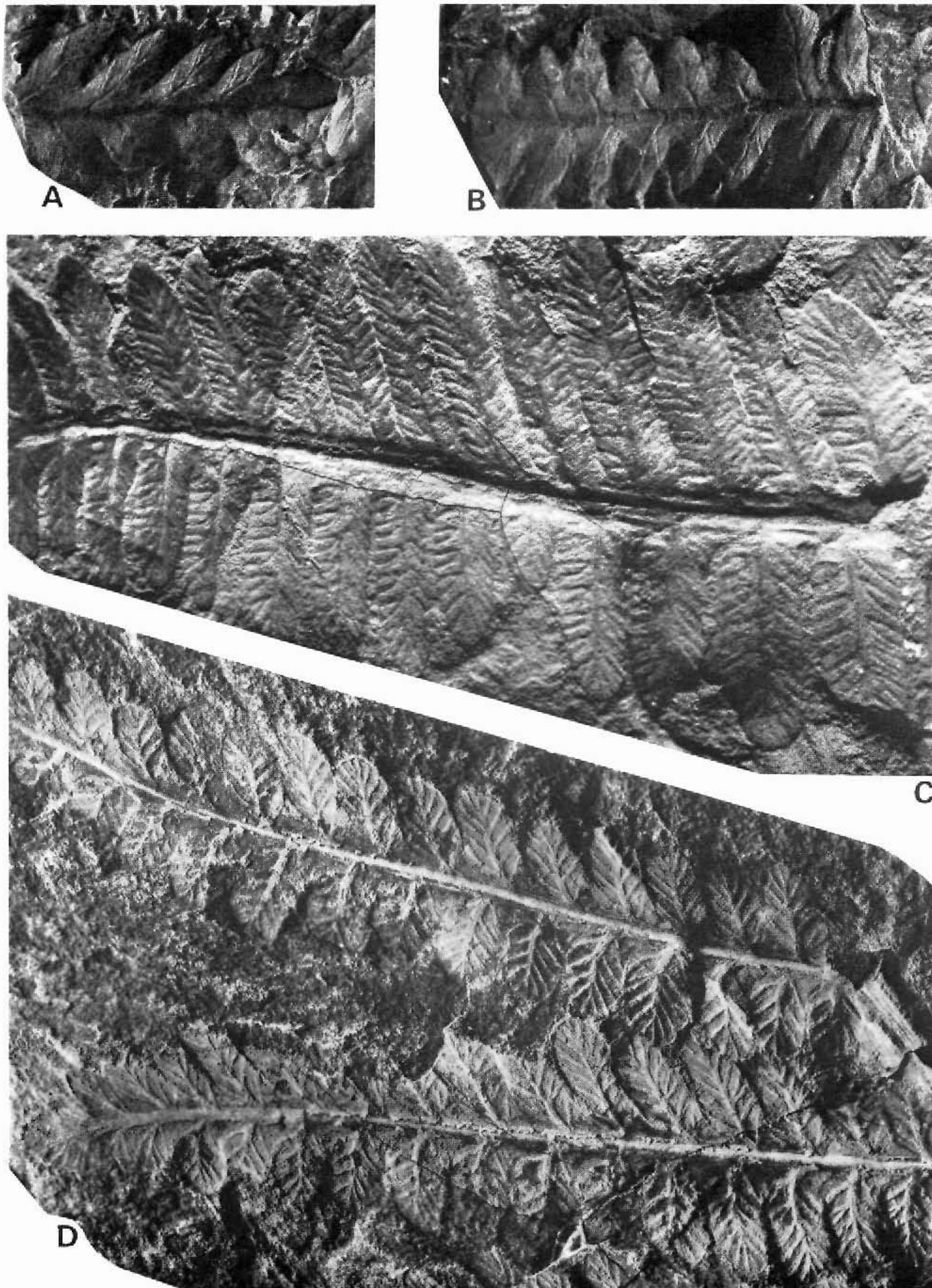


Fig. 3A, B. *Prynadaeopteris venusta* Radczenko, × 3. MGUH 15.966 from GGU 255770.
3C, D. *Pecopteris* cf. *P. helenaeana* Zalessky, pinna fragments showing some of the variation in pinnule size and venation, × 3. MGUH 15.967 and 15.968 from GGU 255770.

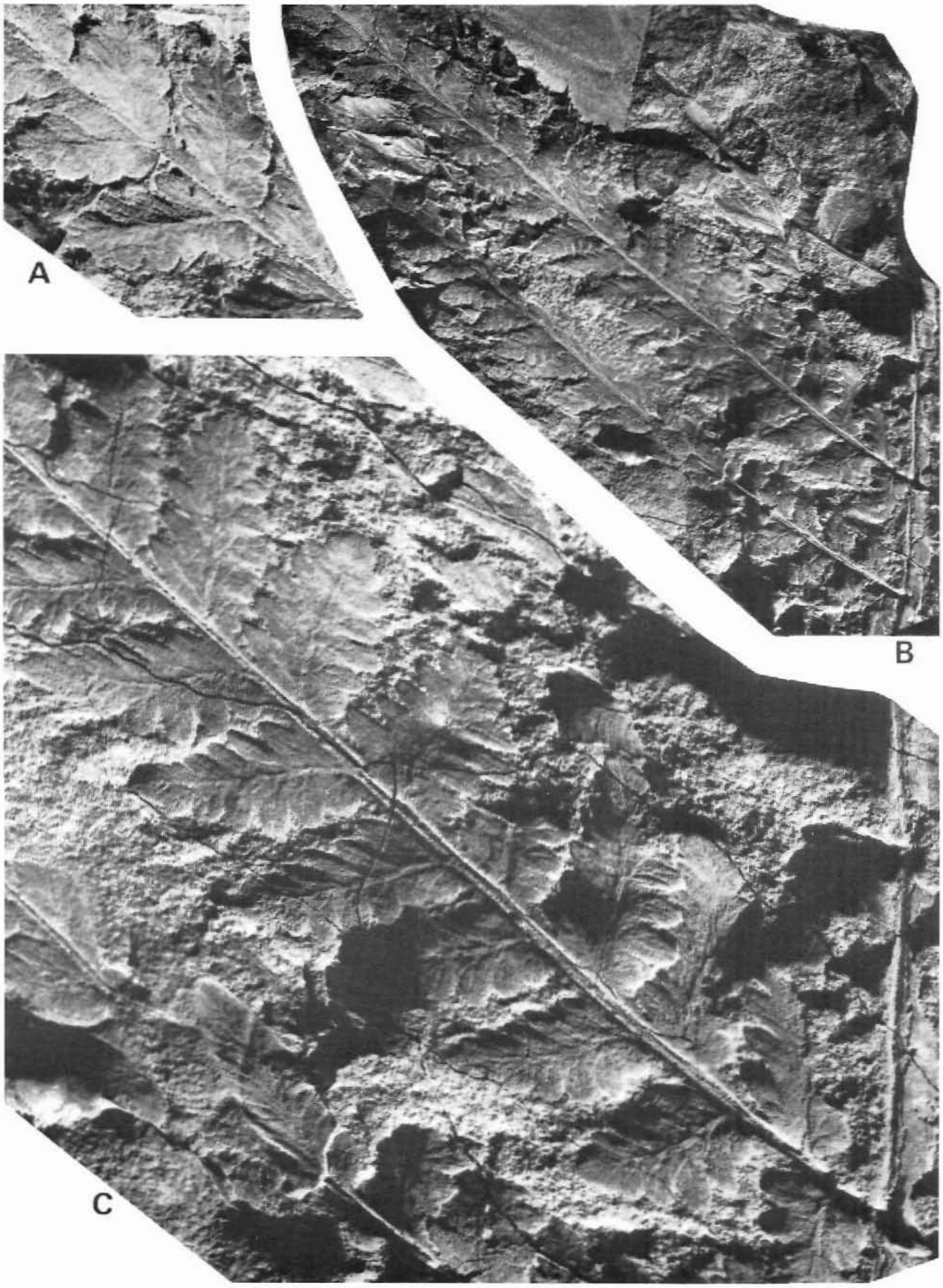


Fig. 4A–C. *Prynadaeopteris venusta* Radczenko. Single specimen × 1 (B) and × 3 (A, C) showing pinnule shape in a lobing part of the frond. MGUH 15.969 from GGU 255770.

*P. helenaeana* have been described as up to 7 mm wide, whereas the specimens in hand show generally narrower pinnules. *P. helenaeana* Zalessky occurs in the Upper Permian of the Pechora and East European areas (cf. Meyen *in* Vakhremeev *et al.,* 1978). A much more remote resemblance exists with regard to *Pecopteris robustissima* Wagner of the upper Stephanian in western Europe and the Caucasus (Shchegolev, 1979).

*Prynadaeopteris venusta* Radczenko (figs 3 and 4) has been found in smaller pinna fragments (remains of up to penultimate order) with quite variable, thin-limbed pinnules which tend to a subtriangular shape and which show very gradual lobing. The venation consists of a thin, flexuous midvein and widely spaced, simple to once forked laterals. Some specimens exhibit marginal sori placed at the end of lateral veins. Although the preservation is too poor to show the annulus, the obvious comparison is with *Oligocarpia.* The foliage is also quite similar to that of *Oligocarpia leptophylla* (Bunbury) Grauvogel-Stamm & Doubinger from the upper Stephanian and Autunian of Europe. However, a more direct comparison can be made with *Prynadaeopteris venusta* Radczenko, a species close to *Prynadaeopteris anthriscifolia* (Goeppert) Radczenko. The genus *Prynadaeopteris* shows sori similar to those of *Oligocarpia,* but apparently without an annulus (Fefilova, 1973). *P. anthriscifolia* has often been compared and even placed in synonymy with *'Pecopteris' leptophylla* Bunbury, but the comparison has been with *Dicksonites leptophylla* Doubinger (= *Pecopteris leptophylla* Zeiller, *non* Bunbury). It seems likely that the genus *Prynadaeopteris* and its affinities need to be examined more closely.

*Sphenophyllum* cf. *S. biarnicum* Zalessky occurs with a single fragmentary whorl showing five leaves of unequal size (probably originally six leaves in the whorl), up to a maximum of 15 mm long at 6–7 mm width, with the distal border broadly rounded and grading into lateral borders. Veins are rather widely spaced and end on the distal border as well as high on the lateral borders. This specimen is similar to Zalessky's (1937, p. 44–46) species from the Pechora Basin, particularly in the size and shape of the leaves. The relatively wide veining also coincides, but there seems to be a higher proportion of veins abutting onto the lateral border in the specimen figured from the northern USSR. It is also possible to compare with *Sphenophyllum speciosum* Royle and *Sphenophyllum sinocoreanum* Yabe. All these are Late Permian species.

*Cordaites* cf. *C. sylovaensis* (Neuburg) Meyen refers to cordaitean leaf fragments with closely spaced parallel veins with very occasional vein bifurcations. S. V. Meyen (personal communication, 1980) has suggested the comparison.

A branch fragment with attached, simple leaves shows a resemblance to *Bardella,* a presumed conifer described by Zalessky (1937). The specimen is poorly preserved and the identification is highly tentative.

## Discussion

The preliminary identifications made thus far indicate the presence of six taxa, viz. *Rhipidopsis* sp., *Pecopteris (Asterotheca ?)* cf. *P.(A?) helenaeana* Zalessky, *Prynadaeopteris venusta* Radczenko, *Sphenophyllum* cf. *S. biarnicum* Zalessky, *Cordaites* cf. *C. sylovaensis* (Neuburg) Meyen and *?Bardella* sp. This assemblage is most comparable to that of the Upper Permian (Kazanian-Tatarian) of the Pre-Urals Pechora Basin. The Pechora Province (Meyen *in* Vakhrameev *et al.,* 1978, p. 96) forms a special palaeofloristic unit on the western margin of the Angara Realm, showing transitions to the Taimyr-Kuznetsk area to the east and the East European area to the west. It is characterised by the presence of Angaran genera together with a more varied representation of ferns, as well as *Rhipidopsis,* etc. Among the North Greenland floral remains there are several that also invite comparison with the Kuznetsk and Tunguska basins, whilst the *Rhipidopsis* remains are most similar to those recorded from Mongolia and north-east China. It is clear that the assemblage from North Greenland represents a palaeofloristic zone marginal to the general Angara Realm and bordering more equatorial floras of the Euramerican and Cathaysian areas. The difference between the latter two 'provinces' is apparently related to more arid and more humid climatic regions and is not a matter of palaeolatitude. The palaeofloristic zone to which the North Greenland flora belongs, is most likely to be interpreted as a latitudinal belt on the northern hemisphere of the Permian plate configuration. Its floras may be regarded as warm temperate, and a humid climate may be envisaged.

The palaeofloristic interpretation of the North Greenland plant remains, i.e. the identification with the Pechora Province, apparently agrees well with the recent records of Late Permian and Triassic microfloras from East Greenland reported by Balme (1979), who showed assemblages comparable to those of East Europe. This may be partly a matter of palaeolatitude and partly a reflection of the more arid climate of the North-West European Zechstein and early Trias.

## Conclusions

The presence of floral remains belonging to a palaeofloristic zone marginal to the Angara Realm is not wholly unexpected in North Greenland. A prediction to that effect is implicit in the map of Permian floral provinces published by Wagner (1962), and a similar prediction is contained in the map published by Meyen (1973). The significance of floras for the reconstruction of palaeolatitudinal belts has long been recognised but fitting the floristic data to palaeomagnetic reconstructions of the late Palaeozoic plate configurations is still difficult. On the latest reconstruction of the northern hemisphere for 240 m.y. by Smith *et al.* (1981) the North Greenland and northern Ural occurrences do occupy a common palaeolatitude in about 45°N. However, when traced eastwards to the Soviet Far East and north-east China, the marginal Angaran belt appears to cross the lines of palaeolatitude at a high angle. The location of this region is poorly constrained by the palaeomagnetic data.

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