Brachiopod zonation and age of the Permian Kapp Starostin Formation (Central Spitsbergen)

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This study has defined five brachiopod assemblage zones within the Permian Kapp Starostin Formation of Festningen, Central West Spitsbergen. They are designated as the *Horridonia timanica* zone, the *Waagenoconcha* sp. A (Gobbett 1964) zone, the *Megousia weyprechti* zone, the *Pterospirifer alatus* zone and the *Haydenella wilczeki* zone in ascending order. Only the lower three zones are recognized in the same formation of Sveltihel.

The first zone, which is exactly equivalent to the 'Spirifer Limestone' as well as the Vøringen Member of the Kapp Starostin Formation, is probably Kungurian in age. The last zone, situated near the uppermost portion of the Hovtinden Member, may possibly have a brachiopod assemblage matching that of the *Cyclolobus*-bearing beds of the Foldvik Creek Formation in Central East Greenland. Consequently, the uppermost beds of the Kapp Starostin Formation are chronologically dated as late Permian, most probably as Dzhulfian of the Tethys Province.

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It has been well known for a long time that there is a debate among Permian workers over the age of the 'Productus Chertstones', 'Brachiopod Cherts' and 'Spirifer Limestone' in the Svalbard Archipelago, in spite of the presence of rich and well-preserved megafossils including brachiopods, bryozoans, corals and sponges. This unsatisfactory situation is attributed to the complete lack of ammonoids or fusulinids, which are more suitable for age determination, in those beds. The name Tempelfjorden Group was proposed to replace the old terms of 'Brachiopod Cherts' and 'Spirifer Limestone', and the name Kapp Starostin Formation was used rather restrictedly by Cutbill & Challinor (1965) for the marine Permian distributed in the Spitsbergen trough area. The most recent comments on the age of the uppermost beds of the Tempelfjorden Group were given by Steel & Worsley (1984) as: 'There remains much uncertainty as to how far sequences assigned to the group extended into the Late Permian and opinions vary considerably: we indicate a ?Kazanian age for the youngest beds and hope that studies of palynomorphs, conodonts and foraminifers now in progress may elucidate this problem'. On the other hand, various ages have also been suggested since the 1900s for the lower border of the Tempelfjorden Group or the Kapp Starostin Formation. In short, these two problems seem to be debatable even today.

In 1984, a cooperative study between Norsk Polarinstitutt and Hokkaido University, Japan was undertaken in West Central Spitsbergen, the main objective of which was to obtain detailed stratigraphical and palaeontological information about the Permian and the Permian-Triassic boundary. For these purposes, two stratigraphical sections of the Kapp Starostin Formation exposed along the south side of Isfjorden were measured both at Festningen and at Sveltihel, the latter being located about 60 km east of the former (Fig. 1). Study in Japan led to the recognition that the brachiopod assemblage of the upper part of the Kapp Starostin Formation was allied, as a whole, to that of the Upper Permian Foldvik Creek Formation in Central East Greenland. As a result, the more or less precise age of the uppermost beds of the Kapp Starostin Formation could be deduced.

Stratigraphy

As stated earlier, the name Tempelfjorden Group was introduced by Cutbill & Challinor (1965)

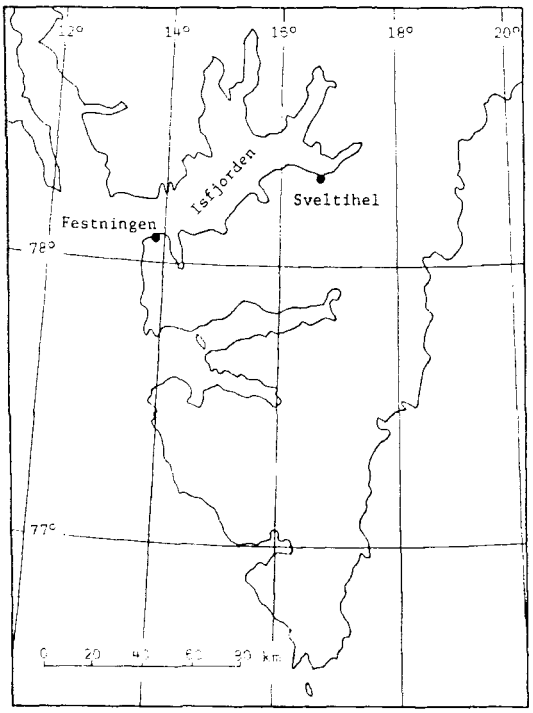

Fig. 1. Map of southern Spitsbergen showing the location of Festningen and Sveltihel.

for marine late Permian sequences exposed in Svalbard. According to them, this group comprised the Kapp Starostin Formation in the Spitsbergen trough area, the Tokrossøya Formation on Sørkappøya and 'Spirifer Limestone' on Bjørnøya. The name Miseryfjellet Formation was later given to the 'Spirifer Limestone' on Bjørnøya by Worsley & Edwards (1976). The type section designated by Cutbill & Challinor for the Kapp Starostin Formation was Festningen, Central West Spitsbergen. A three-fold division of the Kapp Starostin Formation was further proposed by them, in which they delineated in ascending order the Vøringen, Svenskeegga and Hovtinden Members.

A. Festningen section

The schematic section simplified from the detailed column measured by the Japanese members at Festningen is given in Fig. 2. The Kapp Starostin Formation is about 400 m thick and can be classified into 12 lithologic units. At its base the Vøringen Member, formerly called 'Spirifer Limestone' or 'Limestone A' (Gee et al. 1952), is composed of only one lithologic unit (Unit 1) which is made up of white coarse limestones in the lower part and grey marly limestones in the upper, and is dominated by brachiopod fossils and accompanied by a lesser number of bryozoans, corals and so on.

The Vøringen Member is overlain by the Svenskeegga Member, which contains Units 2, 3, 4 and 5. Among these, Units 2–4 are made up of clastic rocks, such as sandstone, shale and chertstone, and are very poor in organic remains. Unit 2 is characterized by the inclusion of calcareous nodules at several horizons. The uppermost Unit 5 consists mostly of light-grey bedded limestones and is prolific in megafossils, such as brachiopods, corals, bryozoans and sponges.

The Hovtinden Member may be better subdivided into Lower, Middle and Upper Beds. Units 6–8 are included in the Lower Bed, of which Units 6 and 7 consist lithologically of shales and chertstones, while Unit 8 consists of limestone. Brachiopods were collected from several horizons of Units 6 and 7. Unit 8 is marked by a sudden increase of large brachiopods and bryozoans, to which corals and sponges are associated. The Middle Bed is composed of Unit 9, represented by shales with a few brachiopods and pelecypods in its upper part, and Unit 10, consisting mostly of limestones rich in brachiopods and bryozoans. The Upper Bed comprises Units 11 and 12 and is composed mostly of shales. A glauconitic sandstone layer was observed in Unit 11, while some nodular limestone lenses are intercalated in Unit 12. Brachiopods and corals were found in Unit 11, and some sponge remains were collected from the uppermost beds of Unit 12.

B. Sveltihel section

The Kapp Starostin Formation outcrop at Sveltihel was briefly described by Gobbett (1964) and by Major & Nagy (1972). The formation measured about 340 m in thickness and was lithologically divided into 11 units, as shown in Fig. 3. The Vøringen Member, corresponding to Unit 1, is composed mostly of limestones and sandy limestones, and it yielded numerous brachiopods together with some bryozoans, corals and sponges, as at Festningen. The Svenskeegga Member is represented by Units 2, 3 and the lower half of Unit 4, all of which are made up of

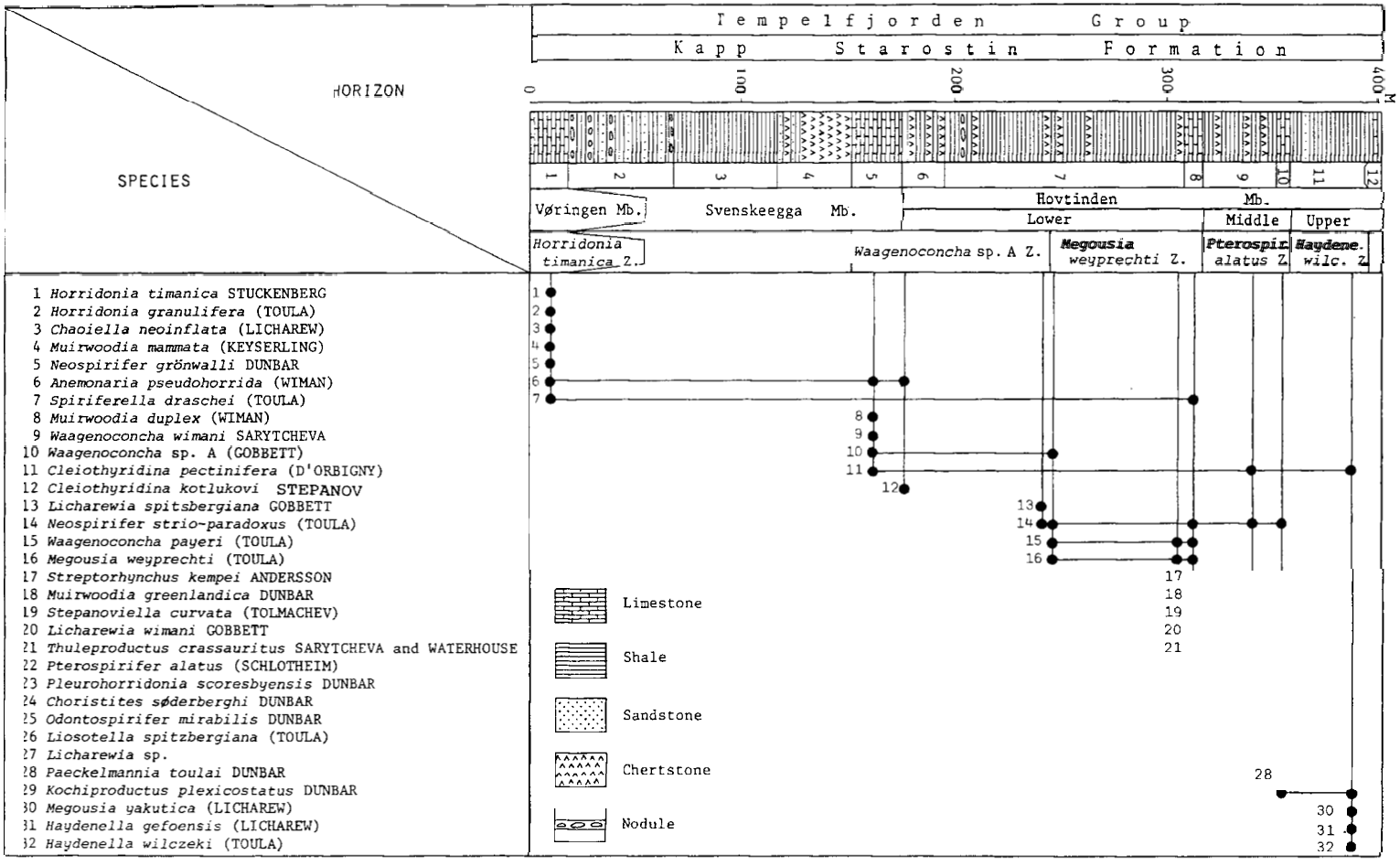

Fig. 2. Range chart of the brachiopods of the Kapp Starostin Formation at Festningen, Central West Spitsbergen

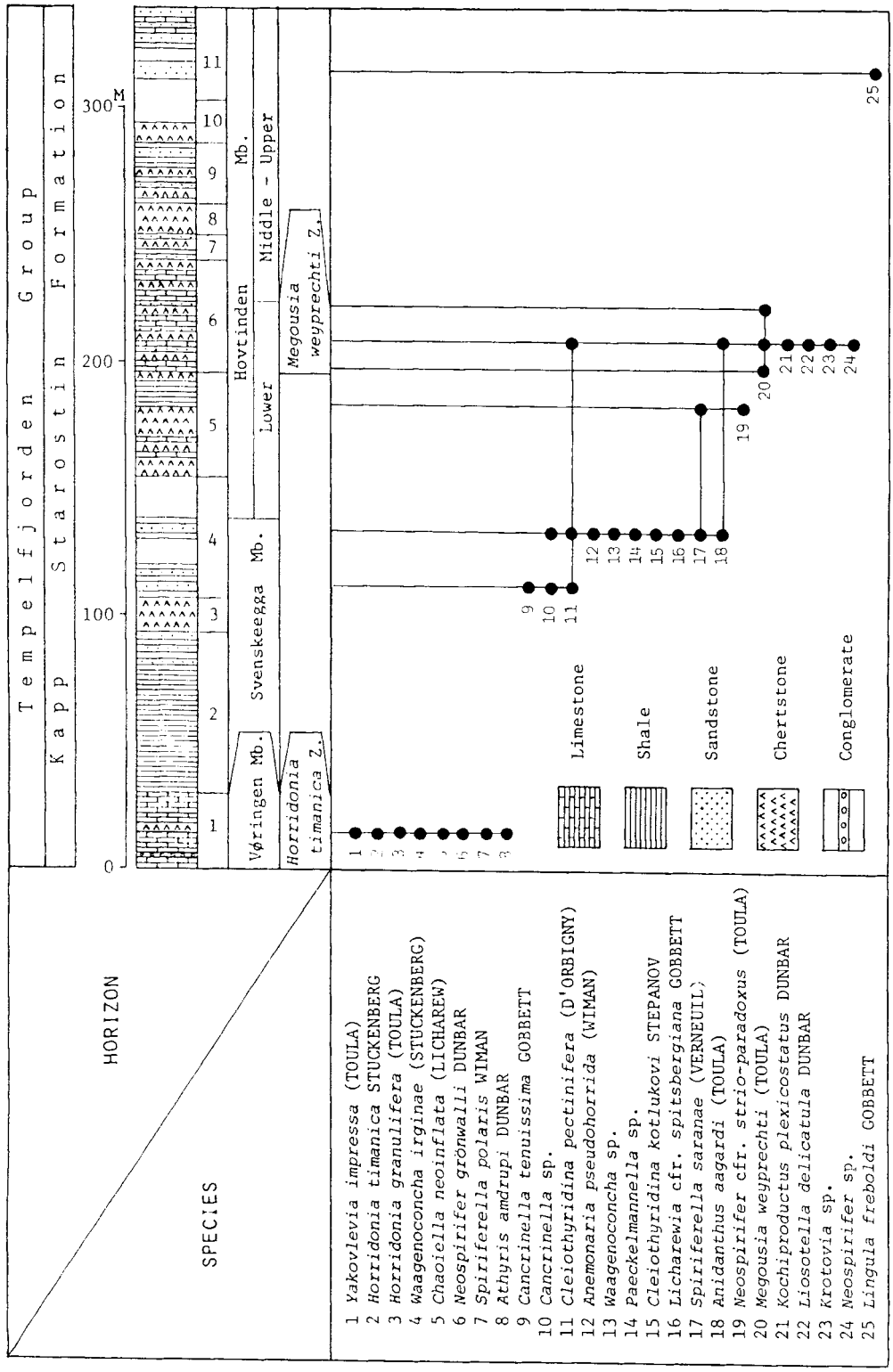

Fig. 3. Range chart of the brachiopods of the Kapp Starostin Formation at Sveltihel, Central Spitsbergen.

various kinds of clastic rocks. Brachiopods were only found in Unit 4. All beds from the upper half of Unit 4 to Unit 11 may be included in the Hovtinden Member, and they are mostly composed of altered cherts with thin limestone as well as shale layers, except for the uppermost Unit 11 represented by glauconitic sandstones. Amongst these units, Units 5 and 6 contain several layers yielding brachiopod remains.

Brachiopod zonation

Stepanov (1957) considered that the brachiopod fauna of the whole 'Brachiopod Cherts' represented only one period, and he proposed a Svalbardian Stage for them. Gobbett (1964) basically followed Stepanov's view in this and wrote: 'The brachiopods described by Frebold (1937) from 23 horizons facilitate a three-fold division of the section (Forbes et al. 1958). However, these three groups of species are based on collections which are small and poorly-preserved in comparison with those from inner Isfjorden. Extensive collecting from the Brachiopod Chert, including the Spirifer Limestone, shows that the brachiopod fauna of this formation is essentially uniform.'

According to our own examination, however, brachiopod assemblages vary considerably from horizon to horizon, apart from the presence of a few long-ranging species, as shown in Fig. 2. So we support Frebold (1937). Most of the brachiopod species collected from the Vøringen Member (Unit 1) are of early Permian forms, while late Permian ones are enumerated in Unit 5 of the Svenskeegga Member and in Units 8, 10 and 11 belonging to the Hovtinden Member. Five brachiopod zones are recognized within the Kapp Starostin Formation of Festningen as the *Horridonia timanica* Zone, the *Waagenoconcha* sp. A (Gobbett 1964) Zone, the *Megousia weyprechti* Zone, the *Pterospirifer alatus* Zone and the *Haydenella wilczeki* Zone from old to young, on the basis of the vertical distribution of brachiopod species.

The *Horridonia timanica* and *Megousia weyprechti* Zones are also recognized at Sveltihel (Fig. 3). The occurrence of *Cleiothyridina kotlukovi* and *Anemonaria pseudohorrida* in Unit 4 and its stratigraphical position at Sveltihel strongly suggest that this unit may correspond to Unit 5, the lower part of the *Waagenoconcha* sp. A Zone at Festningen (Fig. 4).

The *Horridonia timanica* Zone is the lowest zone, characterized particularly by the abundance of productoid brachiopods including *Horridonia timanica, H. granulifera, Yakovlevia impressa, Waagenoconcha irginae, Muirwoodia mammata,* and *Chaoiella neoinflata.* Other notable species are *Neospirifer grönwalli, Spiriferella polaris* and *S. draschei.* The absence of *Yakovlevia impressa* at Festningen is noteworthy. This may be due to environmental control. The *Waagenoconcha* sp. A (Gobbett) Zone is established with the vertical distribution of the named species from Unit 4 to the lower half of Unit 7 at Festningen. Other diagnostic species of this zone are *Muirwoodia duplex, Waagenoconcha wimani* and *Cleiothyridina kotlukovi.* Special attention should be paid to the first appearance of a characteristic late Permian genus *Licharewia* in the lower part of the equivalent of this zone at Sveltihel. The *Megousia weyprechti* Zone is clearly delineated both at Festningen and Sveltihel. *Megousia weyprechti, Waagenoconcha payeri, Muirwoodia greenlandica, Stepanoviella curvata, Licharewia wimani, Streptorhynchus kempei,* and *Thuleproductus crassauritus* are confined to this zone, as far as our collection is concerned. Gobbett (1964), however, described *Streptorhynchus kempei* from the 'Spirifer Limestone' of Spitsbergen. The *Pterospirifer alatus* Zone is identified only at Festningen and is characterized by the following species: *Pterospirifer alatus, Pleurohorridonia scoresbyensis, Choristites søderberghi, Odontospirifer mirabilis, Liosotella spitsbergiana,* and *Paeckelmannia toulari.* Several species from the *Megousia weyprechti* and *Pterospirifer alatus* Zones are common to those described from the Foldvik Creek Formation in Central East Greenland. The *Haydenella wilczeki* Zone lies within the uppermost zone, and diagnostic species of this zone are *Haydenella wilczeki* and *H. gefoensis.* This zone has been recognized only at Festningen.

There may be several possible reasons for the remarkable stratigraphical changes in brachiopod assemblage recognized within the Kapp Starostin Formation. Malkowski & Hoffman (1979) suggested that the presence of some changes in relative water depth probably originated from the sea level change during the interval of deposition of the Kapp Starostin Formation, based on the analysis of the lithofacies and biofacies. This seems to be one of the reasons for the above mentioned changes of the brachiopods.

It is noteworthy, however, that the same bio-

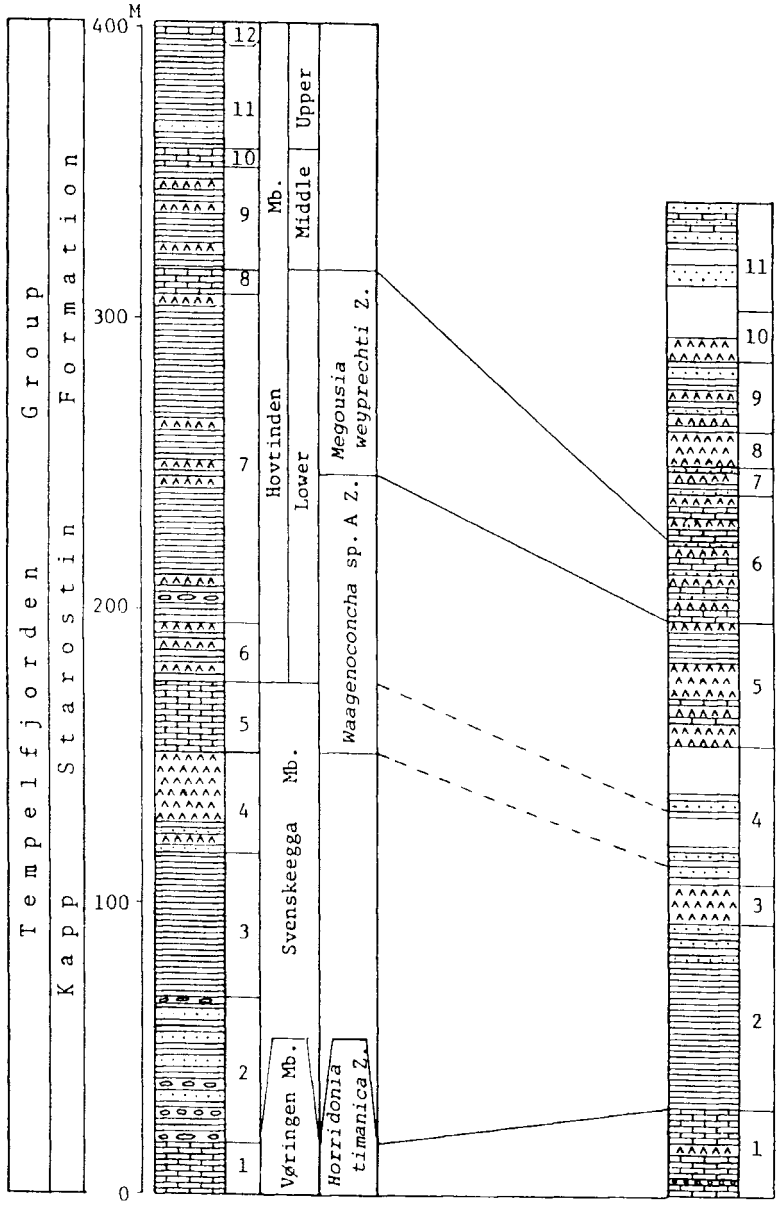

Fig. 4. Correlation of the brachiopod zones between Festningen and Sveltihel.

stratigraphical relations in brachiopod assemblage are basically traceable in the counterparts of the Kapp Starostin Formation in Central East Greenland, specifically in the Foldvik Creek Formation, and in Ellesmere Island, as well as in the Assistance and Trold Fiord Formations (Liao pers. comm. 1986). This means that the vertical changes of brachiopod assemblages in the Kapp Starostin Formation are not locally restricted only to the Spitsbergen trough area, but are also extended to the other parts of the Boreal Sea areas. Therefore, the brachiopod zonation presented here undoubtedly has a chronostratigraphical significance and has an effect on correlation between the Permian sequences distributed in the Boreal Sea areas.

Correlation with East Greenland

The Tethyan Permian sequences usually contain abundant ammonoids, fusulinids, conodonts and brachiopods that are useful for international correlation and age-determination. So a correlation of the Kapp Starostin Formation with rocks of the Tethys could be expected. At present, however, this is impossible with any certainty using palaeontological means. There are two major reasons for this difficulty: (1) neither ammonoids nor fusulinids have been discovered in the Kapp Starostin Formation, and the occurrence of conodonts is rare and confined to the Vøringen Member, which comprises the lowest beds of the formation; (2) the brachiopod fauna in the Kapp Starostin Formation has very little similarity to corresponding faunas in the Tethys. Nevertheless, we have a reasonably satisfactory method by which the relative age of the Kapp Starostin Formation may be determined. This relies upon brachiopod correlation of the Kapp Starostin Formation with the more precisely aged Upper Permian of Greenland, already dated by the ammonoid *Godthaabites kullingi*.

Gobbett (1964) argued that the Permian of Central East Greenland belonged to the uppermost part of the Permian and was thus considerably younger than the Svalbardian, which was actually represented by the 'Spirifer Limestone' and 'Brachiopod Cherts' (now the Kapp Starostin Formation). We do not accept this, but propose that the upper half of the Hovtinden Member of the Kapp Starostin Formation is mostly contemporaneous with the Foldvik Creek Formation in Central East Greenland, while the Vøringen Member of the formation agrees in age with the upper part of the Upper Marine Group (from G-300 to H-119) of Northeast Greenland, based on the high degree of similarity of brachiopods.

As far as the brachiopods from East Greenland are concerned, no new systematic contributions have been made since Dr. Dunbar's papers appeared in 1955 and 1962. Therefore, we are now obliged to reproduce four old sections provided with brachiopod information, in order to discuss correlations between Spitsbergen and Greenland (Fig. 5). One of them is from Amdrup Land of Northeast Greenland (Dunbar 1962), while the remaining three are from Scoresby Land, Kap Stosch, and Clavering Ø of Central East Greenland (Maync 1942; Dunbar 1955). The upper part of the Upper Marine Group (now known as Mallemuk Mountain Group) of Northeast Greenland roughly corresponds to the *Horridonia timanica* Zone ('Spirifer Limestone') of Spitsbergen, based on the mutual occurrences of some diagnostic species, notably *Yakovlevia impressa, Athyris amdrupi, Neospirifer grönwalli, Chaoiella neoinflata,* and *Horridonia granulifera*. The upper limit of this group might be cut by the present topographical surface, consequently the equivalent beds to the upper half of the Kapp Starostin Formation are not presented in this area. As a matter of fact, no definite late Permian faunal elements have been found in Northeast Greenland, although Håkansson & Stemmerik (1984) suggested the presence of a highly diverse late Permian fauna in Peary Land.

In Central East Greenland the marine beds of the Foldvik Creek Formation rest on non-marine beds or directly on metamorphic basement and are believed to be late Permian in age, on account of the occurrence of an ammonoid genus *Godthaabites* in their upper part. The formation is composed of limestones, dolomites, 'Productus Limestone', Martinia limestone or shale, Posidonia shale, in addition to gypsum and red conglomerate beds. Even though rapid lateral changes in lithofacies are characteristic and the marine members are in part intertonguing and coeval, two brachiopod zones can be stratigraphically discriminated within this formation, that is, lower Fossil I Zone and upper Fossil II Zone. The brachiopods found in those two zones justify a firm correlation of the Fossil I Zone and the Fossil II Zone to the upper part of the *Megousia weyprechti* Zone and the *Pterospirifer alatus* Zone of Spitsbergen, respectively. The Fossil I Zone in Greenland and the upper part of the *Megousia weyprechti* Zone in Spitsbergen share relatively distinctive forms as *Streptorhynchus kempei, Waagenoconcha payeri* and *Muirwoodia greenlandica*. On the other hand, the Fossil II Zone is easily compared with the *Pterospirifer alatus* Zone, on the basis of the mutual occurrences of *Pterospirifer alatus, Pleurohorridonia scoresbyensis, Choristites søderberghi* and *Odontospirifer mirabilis*. At the Schucherts Flod Valley of Scoresby Land the Fossil I Zone is not developed, while the Fossil II Zone is lacking at River 14, east of Kap Stosch, although the elements of the Fossil II Zone are unearthed together with those of the Fossil I Zone from the 'white block' derived from the underlying beds to be included

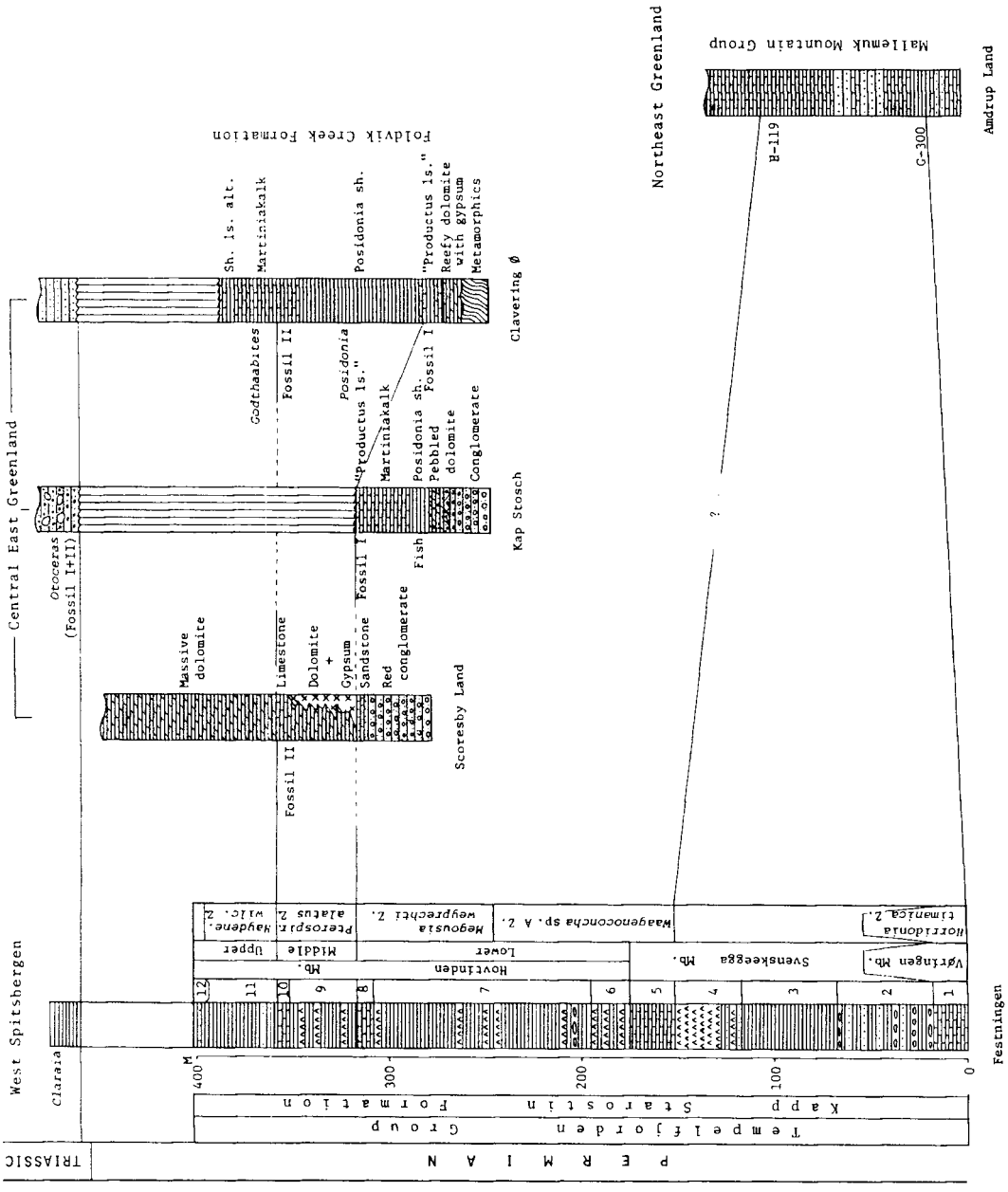

Fig. 5. Correlation of the Permian brachiopod zones between Spitsbergen and Greenland.

in the Triassic *Otoceras* Zone. The Foldvik Creek Formation near the southern coast of Clavering Ø is provided with both. The occurrence of an ammonoid *Godthaabites* just above the Fossil II Zone is noteworthy. The *Godthaabites*-bearing beds may be equivalent stratigraphically to the *Haydenella wilczeki* Zone, uppermost brachiopod zone of the Kapp Starostin Formation.

Age assignment

The age of the Kapp Starostin Formation, based mainly on brachiopods that are common to Spitsbergen and the USSR, has been assigned differently by many workers. The lower boundary of the formation has been regarded as ranging from Sakmarian to Ufimian in age, and the upper from Sakmarian to latest Permian.

Age of the lowest beds of the Kapp Starostin Formation

Malkowski & Szaniawski (1977) were greatly impressed by the supposed Leonardian affinities of the conodonts collected from the Vøringen Member in Polakkfjellet (Torell Land) and the Hornsund regions. On the other hand, Sosipatrova (1967) and Stepanov (1967) considered the lowest boundary of the formation to be Kungurian in age, based on foraminifers and brachiopods, respectively. Further, Burov et al. (1965) and Ustritsky (1971), using brachiopods, considered the formation only to have started after the Kungurian.

Among these opinions, it should be noted that a conflicting age has been given to the brachiopod assemblage of the lowest beds of the 'Brachiopod Cherts' (= 'Spirifer Limestone') and the Kapp Starostin Formation (= Vøringen Member). The presence of *Licharewia* and several species common to the Upper Permian Foldvik Creek Formation of Central East Greenland in the 'Spirifer Limestone' strongly denotes a late Permian age for the lowest beds of the Kapp Starostin Formation. Gobbett (1964) described two species of *Licharewia, L. spitsbergiana* and *L. wimani* from the 'Spirifer Limestone' of Ny Friesland, Northeast Spitsbergen. The presence of *Licharewia* in the 'Spirifer Limestone' is important, because this genus is unknown in the Lower Permian of the USSR or elsewhere. *Licharewia spitsbergiana* was described only from the 'Spirifer Limestone' on Mertonberget, Chydeniusbreen, Ny Friesland. On the other hand, specimens of *Licharewia wimani* were not figured by Gobbett. He proposed this new species from the specimens figured by Wiman (1914) from Lovénberget, Ny Friesland. Cutbill (1968) tentatively correlated the beds from which Wiman collected brachiopods on Lovénberget to the Svenskeegga Member in West and Central Spitsbergen. Consequently, there seems to be a considerable uncertainty regarding the precise stratigraphical occurrence of this genus in Ny Friesland, Northeast Spitsbergen. Actually, we did not find *Licharewia* in the Vøringen Member, but found it in both the Svenskeegga and Hovtinden Members of the surveyed area.

According to Gobbett (1964), the following species were common between the Svalbardian Stage and the Upper Permian Foldvik Creek Formation in Central East Greenland: *Krotovia licharewi, Horridonia timanica, Streptorhynchus kempei, Neospirifer strio-paradoxus, Spiriferella keilhavii, Spiriferellina cristata* and *Craspedalosia pulchella*. Of these, the first species was only found in the overlying beds of the 'Spirifer Limestone', and the remaining six were described by the finder from the 'Spirifer Limestone'. However, the specific identification of *Sowerbina maynci* described from the Foldvik Creek Formation by Dunbar (1955) with *Horridonia timanica* is very questionable. *Streptorhynchus kempei* and *Neospirifer strio-paradoxus* are more abundant in the Hovtinden Member than in the Vøringen Member of Central Spitsbergen. *Spiriferella keilhavii* and *Spiriferellina cristata* are relatively long-ranging species. The occurrence of *Craspedalosia pulchella* in the 'Spirifer Limestone' or the Tokrossøya Formation is noteworthy, because the age of this species is well dated to late Permian, and it has been known to occur from the Lower Kazanian of the Kanin Peninsula, USSR (Stepanov et al. 1975), in addition to the occurrence in the Fossil I Zone at Forposten on Clavering Ø, Central East Greenland. In Svalbard, specimens assigned to this species were, according to Gobbett (1964), detected from the Miseryfjellet Formation ('Spirifer Limestone') of Bjørnøya, the Tokrossøya Formation of Sørkappøya and the 'Spirifer Limestone' on the Pyramiden summit in Dickson Land. The Miseryfjellet Formation of Bjørnøya and the Tokrossøya Formation of Sørkappøya may partly include Upper Permian sediments (Cutbill & Challinor 1965), and there is considerable doubt regarding the

stratigraphical position of the beds from which specimens were collected on the Pyramiden summit. In short, the stratigraphical occurrence of *Craspedalosia pulchella* in Svalbard is also rather uncertain.

On the other hand, the occurrence of such species as *Horridonia timanica, Neospirifer grönwalli, Waagenoconcha irginae, Spiriferella draschei* and *Yakovlevia impressa* from the Vøringen Member indicates the Kungurian Age of the member. Ivanova (1972) described *Horridonia timanica, Yakovlevia impressa, Waagenoconcha irginae* and *Spiriferella draschei* from the late Artinskian Talatinsk Formation and the Kungurian Lekborkisk Formation of Pechora, USSR. Kulikov (1974) listed *Horridonia timanica, Neospirifer grönwalli, Waagenoconcha irginae* and *Spiriferella* cf. *draschei* from the Kungurian of the Urals. Although a general uncertainty relating to the specific identification and to the stratigraphical range of these species may exist, these occurrences strongly suggest the Kungurian age for the lowest beds of the Kapp Starostin Formation. It thus appears that *Yakovlevia impressa* is restricted to the early Permian in the USSR and that it is one of the most important species for the correlation of these rocks. An important matter to decide is whether the Vøringen Member is early Permian or late Permian in age. In this paper, the age of the member is tentatively estimated to be early Permian, in a two-fold division, based more on the occurrence of *Yakovlevia impressa* than the uncertain occurrences of *Licharewia* and *Craspedalosia pulchella*. However, further study is required.

Age of the uppermost beds of the Kapp Starostin Formation

Recently, most authors presumed the age of the uppermost beds of the Kapp Starostin Formation to be early Kazanian, because the brachiopods from the upper part of the formation indicated a close relationship with the Kazanian of the USSR. In this respect, the youngest age assumption was offered by Cutbill & Challinor in 1965, who maintained that the formation represented the Kungurian and the whole Upper Permian, but without presenting any palaeontological evidence. We are most concerned that the age of the upper border of the Kapp Starostin Formation should be discussed more precisely.

For this purpose, a critical evaluation of *Pterospirifer alatus*, one of the diagnostic species of the Lower Zechstein, is first taken into consideration. The occurrence of this species is restricted on Spitsbergen to the Middle Bed of the Hovtinden Member of the Kapp Starostin Formation and in Greenland to the Fossil II Zone of the Foldvik Creek Formation. Quite recently, Dr. Kozur of the Hungarian Geological Institute contributed very important comments to the Newsletter No. 11 of SCPS (Subcommission on Permian Stratigraphy), dealing with the age of the Zechstein in the Germanic Basin. He pointed out that the base of the Zechstein lay in the Upper Abadehian, and it was not far from the Dzhulfian base in the Tethys. If this assumption is correct, either the Middle Bed of the Hovtinden Member or the Fossil II Zone of the Foldvik Creek Formation is reasonably dated to late Permian, in a threefold division. The discovery of this species has been reported from the Lower Permian of China (Ding & Qi 1983) and the Lower Kazanian of the Baltic Province of USSR (Suveizdis 1984). However, the Chinese specimen figured seems too poorly preserved to make a specific identification, while the Russian specimen has not been described or figured.

As described earlier, the uppermost brachiopod zone of the Kapp Starostin Formation, the *Haydenella wilczeki* Zone at Festningen is exactly correlated to the upper part of the Martinia limestone including an ammonoid *Godthaabites* at Clavering Ø, Central East Greenland. Most ammonoid workers regard *Godthaabites* as synonymous with *Cyclolobus* except for Waterhouse (1972) and Zakharov (1983). The stratigraphical distribution of *Cyclolobus* and *Godthaabites* is shown in Table 1. They are mostly confined to rocks of Abadehian-Dzhulfian ages in the Tethys faunal realm. The highest horizon of the representatives of these genera so far known is the Upper Dzhulfian *Vedioceras* Zone in Transcaucasia, except for the occurrence in the uppermost Permian of the Kitakami Mountains, Japan (Ehiro & Bando 1985). Although the *Cyclolobus*-bearing horizon in the Kitakami Mountains is thought to be Changhsingian or Dorashamian in age, there does appear to be some doubt. As pointed out by Balme (1979), Teichert & Kummel (1976) discussed these matters in detail and then accepted the view of Furnish (1966) that the presence of *Cyclolobus* indicated a post-Guadalupian age for the Martinia limestone in Central East Greenland.

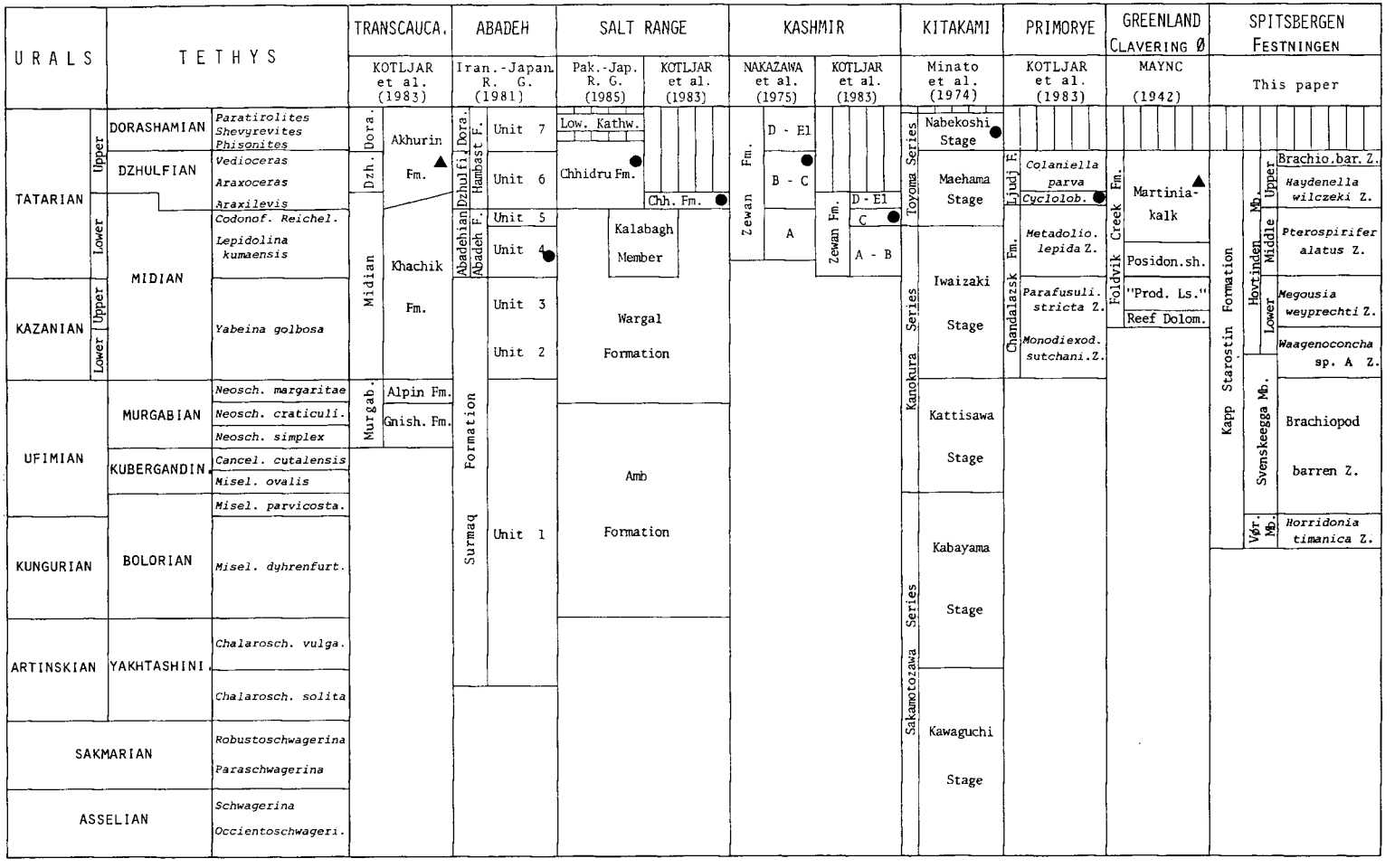

Table 1. Correlation of the Permian.

▲: Occurrence of *Godthaabites*
●: Occurrence of *Cyclolobus*

In short, the uppermost beds of the Kapp Starostin Formation of Festningen are estimated with high possibility to be late Permian in age and most probably to be Dzhulfian. Kotljar (1984) presented a synopsis of the correlation of the Permian between the Urals and Tethys in which she correlated the Tatarian Stage of the former to the whole of the Upper Midian, Dzhulfian, and Dorashamian of the latter, as shown in Table 1. If this correlation is acceptable, the Kapp Starostin Formation lies within the interval from late Kungurian to early or even early late Tatarian of the Russian Permian standard.

Conclusion

The Kapp Starostin Formation commencing with the 'Spirifer Limestone' is about 400 m thick at Festningen and about 340 m at Sveltihel, West Spitsbergen. Taking into account the stratigraphical and palaeontological evidence, the following conclusions may be introduced with regard to the Kapp Starostin Formation:

a) Five brachiopod zones are identified within the formation: they are the *Horridonia timanica* Zone, the *Waagenoconcha* sp. A (Gobbett 1964) Zone, the *Megousia weyprechti* Zone, the *Pterospirifer alatus* Zone, and the *Haydenella wilczeki* Zone in ascending order.

b) The basal part, that is, the 'Spirifer Limestone', is contemporaneous with the uppermost part of the Upper Marine Group (Mallemuk Mountain Group) in the Holm Land and Amdrup Land areas of Northeast Greenland, based on the mutual occurrences of some diagnostic brachiopod species, probably indicating a Kungurian age.

c) The upper part of the Kapp Starostin Formation, represented by the upper three zones, roughly corresponds to the Permian Foldvik Creek Formation in Central East Greenland.

d) Two brachiopod zones are recognized in the Foldvik Creek Formation. The lower zone (Fossil I Zone) is contemporaneous with the *Megousia weyprechti* Zone, and the upper one (Fossil II Zone) with the *Pterospirifer alatus* Zone of West Spitsbergen. The occurrence of an ammonoid *Godthaabites* or *Cyclolobus* just above the upper Fossil II Zone in Central East Greenland is noteworthy. As a result, the *Haydenella wilczeki* Zone in the Kapp Starostin Formation can be stratigraphically correlated with the *Godthaabites*-bearing beds in Central East Greenland, and must consequently be post-Guadalupian (most probably Dzhulfian) in age.

e) In conclusion, we recommend the Kapp Starostin Formation at Festningen, yielding ample and various kinds of fossils, as the standard section of the Middle-Upper Permian in the Arctic region. The uppermost Permian (Changhsingian or Dorashamian) may, however, be missing.

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