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Loganellia (Thelodonti, Agnatha) from the Lower Silurian of North Greenland

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ABSTRACT:

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Isolated thelodont scales from several Lower Silurian samples from North Greenland are re-described and compared with European forms, to assess their taxonomical, stratigraphical and palaeogeographical significance. *Loganellia scotica* s. s. (TRAQUAIR, 1898) scales, described from the Lafayette Bugt Formation, are more restricted than commonly supposed, being found only in Scotland and North Greenland. Reassignment of some thelodont scales from *L. scotica* to *L. grossi* (FREDHOLM, 1990) suggests a middle Wenlock age for the Kap Morton Formation.

Key words: Silurian, Thelodonts, North Greenland, taxonomy, stratigraphy.

INTRODUCTION

Vertebrate remains from the Silurian of North Greenland are rare when compared to the more common and famous Devonian vertebrate fossils of eastern Greenland (BENDIX-ALMGREEN 1976, and references therein). Two anaspid fragments collected in 1966 from Kap Tyson (Text-fig. 1), south-western Hall Land during Operation Grant Land (a joint field project between the geological surveys of Canada and Greenland), were identified by R. THORSTEINSSON *in* NORFORD (1972), and provided the first evidence of Silurian vertebrates from North Greenland; the identification has been confirmed (*author's observation*). Thelodont scales were later reported together with acanthodian and heterostracan remains by BENDIX-ALMGREEN & PEEL (1974) on the basis on residues from the Chester Bjerg Formation at Halls Grav in Hall Land (Text-fig. 1), collected in 1965 during the same field project. Some of this material, which is of Late Silurian-Early Devonian age, was subsequently figured by BENDIX-ALMGREEN (1976) and TURNER & PEEL (1986), and full description of the diverse fauna of thelodonts and other associated vertebrates is in progress (see also BLOM *in press*). Isolated thelodont scales were also found from four other localities of Early Silurian age, collected during the North Greenland Project of the Geological Survey of Greenland (1978-85). Previous fieldwork had also resulted in finds of anaspid and heterostracan remains from strata close to the Wenlock-Ludlow boundary in Washington Land (Text-fig. 1; *see* BENDIX-ALMGREEN 1986). The thelodont fauna, yielding a variety of different loganiid scales, was described by TURNER & PEEL (1986). Most scales, however, were not illustrated and loosely assigned to *Loganellia scotica* (TRAQUAIR, 1898), a species which has subsequently been the object of much biostratigraphical discussion and is now regarded as characteristic for marine facies of the Llandovery Series in Europe (MÄRSS 1989, MÄRSS & *al*. 1995).

The present paper presents comparative descriptions of scales of *Loganellia scotica* (TRAQUAIR, 1898) and *Loganellia grossi* (FREDHOLM, 1990), from North Greenland, with reference to the European type material. The second half of the paper discusses Lower Silurian thelodont correlation between Laurentia and other Silurian continents, based on these two taxa and other more problematic species from the same material.

The Lower Silurian thelodont-bearing localities are from strata forming part of the North Greenland segment of the Franklinian Basin (HIGGINS & *al*. 1991a, b; TRETTIN 1991), which extends across the Canadian Arctic Islands to North Greenland. The basin was probably initiated during latest Proterozoic time and closed in the Devonian during the Ellesmerian Orogeny. During most of the basin history the North Greenland segment was characterized by a carbonate-dominated shelf succession in the south and a siliciclastic-dominated deep water basin in the north. This scenario persisted until the late Silurian when the southward expanding trough drowned the shelf completely. Lower Silurian thelodont-bearing formations, the Kap Morton Formation, Lafayette Bugt Formation and Wulff Land Formation, all reflect this final drowning of the platform, when the shelf was inundated by hemipelagic mudstones and siltstone turbidites, and carbonate sedimentation was only locally maintained around major mound complexes. The material under discussion is derived from these off-reefal strata of platy limestones, lime mudstones and shales, suggesting an open shelf to slope environment in the belt of carbonate buildups (HIGGINS & *al*. 1991a, b).

SYSTEMATIC PALAEONTOLOGY

Theolodonti
Order Katoporida GROSS, 1967
Family Loganidae KARATAJUTE-TALIMAA, 1978

Genus *Loganellia* TURNER, 1991

Loganellia scotica (TRAQUAIR, 1898)
(Pl. 1, Text-fig. 2)

MATERIAL: About 100 scales from GGU sample 82543 collected from "Sunmark Mountain" and 10 scales from GGU sample 82679 collected at Kayser Bjerg, both from the Lafayette Bugt Formation, Hall Land.

DESCRIPTION: The sample from "Sunmark Mountain" contains a wide variety of well preserved *Loganellia scotica* (TRAQUAIR, 1898) scales that are very similar to the type material from Scotland (MÄRSS & RITCHIE 1998). They are small, about 0.2-0.4 mm in length, and vary

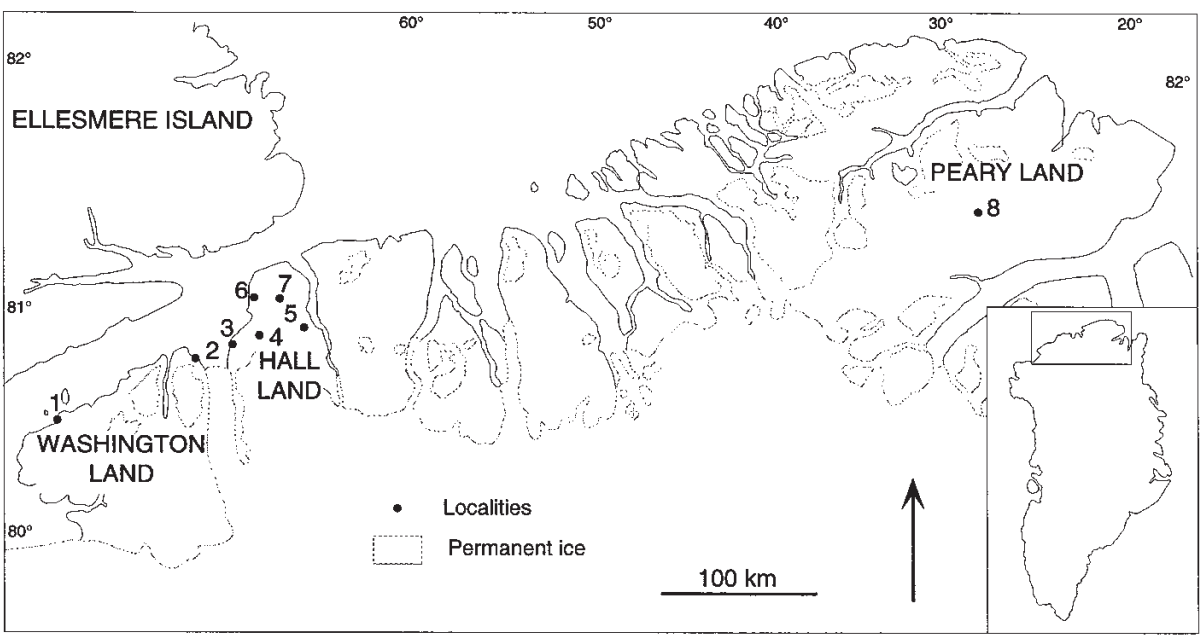

Fig. 1. Silurian-Devonian vertebrate-bearing localities in North Greenland: 1 – Kap Independence, 2 – Kap Lucie Marie, 3 – Kap Tyson East outcrops, 4 – "Sunmark Mountain", 5 – Kayser Bjerg, 6 – Halls Grav (Observatory Bluff), 7 – The Monument, 8 – central Peary Land

between pale yellow-grey and black in colour. The scales are here divided into cephalo-pectoral, lateral, orbital, postpectoral, precaudal and pinnal scales, depending on from which area of the body they originate. This classification for *L. scotica* was suggested by MÄRSS & RITCHIE (1998) and is based on notable differences in scale morphology and body position found in the articulated type material from Scotland.

Scales from the cephalo-pectoral area are common with rounded, oval, rhomboidal or irregular outline and have a smooth and flat or slightly convex crown surface (Pl. 1, Figs 1-2, 8-9, 17). The crown margin is crenulated with variably deep notches that are radially arranged in the scales situated more anterior in this area (Pl. 1, Figs 1-2). Scales situated more posterior in the cephalo-pectoral area have in general more anteriorly facing notches. In these scales the posteriorly-pointing apex projects over the base. In scales closer to the postpectoral area, the marginal notches tend to be more elongated and furrow-like (Pl. 1, Figs 8-9). The base in the more posterior cephalo-pectoral scales is quite swollen often with basal lobes around an almost central pulp aperture and cavity (Pl. 1, Fig. 17).

The orbital and the anterior lateral scales are round with a moderately high and ridged conical crown (Pl. 1, Figs 3-6). The low base is larger than the crown and possesses a central pulp aperture. Lateral scales situated closer to the trunk are lower, more elongated and have more posteriorly directed apices (Pl. 1, Fig. 6).

Trunk scales are represented by postpectoral and precaudal scales (Pl. 1, Figs 7, 10-13, 15-16). They can be difficult to distinguish in disarticulated material since the two types grade into each other, showing the same basic crown structures, but they differ mainly in size and proportions. The crown is rhomboidal, with a rounded anterior and more pointed posterior, with a clear projection over the smaller base. The median crown area is wedge-shaped in outline with a wide median furrow of

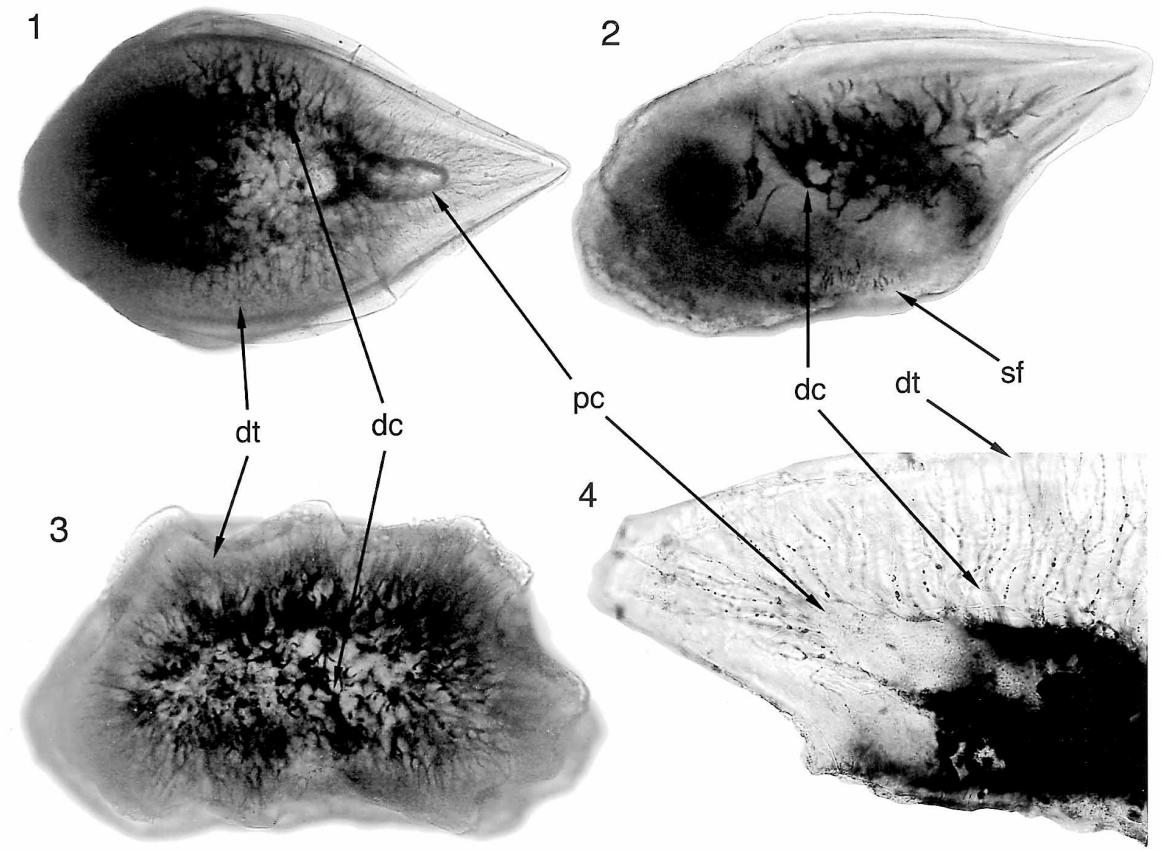

Fig. 2. *Loganellia scotica* (TRAQUAIR, 1898): Histology of scales from "Sunmark Mountain", Lafayette Bugt Formation, Hall Land; **1** – Trunk scale in crown view, immersed in aniseed oil, MGUH VP 3377, × 200; **2** – Trunk scale in lateral view, immersed in aniseed oil, MGUH VP 3378, × 312; **3** – Cephalo-pectoral scale in crown view, immersed in aniseed oil, MGUH VP 3379, × 243; **4** – Trunk scale in vertical longitudinal section, MGUH VP 3380, × 346; abbreviations: dc – dentine canals, dt – dentine tubules, pc – pulp canal, sf – canals for Sharpey's fibres; all specimens from GGU sample 82543

variable depth or more seldom with a flat upper surface. In almost all scales from "Sunmark Mountain" the furrow is quite deep. One or two marginal ridges or wings characterize the lateral area of postpectoral and precaudal scales and the ridges converge at the posterior crown apex. The base is displaced anteriorly, without projecting, and the pulp aperture is situated more posteriorly (Pl. 1, Fig. 10).

MÄRSS & RITCHIE (1998) recognised two types of pinnal scales but in the "Sunmark Mountain" material it is only possible to find one. It is characterized by being a small and narrow type of trunk scale with two lateral ridges (Pl. 1, Figs 14, 18-19).

All scale types are histologically similar with fine tightly packed dentine tubules that converge and meet, forming a tree-like branching pattern (Text-fig. 2). The tubules reach canal thickness before they end in the base or open into the clear pulp cavity or pulp canal. The morphological set from "Sunmark Mountain" differs, however, in development of the pulp cavity. In the diagnostic trunk scales the pulp cavity and canal are developed in the posterior part (Text-fig. 2.1,4). A quite narrow posterior pulp aperture widens slightly internally to a pulp cavity, which extends posteriorly forming a short, but wide, pulp canal. Lateral and cephalo-pectoral scales of more posterior nature have shorter pulp canals and the aperture is situated closer to the centre. Most cephalo-pectoral and the orbital scales have no pulp canal developed from the wide and open central pulp cavity (Text-figs 2-3).

REMARKS: The scales from "Sunmark Mountain" differ slightly from the Scottish type material (MÄRSS & RITCHIE 1998) by having a deeper median furrow in almost all postpectoral and precaudal scales. Equivalent scales from Scotland, especially the larger sized scales found isolated in small nodules, often have a shallower furrow or an almost flat and smooth median area. The small size of the North Greenland scales implies that this set of *Loganellia scotica* (TRAQUAIR, 1898) scales originates from small or medium sized articulated animals, similar to the smaller specimens of the Scottish thelodonts described by MÄRSS & RITCHIE (1998).

The systematic position of the North Greenland scales is justified by the histological similarity to the Scottish material. GROSS (1967) defined the histology of *L. scotica*, based on material from Scotland, showing dentine canals and tubules that arise either directly from the base or from a short but wide pulp canal/cavity. MÄRSS & RITCHIE (1998) found that the pulp canal was weakly developed in scales that originate from articulated specimens. This is probably due to

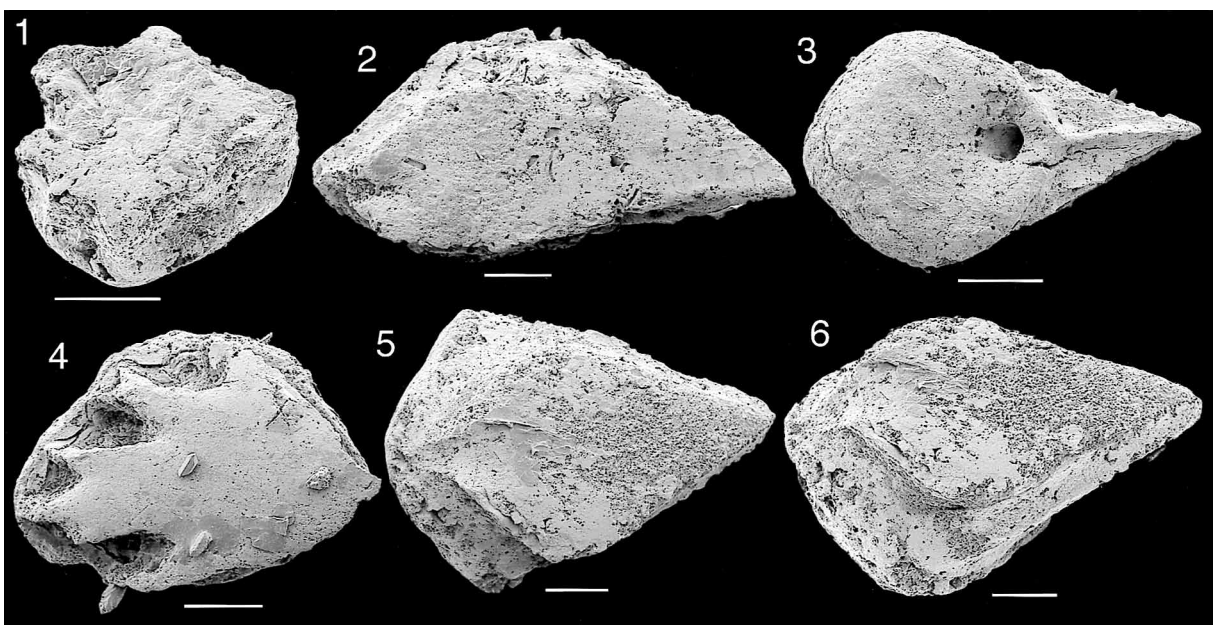

Fig. 3. *Loganellia grossi* (FREDHOLM, 1990): SEM photomicrographs of scales from Kap Morton Formation at Kap Lucie Marie, Washington Land; **1** – Head scale in oblique crown view, MGUH VP 3381; **2** – Trunk scale in crown view, MGUH VP 3382 **3** – Body scale in basal view, MGUH VP 3383; **4** – Transitional scale in crown view, MGUH VP 3384; **5** – Body scale in crown view, MGUH VP 3385; body scale in crown view, MGUH VP 3385; all specimens from GGU sample 242841; scale bars equal 0.1 mm

poor preservation, since better preserved isolated scales from nodules show a clear and short pulp canal (*author's observation*).

TURNER & PEEL (1986, Fig. 2 A) illustrated a body scale from the Kayser Bjerg locality which resembles those from "Sunmark Mountain". Other scales from the same sample, however, are poorly preserved and very few possible head scales are found beside the rare body scales.

Loganellia grossi (FREDHOLM, 1990) (Text-fig. 3)

MATERIAL: About 30 poorly preserved scales from GGU sample 242841 collected from near the base of Kap Morton Formation at Kap Lucie Marie, Washington Land.

DESCRIPTION: Although the scales from Kap Lucie Marie are badly preserved it is possible to find morphological characters that are similar to those diagnosed for *Loganellia grossi* by FREDHOLM (1990) and MÄRSS (1996). Scales from the head region, including rostral and cephalo-pectoral scales (Text-fig 3.1), are rounded with a smooth and very flat crown surface. The crown is low and crenulated by wide, radially arranged marginal notches. The base is approximately as large as the crown, but is slightly higher and has a central pulp cavity. More conical scales are also present and are closely comparable to the oral scale figured by MÄRSS (1996, Pl. 2, Fig. 1). This type of scale, however, could also be situated around the eye or in the anterior part of the lateral area, as shown by MÄRSS & RITCHIE (1998) in the morphological scale variety of the type species *L. scotica*.

The trunk scales from Kap Lucie Marie (Text-fig. 3.2-3, 5-6), including postpectoral and precaudal scales, are similar to the Baltic ones illustrated by MÄRSS (1996), in having a rhomboidal flat crown with a distinct median notch anteriorly and a lateral ridge or wing converging from each side towards the posterior apex. Scales from the posterior part of the fin may follow the main trunk morphology, but with a smaller and narrower outline.

Transitional scales between head and trunk are also present in this material and are characterized by having a rhomboidal outline (Text-fig. 3.4). The crown has notches in the rounded anterior margin of the median crown area and a posterior pointing apex. The very few and poorly-preserved transitional scales found from North Greenland lack the typical down-stepped lateral area shown in the type material from the Baltic region.

REMARKS: Discussion by TURNER & PEEL (1986) of the affinity of these scales to *L. scotica* noted uncertainty about features in the crown morphology. The crown ridges are less pronounced than those in the *L. scotica* scales from "Sunmark Mountain", and they have a deep median anterior notch. These features, however, are more characteristic for the more-recently described *Loganellia grossi* (FREDHOLM, 1990), found in strata of Wenlock age in the Baltic region and Norway (MÄRSS 1996). The similarity with the scales from Norway, earlier described by TURNER & TURNER (1974), was also pointed out by TURNER & PEEL (1986).

The scales from Greenland differ in general from the Baltic type material by showing a quite clear median crest on the lower posterior crown surface. It is difficult to say if this is a diagnostic feature or because of the poor preservation. The poor preservation also deterred histological studies.

ADDITIONAL THEOLODONT MATERIAL

In addition to *Loganellia scotica* (TRAQUAIR, 1898) and *L. grossi* (FREDHOLM, 1990) the North Greenland material also contains other thelodonts of more problematic affinity, including several different types of *Loganellia* scales, as noted already by TURNER & PEEL (1986).

A few scales of uncertain origin from GGU sample 82679 from the Lafayette Bugt Formation at Kayser Bjerg occur among scales similar to those of *L. scotica* type. They were figured and referred to as *Loganella L.* cf. *kummerowi* and *Loganella* sp. n. transitional? scale by TURNER & PEEL (1986). This assignment, however, is questioned since the scale of *Loganellia kummerowi* (GROSS, 1967) (now *Paralogania kummerowi* (KARATAJUTE-TALIMAA 1997)) is poorly preserved. Moreover, *Paralogania kummerowi* and scales of the *L. scotica* group never occur stratigraphically together in Europe. The loganiid scale figured as *Loganellia* sp. nov. transitional? scale by TURNER & PEEL (1986) is similar to the transitional scales of *L. einari*, a Wenlock species described by MÄRSS (1997) which is diagnostic for the upper part of the *L. grossi* Biozone (MÄRSS & *al*. 1995). Conodonts and graptolites from the same section suggest an age close to the Llandovery-Wenlock boundary for this material (DAWES & PEEL 1984), corresponding

to the late Llandovery *L. scotica*/*L. sibirica* Biozone (MÄRSS & *al*. 1995). The age of the material is supported by the presence of *L. scotica* scales, but although the scales of this type are better preserved they are slightly different from the more typical scales described from "Sunmark Mountain". The possible establishment of a new species for this diverse set of *Loganellia* scales, including the ones of *L. scotica* type, was suggested by TURNER & PEEL (1986), but nothing in the poorly preserved material currently support the establishment of a new scale taxon. Until further material is available some of the scales may be referred to *L. scotica* and the others treated under the open nomenclature suggested by TURNER & PEEL (1986).

One transitional scale has been found in Peary Land from the *Monograptus spiralis* Biozone of the Thors Fjord Member, Wulff Land Formation (Text-fig. 1). TURNER & PEEL (1986) compared it with a katoporodid-like scale from the upper Llandovery of the Welsh Borderland (ALDRIDGE & TURNER 1975), but it can also be placed among the similar transitional scales of *Loganellia*.

Together with the *L. scotica* scales from "Sunmark Mountain" are two broken scales. The best preserved one is very long and narrow with eight fine ridges all around the crown. The scale is transparent, showing a long pulp canal extending towards the crown tip from a large slightly posterior pulp cavity. The base is small with a short down-turned anterior process. A possible *Lanarkia* affinity was suggested by TURNER & PEEL (1986), but the material does not exclude a closer relationship to *Loganellia*.

DISCUSSION

The *L. scotica* scales from "Sunmark Mountain" are derived from the Lafayette Bugt Formation of the Peary Land Group (DAWES & PEEL 1984). The presence of *L. scotica* supports the late Llandovery-early Wenlock age for the sample, also indicated by conodonts and graptolites (DAWES & PEEL 1984).

The later parts of the Llandovery Series, including most of the Aeronian and the whole Telychian, are assigned to the *L. scotica*/*L. sibirica* Biozone (MÄRSS & *al*. 1995). Recent work and recognition of new taxonomic elements within the *L. scotica* group have shown that refinement of the Llandovery thelodont bioscheme is possible (ALDRIDGE & *al*. 1996, TURNER, *in press*) and that the record of *L. scotica* s. s. is geographically more restricted than earlier believed. TURNER (in press) assigns some of the supposed *L. scotica* from the Telychian of Ireland (ALDRIDGE & *al*. 1996) and the Welsh Borderland (ALDRIDGE & TURNER 1975) to a new loganiid species which is regarded as being more closely related to *L. sibirica* rather than *L. scotica*. Some rare scales which appear to be closer to *L. scotica* than TURNER'S new species co-occur with this new species in the material from the Welsh Borderland (TURNER, *in press*), but they are very rare and the true affinity of these types of scale taxa can only be settled with better and more complete assemblage of scales. Scales from the *L. scotica* group are also reported from the Baltic (MÄRSS 1989), Norway (TURNER, *in press*), Eastern Canada (TURNER & NOWLAN 1995), Canadian Arctic (MÄRSS & *al*. 1998), Timan Pecora region (TALIMAA, *in press*) and Siberia (KARATAJUTE-TALIMAA & PREDTECHENSKYJ 1995, TALIMAA, *in press*). Scales from Norway and Eastern Canada are similar to the new species of TURNER (*in press*). The scales from Timan Pecora region and Siberia also differ from *L. scotica* s. s. and provide a basis to establish several new species (TALIMAA, *in press*). Small *L. scotica*-like scales of Telychian age are reported from the Franklinian Basin in the Canadian Arctic (MÄRSS & *al*. 1998) and may be identical with the scales from North Greenland. Thus, *L. scotica* s. s. is so far only described from Scotland and North Greenland, although it may also be present in the Canadian Arctic.

The sample from the lower part of the Kap Morton Formation at Kap Lucie Marie, Washington Land yielded *Loganellia grossi* scales that were originally reported as *Loganellia* sp. cf. *L. scotica* by TURNER & PEEL (1986). The Kap Morton Formation was formally described by HURST (1980), and he suggested a correlation with the late Llandovery *M. spiralis* Biozone for the lower part of the formation in this area. This was also supported by the presumed presence of *L. scotica*, since the European forms are diagnostic for the late Llandovery (MÄRSS & *al*. 1995, MÄRSS & RITCHIE 1998). The formation itself, however, has not yielded any fauna that would allow a more precise age assignment within the Silurian, but the presence of *Kirkidium* (*Khodalovechia*) sp. in the underlying Kap Godfred Hansen Formation suggests an age younger than Wenlock for the Kap Morton Formation (ARMSTRONG 1990). When compared with European occurrences, the few *L. grossi* scales found in the lower parts of the formation, indicate a middle Wenlock age. *L. grossi* has so far only been

found in sections of Wenlock age (MÄRSS 1996) and the type stratum for *L. grossi* is in the uppermost Slite Beds, unit g, middle Wenlock of Gotland, Sweden (FREDHOLM 1990). In Estonia *L. grossi* occurs in the Maasi Beds (Jaagarahu Stage, middle Wenlock), characterizing a regional *L. grossi* Zone below *Loganellia einari* Zone in the Tagavere beds. On Gotland *L. grossi* and *Loganellia einari* MÄRSS, 1996 sometimes occur together, but *L. grossi* appears earlier. Scales from the Sundvollen Formation, Ringerike, Norway were originally described by TURNER & TURNER (1974), as one species, *Loganellia taiti* (STETSON, 1931), but were later assigned to both *L. grossi* and *L. einari* by MÄRSS (1996). The age of the formation was revised from Ludlow to Wenlock (WORSLEY & *al*. 1983, MÄRSS 1986). Three samples from the Severnaya Zemlya Archipelago yielded only *L. grossi* (MÄRSS 1996) and no *L. einari* scales.

Scales of *L. einari* are not found in the Kap Lucie Formation of North Greenland, allowing no more precise age assignment than middle Wenlock for the formation.

CONCLUSIONS

Disarticulated scales from the upper part of the Lafayette Bugt Formation of North Greenland are referred to *Loganellia scotica* s. s. (TRAQUAIR, 1898) from the Telychian (late Llandovery) of Scotland.

Contrary to former reports, the record of *L. scotica* s. s. appears to be geographically very restricted, it being found only in Scotland and North Greenland.

Loganellia scales from the Kap Morton Formation at Kap Lucie Marie, compared earlier to *L. scotica*, are assigned to *Loganellia grossi* (FREDHOLM, 1990) thereby suggesting a middle Wenlock age.

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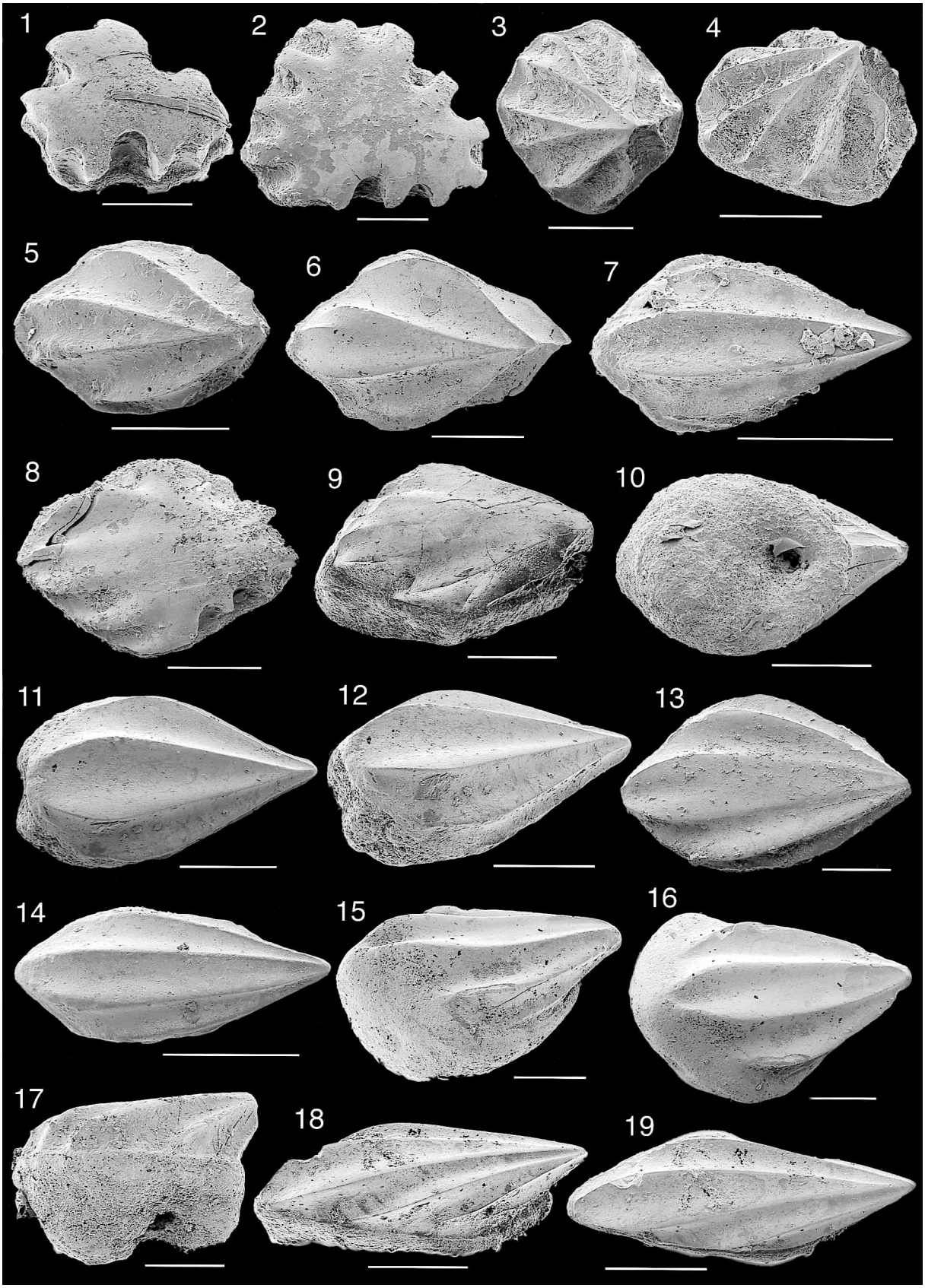
PLATE 1

Loganellia scotica (TRAQUAIR, 1898): SEM photomicrographs of scales from "Sunmark Mountain", Lafayette Bugt Formation, Hall Land

1 – Cephalo-pectoral scale in oblique crown view, MGUH VP 3362
2 – Cephalo-pectoral scale in crown view, MGUH VP 3363
3 – Orbital? scale in crown view, MGUH VP 3364
4 – Orbital? scale in oblique crown view, MGUH VP 3364
5 – Lateral scale in crown view, MGUH VP 3365
6 – Lateral scale in crown view, MGUH VP 3366
7 – Trunk scale in crown view, MGUH VP 3367
8 – Cephalo-pectoral scale in crown view, MGUH VP 3368
9 – Cephalo-pectoral scale in oblique crown view, MGUH VP 3369
10 – Trunk scale in basal view, MGUH VP 3370
11 – Trunk scale in crown view, MGUH VP 3371
12 – Trunk scale in oblique crown view, MGUH VP 3371
13 – Trunk scale in crown view, MGUH VP 3372
14 – Pinnal scale in crown view, MGUH VP 3373
15 – Trunk scale in oblique crown view, MGUH VP 3374
16 – Trunk scale in crown view, MGUH VP 3374
17 – Cephalo-pectoral scale in lateral view, MGUH VP 3375
18 – Pinnal scale in oblique crown view, MGUH VP 3376
19 – Pinnal scale in crown view, MGUH VP 3376

All specimens from GGU sample 82543
Scale bars equal 0.1 mm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