Abstract
The famous Lunz flora from Lower Austria is one of the richest and most diverse Late Triassic floras of the Northern Hemisphere. The historical outcrops (mainly coal mines) are no longer accessible, but showy fossils can still be collected from natural exposures around the town of Lunz-am-See and from several of the old spoil tips. This paper presents an annotated check list with characterisations of all currently recognised gymnosperm foliage taxa in the Lunz flora. The descriptions are exemplified by illustrations of typical specimens and diagnostic features of the leaf morphology and epidermal anatomy. Moreover, a simple identification key for the taxa based on macromorphological features is provided that facilitates identification of newly collected specimens.

1. Introduction
The Carnian (Late Triassic) flora from Lunz in Lower Austria is one of only a few well-preserved floras from the Alpine Triassic (Cleal, 1993; Dobruskina, 1998). The flora includes sphenophytes, ferns, cycadeans, bennettitaleans, conifers, and putative ginkgophytes (Dobruskina, 1989, 1998), and is currently comprised of more than 4,000 specimens (compressions) kept in various museum, geological survey, and university collections in Austria and beyond. The Lunz flora represents one of the richest and most diverse Late Triassic floras of the Northern Hemisphere. Although the classic outcrops (mainly coal mines) are long since closed, Lunz fossils can still be collected from several natural exposures around the town of Lunz-am-See (Figure 1), as well as from some of the old spoil tips in the vicinity of the coal mines. Apart from the unusually high proportion of fertile elements (i.e. reproductive structures) among the fossils (see e.g., Krasser, 1917, 1919; Kräusel, 1948, 1949, 1953; Pott et al., 2010), the most striking feature of the Lunz flora is the superabundance of exquisitely preserved gymnosperm foliage.

It has been suggested that the Lunz flora represents a standard for Carnian floras that can be used for the identification, correlation, and comparison of coeval and slightly younger Mesozoic floras elsewhere (Dobruskina, 1989, 1998). In order to fully serve this purpose, however, a detailed documentation of the composition of the Lunz flora, together with user-friendly identification keys for, and descriptions of, the individual taxa are instrumental. Such tools have not been available to date since the various elements of the Lunz flora have been (formally) described in series of separate papers by different authors (e.g.,
Brief overview of the genera and species

Thirteen gymnosperm foliage taxa, in the rank of species, are currently recognised in the Lunz flora, including five bennettitalean and five cycadalean foliage types, two putative ginkgophytes, and one conifer. In the following sections, brief characterisations of the macromorphology of these foliage types are given. Information on the epidermal anatomy is provided for those taxa that have yielded cuticles and where species definition and discrimination from morphologically similar forms heavily rely on epidermal features such as the architecture of the stomatal apparatus.

BENNETTITALES

Genus *Pterophyllum* Brongniart, 1825

*Pterophyllum* is a morphogenus used for bennettitalean foliage characterised by segmented leaves with laterally or almost laterally inserted, almost parallel-sided leaf segments or leaflets (Figure 2), a striate rachis and cuticles displaying brachyparacytic (syndetocheilic) stomata (Pott et al., 2007e; Pott
21 mm long and 2–9 mm wide. Leaflets insert laterally to the prominent and longitudinally striate rachis and are basally more or less constricted. Constriction is usually prominent in leaflets positioned in the proximal portion of the leaf, but rather indistinct or absent in distally positioned leaflets. Leaflet apices are obtuse to acutely rounded. The length/width-ratio of the leaflets is always >7:1; in some specimens, it reaches up to 22:1. The distal five leaf segments form the apex. The terminal leaflet does not differ in shape from the laterally positioned subterminal leaflets. Numerous parallel veins enter each leaflet and usually fork once near the base. Occasionally additional bifurcations occur in the proximal portions of the leaflets.

Cuticles of *Pterophyllum filicoides* are well-known. The leaves are amphistomatic but with only a few stomata present on the adaxial side, and produce robust cuticles; costal and intercostal fields are distinguishable on both sides of the leaf. Occurrence of stomata is limited to the intercostal fields. Epidermal cells are narrow, rectangular, and elongate to isodiametric (square) in outline. Anticlinal cell walls are generally straight, but cells on the abaxial side may occasionally display faint and irregular undulations. Cells often bear a long and hollow papilla. The dicyclic stomatal complexes are brachyparacytic; stomatal pores are oriented perpendicularly to the veins, stomata are slightly sunken (see Pott et al., 2007e).

*Pterophyllum brevipenne* Kurr ex Schenk, 1864 emend. Pott et al., 2007

Estimated total leaf size: up to 25 cm long (probably not longer) and 6 cm wide

Characters: segmented, leaflets insert laterally to rachis, terminal leaflet similar in shape and size to lateral ones, leaflet length/width ratio always >7:1.

Figures: 3J; 4J, M

*Pterophyllum filicoides* (Schlotheim, 1822)

Zeiller, 1906

Estimated total leaf size: up to 60 cm long (probably more) and 20 cm wide

Characters: segmented, leaflets insert laterally to rachis, terminal leaflet similar in shape and size to lateral ones, leaflet length/width ratio always >7:1.

Figures: 3G, H; 4H, K, L

*Pterophyllum filicoides* leaves are petiolate impari-segmented and oblong to broadly oval. The largest specimens (all incomplete) from Lunz are ~47 cm long and 20 cm wide. The lamina is subdivided into numerous long and narrow, parallel-sided to spatulate leaflets, which are oppositely arranged, >100 mm long and 2–9 mm wide. Leaflets insert laterally to the prominent and longitudinally striate rachis and are basally more or less constricted. Constriction is usually prominent in leaflets positioned in the proximal portion of the leaf, but rather indistinct or absent in distally positioned leaflets. Leaflet apices are obtuse to acutely rounded. The length/width-ratio of the leaflets is always >7:1; in some specimens, it reaches up to 22:1. The distal five leaf segments form the apex. The terminal leaflet does not differ in shape from the laterally positioned subterminal leaflets. Numerous parallel veins enter each leaflet and usually fork once near the base. Occasionally additional bifurcations occur in the proximal portions of the leaflets.

Cuticles of *Pterophyllum filicoides* are well-known. The leaves are amphistomatic but with only a few stomata present on the adaxial side, and produce robust cuticles; costal and intercostal fields are distinguishable on both sides of the leaf. Occurrence of stomata is limited to the intercostal fields. Epidermal cells are narrow, rectangular, and elongate to isodiametric (square) in outline. Anticlinal cell walls are generally straight, but cells on the abaxial side may occasionally display faint and irregular undulations. Cells often bear a long and hollow papilla. The dicyclic stomatal complexes are brachyparacytic; stomatal pores are oriented perpendicularly to the veins, stomata are slightly sunken (see Pott et al., 2007e).

*Pterophyllum brevipenne* Kurr ex Schenk, 1864 emend. Pott et al., 2007

Estimated total leaf size: up to 25 cm long (probably not longer) and 6 cm wide

Characters: segmented, leaflets insert laterally to rachis, terminal leaflet differs from lateral ones, leaflet length/width ratio always >7:1.

Figures: 3J; 4J, M

*Pterophyllum brevipenne*, leaves are petiolate and impari-segmented. They differ from *P. filicoides* in that they are oblong and more lanceolate or spatulate to inverted-conical in outline. The largest leaf portions are up to 22.7 cm long and 6 cm wide. The lamina is subdivided into numerous narrow and short, spatulate leaflets, which are oppositely arranged and closely spaced. Leaflets are up to 27 mm long and 2.5–5 mm wide. Proximal leaflets are short, but increase in length toward the distal third of the leaf.
Figure 3
The proximal one or two leaflets often lack counterparts on the opposite side of the rachis. The leaflets are usually broadly attached to the rachis, but may occasionally display a distinct basal constriction. They are bluntly rounded apically. The length/width-ratio of the leaflets ranges from 4:1 to 6:1 but is always <7:1. The segments insert laterally to the prominent and longitudinally striate rachis. The apical portion of the leaf usually consists of three, sometimes up to five, leaflets; the terminal leaflet usually differs in morphology from the laterally positioned ones in that it is more rounded in outline and distinctly wider distally. Numerous parallel veins enter each of the leaflets. Veins usually fork once near the base. Additional vein bifurcations may sporadically occur; however, the occurrence of additional bifurcations is not limited to the proximal portion of the leaflet as it is in the very similar \( P. \ filicoides \).

Leaves are amphistomatic but with only a few stomata present on the adaxial surface, and produce robust cuticles; costal and intercostal fields are distinguishable on both sides of the leaf. Occurrence of stomata is limited to the intercostal fields. Adaxial stomatal density in \( Pterophyllum brevipenne \) is distinctly higher than that of \( P. \ filicoides \). Epidermal cells are rectangular, and elongate to isodiametric (square) in outline. Anticlinal cell walls are straight. In contrast to \( P. \ filicoides \), anticlinal cell walls in \( P. \ brevipenne \) are never sinuous or faintly undulating. Cells often bear a long and hollow papilla. The dicytic stomatal complexes are brachyparacytic; stomatal pores are oriented perpendicularly to the veins, stomata are slightly sunken (see Pott et al., 2007c).

Genus \textit{Nilssoniopteris} Nathorst, 1909 emend. Pott et al., 2007

Nathorst (1909) introduced the genus \textit{Nilssoniopteris} for entire-margined cycadophyte leaves from the Jurassic of Europe. With regard to macro morphology, some \textit{Nilssoniopteris} fossils may resemble \textit{Anomozamites} Schimper, 1870 emend. Harris, 1969a (see Pott & McLoughlin, 2009). Typical representatives of \textit{Nilssoniopteris} are characterised by an entire-margined leaf lamina. However, some specimens from Lunz show a lamina that is partially lobed or dissected up to the rachis. Fully segmented leaves are traditionally assigned to \textit{Anomozamites}. However, several authors, e.g., Harris (1969a) and Boyd (2000), have illustrated intermediate types. Unfortunately, the information available on the epidermal anatomy of \textit{Anomozamites} is incomplete (Harris 1969a; Pott & McLoughlin, 2009) and does not provide features useful in the discrimination of \textit{Anomozamites} from \textit{Nilssoniopteris}. Boyd (2000) emended the diagnosis of \textit{Nilssoniopteris} to include the lobed leaves that are intermediate between \textit{Nilssoniopteris} and \textit{Anomozamites} and display bennettitalean epidermal anatomy. In order to include also leaves dissected down to the rachis, Pott et al. (2007c) further expanded Boyd’s (2000) diagnosis of \textit{Nilssoniopteris}.

Three morphospecies of \textit{Nilssoniopteris}, i.e. \textit{N. haidingeri}, \textit{N. angustior} and \textit{N. lunzensis}, have recently been described from Lunz (Pott et al., 2007c) based on specimens that were originally interpreted as marattialean ferns of the genus \textit{Macrotaeniopteris} Schimper, 1869 by Krasser (1909a). Epidermal anatomy, especially stomatal morphology, demonstrates that they in fact belong to the Bennettitales.

\textit{Nilssoniopteris haidingeri} (Krasser, 1909)

Pott et al., 2007

Estimated total leaf size: up to 70 cm long and 15 cm wide
Characters: usually entire-margined, but may also be partly segmented; lanceolate, lamina/leaflets insert laterally to rachis
Figures: 3D; 4E, G

\textit{Nilssoniopteris haidingeri} leaves are quite large, (up to nearly 70 cm long and 15 cm), petiolate entirely-margined or partially segmented, almost regular, broadly oval or oblong to lanceolate in outline, and have an obtuse-rounded apex. The rachis is markedly striate. The lamina is usually coarsely divided into several squarish segments that are oppositely to suboppositely arranged and insert laterally to the rachis.

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her on the abaxial side of the leaf. The leaves have robust cuticles. Costal and intercostal fields are distinct on the abaxial, but indistinct on the adaxial side of the leaf. The epidermal cells are rectangular and elongate to isodiametric in outline. Anticlinal walls are smooth. Epidermal cells on the abaxial side often bear a small, solid papilla. Stomata are slightly sunken and only occur close to the rachis on the adaxial side of the leaf, while they are regularly distributed within the intercostal fields on the abaxial side. Stomata are brachyparacytic; stomatal pores are orientated perpendicular to the veins. Subsidiary cells are often slightly more heavily cutinised than the normal epidermal cells. The arrangement of epidermal cells in distinct rows gradually disappears towards the rachis. Epidermal cells positioned close to the lamina margin are much smaller than cells located in the middle portion of the lamina (see Pott et al., 2007c).

Remark: The material was originally assigned to *Taeniopteris haidingeri* Goeppl. msc. nec. Ett. by Stur (1885), which is a nomen nudum and not conspecific with *T. haidingeri* Ettingshausen, 1851 (a marattialean fern), as clearly stated by Stur (1885: ‘nec’). Krasser (1909a) transferred the material to a different genus (i.e. *Macrotaeniopteris*) and *M.* *haidingeri* is a valid name; it has a good diagnosis, illustrations were not necessary before 1912. Pott et al. (2007c) assigned all species of *Macrotaeniopteris* from Lunz to *Nilssoniopteris* based on the bennettitalean nature of their cuticles but erroneously named this species *Nilssoniopteris haidingeri* (Stur ex Krasser); the correct indication of authorities is *Nilssoniopteris haidingeri* (Krasser) Pott et al., 2007.

**Nilssoniopteris angustior** (Stur ex Krasser, 1909) Pott et al., 2007

Estimated total leaf size: up to 35 cm long and 6 cm wide
Characters: segmented, leaflets insert laterally to rachis
Figures: 3B; 4C, D

*Nilssoniopteris angustior* leaves appear to have been relatively large (the largest fragments are up to 29 cm long and 5.2 cm wide). They are petiolate, narrow, oblong to lanceolate in outline, and have an acute apex. The lamina is not subdivided into segments, but occasionally growth aberrations of the leaf margin occur that resemble faint lobations. The lamina is inserted laterally to the striate rachis. It is very narrow close to the petiole, but then rapidly increases in width. Numerous parallel veins enter perpendicular to the lamina and run straight to the margin. Veins usually fork twice close to the rachis.

Cuticles reveal that the leaves are amphistomatic, and stomatal density is considerably higher on the abaxial side of the leaf. The leaves have relatively thin cuticles. Costal and intercostal fields are not clearly differentiated. Epidermal cells are isodiametric, usually rectangular. Virtually every epidermal cell possesses a distinct central cuticular thickening on the outer periclinal wall. This feature becomes more distinct towards the margin of the lamina. Anticlinal cell walls are smooth and well cutinised, partly with triangular cuticular thickenings in the cell corners. Stomata are brachyparacytic, slightly sunken, and occur sporadically in areas close to the rachis on the adaxial side, while stomata and subsidiary cells on the abaxial side are arranged in long rows that are orientated perpendicularly to the rachis; stomatiferous rows alternate with non-stomatiferous bands of cells (see Pott et al., 2007c).

**Nilssoniopteris lunzensis** (Stur ex Krasser, 1909) Pott et al., 2007

Estimated total leaf size: up to 25 cm long and 7 cm wide
Characters: segmented, leaflets insert laterally to rachis, terminal leaflet differ from lateral ones
Figures: 3C; 4F

*Nilssoniopteris lunzensis* is characterised by relatively small petiolate leaves (up to 17.2 cm long and 6.2 cm wide). They are imparipinnate, lanceolate to oval in overall outline and possess a longitudinally striate rachis. The lamina is subdivided into individual segments, which insert laterally to the rachis. Leaf segments are broadly attached, slightly decurrent, irregularly to regularly opposite in position and up to 32.0 mm long and between 4.4 mm and 17.5 mm wide. The apex is formed by the uppermost three leaf segments. Individual leaf segments are more or less rectangular in outline and obtusely rounded apically. The apical leaf segment differs from the lateral segments in being much narrower; however, it is rarely preserved. Numerous parallel veins enter each leaf segment. Veins usually fork once or twice immediately after entering the segment. This species may
Figure 4
be confused with *Pterophyllum*; however, leaflets are much wider in *N. lunzensis* than in both *Pterophyllum* species known from Lunz (see above).

Cuticles are well-known. The leaves are amphistomatic; however, stomatal density is considerably higher on the abaxial side of the leaf. Cuticles are robust; costal and intercostal fields are not clearly differentiated. Epidermal cells are isodiametric, typically rectangular or squarish, not or only slightly elongated. Anticlinal cell walls are smooth and sometimes have triangular cuticular thickenings in the corners. A central idiocuticular thickening may occur on the outer periclinal cell wall. Stomata sporadically occur on the adaxial side, while they are arranged in long rows orientated perpendicular to the rachis on the abaxial side. The stomatiferous rows alternate with non-stomatiferous bands of cells. Stomata are brachycyclic, sunken, and the pores are orientated perpendicular to the cell rows. Long and hollow papillae may occur on the epidermal cells of both leaf sides (see Pott et al., 2007c).

**CYCADALES**

**Genus Nilssonia Brongniart, 1825**

Brongniart (1825) introduced the genus *Nilssonia* for once-pinnate leaves from the Lower Jurassic of Scania (Sweden) that are characterised by a prominent venation. The spelling *Nilsonia*, which is sometimes seen in the older literature, is a typographical error, and the spelling *Nilssonia* is today widely accepted in literature. The most important character used to distinguish *Nilssonia* leaves from *Pterophyllum* is the insertion of the leaf segments to the rachis. Segments are inserted to the upper side of the rachis in *Nilssonia*, while they are laterally inserted in *Pterophyllum* (Figure 2). Additional characters of *Nilssonia* leaves include conical to tongue-shaped leaf segments and veins that do not fork. Cuticles show in most cases actinocytic (or more rarely cyclocytic) stomata (haplocheilic in the sense of Florin, 1933) and often papillate surfaces.

Four species are currently recognised in the Lunz flora, including *Nilssonia sturii*, *N. riegeri*, *N. lunzensis* and *N. neuberi*. *Nilssonia sturii* is the most common representative of the genus in the Lunz flora.

*Nilssonia sturii* Krasser, 1909 emend. Pott et al., 2007

Estimated total leaf size: up to 80 cm long and 26 cm wide

Characters: segmented, leaflets inserted to the upper side of rachis, terminal leaflet unknown, veins unforked

Figures: 3N; 5B, E, F

*Nilssonia sturii* leaves are petiolate, pinnate (segmented), of almost regular, oblong, more or less lanceolate shape; the apex remains unknown. The lamina is subdivided into numerous, irregularly oppositely positioned segments whose length continuously decreases towards the leaf tip. Segments are crescent- to sword-shaped, all of the same general shape, distally tapering and slightly widened at the base. The width of the individual segments may vary considerably, some segments being twice as wide as others. Segments are attached to the upper side of the rachis. Numerous parallel, unforked veins enter each segment and run straight to the segment tip. In adaxial surface view, the prominent rachis is nearly completely covered by the bases of the leaf segments. The largest incomplete leaf portions from Lunz are up to 54.5 cm long and 26.2 cm wide. Leaf segments are up to 13.2 cm long and ranging from 6.7 mm up to 18.8 mm in width at their base.

Cuticles are delicate, but well-known for this species. Leaves are hypostomatic. Costal and intercostal fields are distinguishable on the abaxial but not on the adaxial side. Epidermal cells are polygonal or rectangul are typically rectangular or squarish, not or only slightly elongated. Anticlinal cell walls are smooth and sometimes have triangular cuticular thickenings in the corners. A central idiocuticular thickening may occur on the outer periclinal cell wall. Stomata sporadically occur on the adaxial side, while they are arranged in long rows orientated perpendicular to the rachis on the abaxial side. The stomatiferous rows alternate with non-stomatiferous bands of cells. Stomata are brachycyclic, sunken, and the pores are orientated perpendicular to the cell rows. Long and hollow papillae may occur on the epidermal cells of both leaf sides (see Pott et al., 2007c).

Four species are currently recognised in the Lunz flora, including *Nilssonia sturii*, *N. riegeri*, *N. lunzensis* and *N. neuberi*. *Nilssonia sturii* is the most common representative of the genus in the Lunz flora.
Leaves are amphistomatic and possess delicate cuticles. Costal and intercostals fields are distinguishable on the abaxial, but not on the adaxial side. Epidermal cells are polygonal or rectangular, elongate with acute or pointed ends. The adaxial and abaxial cuticles of *Nilssonia riegeri* are quite similar to those of *N. sturii*, morphologically as well as with regard to cell sizes, but *N. riegeri* differs from *N. sturii* in having stomata on the adaxial side. The monocyclic stomata of *N. riegeri* are oriented irregularly. Stomata are surrounded by an actinocytic ring of 6–8 trapezoid to rectangular subsidiary cells (see Pott et al., 2007a).

**Nilssonia riegeri** (Stur ex Krasser, 1909)
Pott et al., 2007

Estimated total leaf size: up to 35 cm long and 9 cm wide
Characters: segmented, leaflets inserted to the upper side of rachis, terminal leaflet unknown, veins unforked
Figure: 3L

*Nilssonia riegeri* leaves are oblong to lanceolate in outline, pinnate, and the narrow leaf segments are densely spaced. The lamina is subdivided into numerous, irregularly faced, narrow and lanceolate segments. Segments are attached to the upper side of the rachis in a way that they cover most of the rachis. Individual segments taper towards the tip, which results in an irregular outline of the leaf. Leaf segments are narrow, basally slightly expanded, the tip is rounded. All segments are almost equal in width, bent slightly towards the leaf apex, more than five times as long as wide. Five to eight parallel, unforked veins enter the segments. Incomplete leaves are up to 16.0 cm long and 8.9 cm wide. Leaf segments are up to 5.2 cm long; their width ranges between 1.7 mm and 3.3 mm.

Leaves are amphistomatic and possess delicate cuticles. Costal and intercostals fields are distinguishable on the abaxial, but not on the adaxial side. Epidermal cells are polygonal or rectangular, elongate with acute or pointed ends. The adaxial and abaxial cuticles of *Nilssonia riegeri* are quite similar to those of *N. sturii*, morphologically as well as with regard to cell sizes, but *N. riegeri* differs from *N. sturii* in having stomata on the adaxial side. The monocyclic stomata of *N. riegeri* are oriented irregularly. Stomata are surrounded by an actinocytic ring of 6–8 trapezoid to rectangular subsidiary cells (see Pott et al., 2007a).

**Nilssonia lunzensis** Stur ex Pott et al., 2007

Estimated total leaf size: up to 50 cm long and 15 cm wide
Characters: segmented, leaflets inserted to the upper side of rachis, terminal leaflet rhomboidal
Figure: 3M

*Nilssonia lunzensis* leaves are characterised by impari-pinnate, individual segments, which are attached to the upper side of the rachis, strongly decurrent basiscopically and tapering towards their tips, resulting in a rather open appearance of the leaf.
**Nilssonia neuberi** Stur ex Pott et al., 2007

Estimated total leaf size: up to 150 cm long and 40 cm wide
Characters: segmented, leaflets inserted to the upper side of rachis, terminal leaflet unknown, veins unforked
Figure: 3K

*Nilssonia neuberi* leaves clearly differ from all other *Nilssonia* species in the Lunz flora by their large size. Leaves are robust, regularly pinnate with leaf segments widely spaced. Individual leaf segments are slightly decurrent, attached to the upper side of the rachis, long and narrow in outline, and hardly tapering towards their tips. The striate rachis is remarkably thin. Leaf petiole and apex remain unknown. Vascularization is dense, and consisting of a large number of parallel, unforked veins that enter the leaf segments at 90° angles. The largest incomplete leaf portions are 52.5 cm long and 39.3 cm wide, with segments of each up to 23.3 cm long and 12.3–26.4 mm wide.

Cuticles are delicate and rather poorly preserved. Leaves are hypostomatic; costal and intercostals fields are distinguishable only on the abaxial side. Epidermal cells are rectangular, elongate, and narrow to isodiametric in outline. Anticlinal cell walls are straight, periclinal walls smooth, some bearing a thick-walled hollow papilla. Haplocheilic stomata are randomly oriented, monocyclic, and sunken (see Pott et al., 2007a).

**Genus Pseudoctenis** Seward, 1911

The genus *Pseudoctenis* was introduced by Seward (1911) for *Zamites*-type leaves from the Jurassic of Sutherland, Great Britain. However, Seward did not provide a generic diagnosis, but only a comparison to *Ctenis* Lindley et Hutton, 1834 (cycadalean foliage). Although *Ctenis* and *Pseudoctenis* are similar in macromorphology, Seward (1911) noted that they are easily distinguishable based on the occurrence of anastomoses in the venation of *Ctenis*. Harris (1950) concurs with Seward (1911) in that the *Ctenis/Pseudoctenis* series consists of two distinct groups.

The epidermal anatomy of the type species *Pseudoctenis eathiensis* Seward, 1911, and of two addi-
Identification key

1 Lamina entire-margined ...................................................  2
   Lamina partially or completely segmented ...............  3

2 Leaves lack petioles and rachis, tongue-shaped,
   narrow, up to 1.5 cm wide and 20 cm long ..........  Arberophyllum florinii (A)
   Leaves with distinct robust rachis,
   up to 6 cm wide ......................................................  Nilssoniopteris angustior (B)

3 Segments inserted laterally to rachis .................  4
   Segments inserted to upper side of rachis ..........  9 (Nilssonia)

4 Segments broad, laminar,
   less than 3 times longer than wide .................  5
   Segments narrow, more than 3 times longer
   than wide ...............................................................  6

5 Leaves completely segmented, segments narrow,
   leaf length <20 cm ..................................................  Nilssoniopteris lunzensis (C)
   Leaves only partially segmented, entire-margined
   at base and/or tip, large segments, leaves large,
   up to 60 cm long ..................................................  Nilssoniopteris haidingeri (D)

6 Segments actually represent individual leaves,
   each with a single central vascular strand (vein);
   leaves densely arranged, arcuated towards tip,
   leafy twigs small ......................................................  Elatocladus (Stachyotaxus) lipoldii (E)
   Segments with more than 5 parallel veins .............  7

7 Segments long, conical towards tip, segment
   base decurrent, typically loosely spaced,
   venation robust ......................................................  Pseudoctenis cornelii (F)
   Segments parallel-sided or conical towards base,
   segment bases not decurrent, consistently
   densely spaced, venation dense, veins delicate ....  8 (Pterophyllum)

8 Segments parallel-sided, long, always >7 times
   longer than wide, apical segment identical to
   lateral ones, leaves parallel-sided, >50 cm long ....  Pterophyllum filicoides (G)
   Segments parallel-sided or conical at base,
   consistently appearing rounded, always <7 times
   longer than wide, apical segment distinctly different,
   leaf conical in shape, up to 25 cm long ..............  Pterophyllum brevipenne (H)

9 Leaves very large and robust, segments up to
   25 cm long, parallel-sided .....................................  Nilssonia neuberi (J)
   Segments distinctly shorter, conical .................  10

10 Segments acute, pointed, leaves delicate ..........  Nilssonia riegeri
   Segments wide, conical, apically
   obtuse-rounded ....................................................  11

11 Segment bases distinctly decurrent, segment
   spacing typically wide ........................................  Nilssoniopteris lunzensis (K)
   Segments not decurrent, segment spacing
   typically rather dense .........................................  Nilssonia sturii (L)
tional species, i.e. *P. spectabilis* Harris, 1932 and *P. depressa* Harris, 1932 establishes the cycadalean affinities of *Pseudoctenis* based on the presence of haplocheilic stomata (Harris, 1932; Van Konijnenburg-van Cittert & Van der Burgh, 1989), which are especially valuable in distinguishing *Pseudoctenis* leaves from those bennettitalean foliage types that are similar in macromorphology, e.g., certain types of *Pterophyllum* and *Zamites* Brongniart, 1828. One leaf type assignable to the genus *Pseudoctenis* has been described from Lunz (Pott et al. 2007b) that represents one of the earliest occurrences for the genus.

*Pseudoctenis cornelii* Pott et al., 2007

Estimated total leaf size: up to 70 cm long and 15 cm wide

Characters: loosely segmented, leaflets insert laterally to rachis, terminal leaflet unknown, venation prominent

Figures: 3F; 5A, C, D

*Pseudoctenis cornelii* leaf fragments are up to 14.5 cm long; based on the material at hand adult leaves of *P. cornelii* are estimated to have grown up to 70 cm long. The blade has a somewhat lax appearance because the leaf segments are relatively loosely spaced. Tongue-shaped leaf segments extend from the rachis at angles between 80° and 90°. They are oppositely to sub- oppositely positioned, polymorphous (size and shape strongly depend on the position in the leaf), generally oblong in outline, tapering, and with rounded tips. The largest leaf segments may be >70 mm long and up to 6.5 mm wide. The segments are wholly adherent to the rachis and basiscopically decurrent. The venation is conspicuous. Seven to twelve parallel veins, forking once shortly after entering, enter each leaf segment from the rachis.

Cuticles are well-preserved. The leaves are hypostomatic. Both the adaxial and abaxial epidermis are differentiated into costal and intercostal fields. Epidermal cells are rectangular or elongate to isodiametric in outline; anticlinal walls are slightly undulated to sinuous. The intercostal fields of the abaxial cuticle are broad, between 350 and 450 µm wide, and composed of polygonal to broadly rectangular, isodiametric cells. Stomata are confined to the intercostal fields, haplocheilic, regularly scattered across the intercostal fields, randomly oriented, and surrounded by 4–6 subsidiary cells. Each subsidiary cell bears a small hollow papilla that overarches the pit mouth and covers the sunken guard cells (see Pott et al., 2007b).

**GINKGOALES**

**Genus Arberophyllum** Doweld, 2000

*Arberophyllum* forms an isolated taxon that differs in various morphological traits from other members of the Mesozoic ginkgophytes (Tralau, 1968; Dobruskina, 1998). The most characteristic features of *Arberophyllum* are strap-shaped leaves that lack petioles. The genus name *Arberophyllum* is a substitute for the original genus name *Glossophyllum* Kräusel, 1943, used i.a. by Kräusel (1943), since *Glossophyllum* (Müller Hal., 1851) Hampe, 1879 is preoccupied by a genus of mosses and the name of the fossil genus thus is a younger synonym and had to be replaced (for details, see Doweld 2000).

*Arberophyllum florinii* (Kräusel, 1943)

Doweld, 2000

Estimated total leaf size: up to 20 cm long and 2 cm wide

Characters: tongue-shaped leaves without petioles, lamina entire-margined

Figures: 3A; 4A, B

*Arberophyllum florinii* leaves are common in the Lunz flora and usually yield excellently preserved cuticles. Kräusel (1943) assigned the species to the gymnosperm order Ginkgoales based on epidermal anatomy. The most characteristic features of *A. florinii* are tongue-shaped leaves, up to 20 cm long and 1.5 cm wide, that lack petioles and a central rachis. Leaves of *A. florinii* in the Lunz flora are very distinctive, also due to their thick, leathery cuticles that easily chip off from the rock.

Cuticles are well-preserved. The leaves are hypostomatic. Both the adaxial and abaxial epidermis are differentiated into costal and intercostal fields. Epidermal cells are rectangular or elongate to isodiametric in outline; anticlinal walls are slightly undulated to sinuous. The intercostal fields of the abaxial cuticle are broad, between 350 and 450 µm wide, and composed of polygonal to broadly rectangular, isodiametric cells. Stomata are confined to the intercostal fields, haplocheilic, regularly scattered across the intercostal fields, randomly oriented, and surrounded by 4–6 subsidiary cells. Each subsidiary cell
Table 1.
Comparison of the historical and modern taxa names (green) of gymnosperm foliage from Lunz.
Stomata are separated from one another by one to several ordinary epidermal cells. However, they are usually interconnected by idiocuticular striae. Guard cells are sunken and possess prominent circum-poral thickenings. The guard cells are surrounded by 5–7 subsidiary cells, which are more heavily cutinised than the normal epidermal cell. A distinct and solid papilla extends from each subsidiary cell and overarches the pit mouth (see Pott et al., 2007d).

**Genus Ginkgoites Seward, 1919**

Based on works by himself, Seward (1919) introduced the genus *Ginkgoites* to accommodate fossil leaves that are similar in morphology to leaves of the extant *Ginkgo biloba* Linnaeus, 1771, but that cannot be positively assigned to the extant genus *Ginkgo* Linnaeus, 1771 with certainty.

*Ginkgoites lunzensis* (Stur, 1885) Florin, 1936

Estimated total size: up to 15 cm long and 10 cm wide
Characters: fan-shaped, dissected, leaflets band-like
Figure: 6

Kräusel (1943) described several specimens from Lunz under the name *Ginkgoites lunzensis* and provided illustrations of well preserved cuticles. Although the specimens based on morphology alone could also be interpreted as fern aphlebiae, the cuticles provide evidence for seed plant affinities. Kräusel (1921) first assigned the leaves to the genus *Baiera* Braun, 1843 but later changed his opinion and reassigned them to *Ginkgoites* based on earlier studies by Florin (1936). Leaves of *G. lunzensis* resemble very large leaves of the extant *Ginkgo biloba*. They are fan-shaped with an actinomorphically dissected lamina. The dissection may reach down to the leaf base. Leaf segments are band-like with almost parallel margins and several delicate parallel veins producing a palmate venation due to regular bifurcation. Preserved leaf fragments are up to 10 cm long; Kräusel (1921) suggested a total leaf length of up to 15 cm. Due to the fragmentary preservation of the less-than-ten specimens that have been discovered from Lunz to date, this species was not included in the identification key included in this paper (see below). Details of the epidermal anatomy of the leaves are given in Kräusel (1943).

**PINALES**

Genus *Elatocladus* Halle, 1913 emend. Harris, 1979

The systematic position of this Mesozoic conifer-like leaf type remains uncertain. Although affiliation with the Coniferales has been invoked, this issue is by no means settled (Florin, 1958; Harris, 1969b, 1979; Arndt, 2002). The general difficulties in assigning sterile leafy conifer or conifer-like twigs to clearly demarcated morphogenera were discussed in detail by Harris (1979). This author used criteria such as leaf proportions, leaf base and tip shapes, leaf divergence and manner of leaf insertion as discriminative features of genera. He favoured the assignment of sterile conifer shoots bearing divergent, elongate, dorsiventrally flattened, univeined leaves to *Elatocladus* in agreement with an earlier proposal by Berry (1924). Rees and Cleal (2004) adopted a similar strategy and, in accordance with their study, we here follow Harris’ (1979) diagnosis of *Elatocladus*. However, we note that very similar or conspecific leafy axes have been inferentially linked, although never convincingly found attached, to *Palissya* Endlicher, 1847 cones by several workers (Nathorst, 1908; Florin, 1958; Parris et al., 1995; Schweitzer & Kirchner, 1996). Although *Elatocladus* has generally been used for younger (Jurassic–Cretaceous) shoots and leaves than those described below (Late Triassic), temporal separation is not a strong basis for differentiation of morphotaxa, and we note that Harris (1935) also recognised several species of this genus from Rhaetian deposits of Greenland.

*Elatocladus (Stachyotaxus) lipoldii* Kräusel, 1949

Estimated total size: up to 20 cm long and 4 cm wide
Characters: leafy twigs, leaves with prominent mid-vein
Figure: 3E
The leafy coniferalean twigs from Lunz were assigned to *Stachyotaxus lipoldii* by Kräusel (1949), who also studied cuticles of the leaves. Originally, they were erroneously included in *Pterophyllum* by Stur (1885), but the leaves show only a single prominent midvein, which separates it from *Pterophyllum* that possesses several parallel veins per leaflet. Following the definitions and studies by Harris (1979), as well as those by several other workers, we feel that it would be more reasonable to transfer the leafy twigs from Lunz to *Elatocladus*. The twigs are stalked, up to 20 cm long, and bear several acute leaves (not leaflets in the sense of Kräusel, 1949), which are bent slightly forward towards the apex of the twigs. Leaf apices are somewhat acute, but mainly bluntly rounded. Leaves are up to 20 mm long and 3 mm wide. Kräusel (1949) described cuticles with haplocheilic stomata. *Elatocladus lipoldii* is the only conifer species known from the Lunz flora to date; it is a less common element than, e.g., *Pterophyllum* and *Nilssonia* leaves, but adds another typically Rhaetian genus to the inventory of the Lunz flora (cf. Pott et al., 2007e, 2008; Pott & McLoughlin, in press).

**Comments on the key:**

Drawings included in the key are simplified or generalised, and slightly oversubscribed to underline the main characteristics of the species. A typical specimen of each species, along with typical features of the cuticles, is illustrated in Figures 3–6.

The identification key largely relies on macro-morphological features because it was our intention to keep it as simple as possible and make it usable for a broad audience. Characteristics of the epidermal anatomy are not included since cuticular analysis requires some effort and may not be available to everyone interested in the fossils from Lunz. The key was tested and works well for most hand specimens. It has to be taken into account, however, that some small and/or ill-preserved specimens may not be safely identified down to species level based exclusively on macromorphology. The macromorphological differences between the species are sufficiently well recognisable in fossils that show a larger portion of the leaf. Fossils of entire but particularly small leaves pose another problem with regard to identification since they may represent immature foliage or mature foliage of juvenile plants or seedlings that does not display all the features characteristic of mature leaves from full-grown individuals of the same taxon (cf. Pott et al., 2007e; Pott & McLoughlin, 2009). In all of these instances, only the preparation of cuticles provides a data set of sufficient clarity for species identification. For detailed information on the epidermal anatomy of the species, the reader is referred to the publications that are indicated along with the species descriptions.

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