Jurassic Plant Fossils at Marske Quarry

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In November 2012 Tees Valley Regionally Important Geological Sites (TVRIGS) Group secured a grant from the Heritage Lottery Fund for their project, Jurassic Plants at Marske Quarry, Errington Woods, New Marske. TVRIGS are using the money to tell the story of Marske sandstone quarry and the Jurassic plant fossils that were collected there around the end of the 19th and early 20th Centuries when the quarry was a well-known fossil site. The project aims to revive local and national interest, with workshops for local school children, an open day for the public at Dorman Museum in Middlesbrough, which houses a collection of fossils from the site, and an event at the quarry to see where the fossils came from.

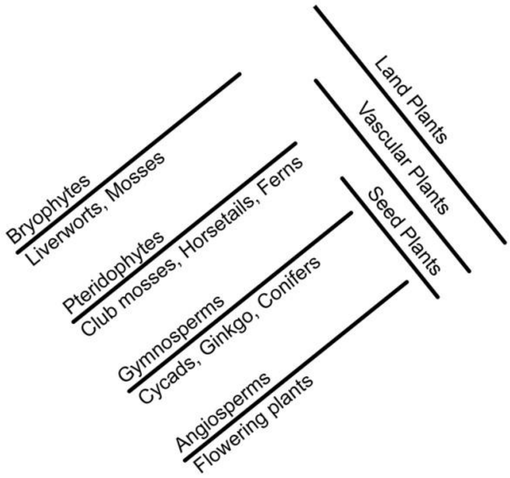
The former importance of the quarry and its fossil plants came to the attention of TVRIGS from information passed on by CNFC President Vic Fairbrother, who had found references to the quarry in CNFC Record of Proceedings, in papers by Rev. John Hawell (1902) and Rev. George J. Lane (1907-8 & 1908-9). Early collecting and examination of the fossils was undertaken by CNFC. A visit by the Yorkshire Geologists is recorded and a distinguished visitor was Professor A.G.Nathorst, geologist, paleobotanist and arctic explorer from the Swedish Natural History Museum, Stockholm. Particular fossils were sent for identification to Mr A.C.Seward, author of *The Jurassic Flora of Yorkshire* and later to become Professor Sir Albert Seward, Professor of Botany at Cambridge University. He named a new species from the quarry *Dictyozamites hawellii* after its collector, Rev. John Hawell, then President of CNFC. Later, Marske quarry was commemorated in a new genus of fossil conifers, *Marskea,* described and named by Professor Rudolf Florin of the Bergius Botanical Garden in Stockholm, from a specimen collected in the quarry.

My involvement with the TVRIGS Group came about through a chance conversation with their chairman, Alan Simkins. He described the nature of their project and went on to say that, although proficient geologists, the group members knew little about fossil plants and had so far been unable to find anyone with the necessary expertise in paleobotany to instruct them. When I explained my academic credentials in paleobotany I was duly commissioned to provide appropriate instruction. On 23rd January 2013 Paul Forster and I, as representatives of CNFC, met with Alan Simkins and John Waring of TVRIGS at the Dorman Museum to view the Marske quarry fossils from the museum collection, which Paul photographed. Then, on 14th February I delivered a PowerPoint presentation on *The Yorkshire Jurassic Flora* and its botanical and paleobotanical background at a meeting of TVRIGS in the Dorman Museum. The following schedule formed the basis of the PowerPoint presentation and printed copies of it were given to group members.

The Yorkshire Jurassic Flora

The Botanical Background

Land Plants fall into four structural and functional categories – Bryophytes, Pteridophytes, Gymnosperms and Angiosperms – that correspond to the four major evolutionary steps from the initial colonisation of the land to the evolution of the flowering plants, which now constitute the dominant vegetation of the earth.



The first evolutionary step entailed the development of a water resistant surface layer, the **cuticle**, to prevent dehydration, and reproduction via wind dispersed spores. The **Bryophytes** (liverworts, hornworts and mosses) are our simplest land plants. They lack specialised water- and food-conducting vascular tissues and so are unable to attain large size. Many grow flat on the ground and even the largest attain a height of only a few centimetres. They depend on the presence of water for fertilization – they have motile sperms – and so most are confined to moist habitats. The extant liverworts are probably the closest plants we have to the first colonisers of the land.

The second step was the evolution of vascular tissues and in particular of the water-conducting tissue **xylem**, commonly known as wood. The walls of the conducting cells of the xylem are impregnated with a complex polymer called **lignin**, which, in addition to rendering them water-proof, confers on them great strength and rigidity. The presence of lignified xylem provides the potential for attaining large size. The **Pteridophytes** (club mosses, horsetails, and ferns) are vascular plants but, like the Bryophytes, they reproduce via wind dispersed spores and also have motile sperms which make them dependent on water for fertilization, thus generally restricting them to moist habitats.

The third step was the evolution of **seeds**, which removed the need for the presence of free water for fertilization to occur, thus opening up the potential for colonising drier habitats. The **Gymnosperms** (Cycads, *Ginkgo,* Conifers and Gnetales) have evolved more complex vascular systems than those of Pteridophytes. This permits the attainment of greater size and most are trees. All possess naked seeds, which are borne either on stalks or on scales in cones, but which remain open to the atmosphere, an essential requirement for their mode of pollination by wind dispersed pollen grains.

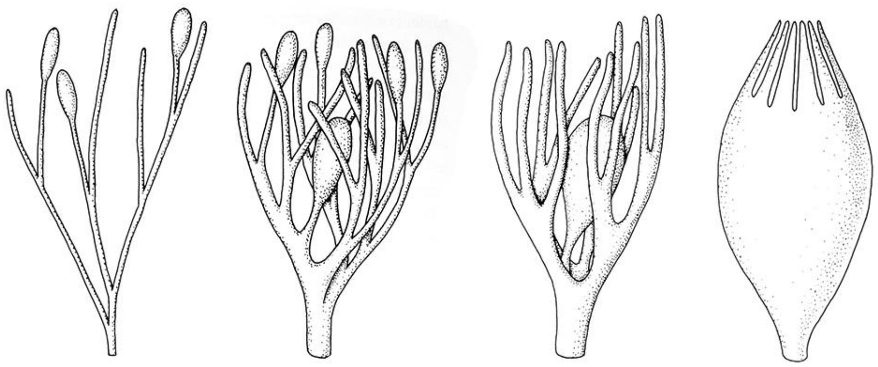
The fourth step was the complete enclosure of the seeds in an ovary, which develops into a fruit. This is the level of evolution attained by the **Angiosperms** (flowering plants).

The Evolution of Seeds

The spores of Pteridophytes are borne in a structure called a sporangium. During the late Devonian and early Carboniferous periods several disparate groups of plants at the pteridophyte level evolved a condition called **heterospory**, the production of sporangia and spores of two sizes: megasporangia producing **megaspores** and microsporangia producing **microspores**. Each megasporangium produced four large megaspores, which were functionally female; each microsporangium produced numerous microspores, which were functionally male.

Heterospory is the essential first step leading to the evolution of seeds. The subsequent series of steps probably occurred independently in several pteridophytic groups but led eventually to the evolution of the two earliest recognised groups of seed-bearing plants, pteridosperms and cordaites.

The immature seed before pollination and fertilization is called an **ovule**. The sequence of evolution from megasporangium to ovule entailed the reduction of megaspores from four to one, the retention of the megaspore in the sporangium, and the enclosure of the megasporangium by surrounding branchlets (called **telomes**), which eventually fused to form a sheathing **integument**.



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The microspores became pollen grains

The Nature of Plant Fossils

Plant fossils are almost always fragmentary. The simplest way to understand the reason for this is to visualise a wood in autumn, with the ground littered with detached leaves, leaf fragments, twigs, fructifications or seeds, occasionally a branch or fallen tree trunk, with much of the material partially decayed by fungi. Essentially, this is the kind of material that has given rise to our fossils. After being detached from the plant the Jurassic fossils have been preserved in a range of aquatic habitats, including freshwater ponds and lakes, coastal marsh and various marine deposits. It is a consequence of the fragmentary nature of the fossils that different parts of a plant have commonly been assigned to different **form genera**. Determining which bits belong to the same plant species entails detailed microscopic study of features such as vein patterns and preserved cellular details.

There are three main modes of preservation of plant fossils: **petrifactions**, in which tissues are structurally preserved by infiltration with calcite, silica or pyrite; **compressions**, in which the tissues are compressed as a thin layer of coal-like material; and **casts** and **impressions**, which contain no tissue residues. Most of the Yorkshire Jurassic plants are preserved as compressions, which, when suitably treated, have yielded much information on structure, particularly of cuticles.

Plant Groups Represented in the Yorkshire Jurassic

Bryophytes
The sole representative of this group is a liverwort, *Hepaticites arcuatus*.

Pteridophytes
Two categories of Pteridophyta are present. **Sphenopsids** are represented by *Equisetum columnare* and **Filicopsids** are represented by a range of ferns, most of them attributed to extant families and genera.

Gymnosperms
Gymnosperms are represented by a very diverse assemblage of **Pteridosperms, Cycadales**, **Bennettitales, Ginkgoales** and **Coniferales**. A little understood group, **Czekanowskiales,** was formerly included in Ginkgoales but is now treated as a separate group of Gymnosperms.

Pteridosperms were so called because the first ones to be recognized had fern-like foliage bearing seeds. In many pteridosperms the seeds are borne in an open **cupule**. Five species represented by leaf fossils are assigned (tentatively) to this category. *Caytonia*, formerly classed as a pteridosperm is now in its own order, **Caytoniales**, thought to be a derivative of the pteridosperms. The berry-like female fructification of *Caytonia* that contains the seeds is regarded as a modified pteridosperm cupule.

Cycadales include both living and fossil members. A cycad is typically a small tree with a stout, unbranched trunk bearing a crown of large pinnate leaves. Male fructifications are cones consisting of scales (microsporophylls) covered on the under surface with pollen sacs (microsporangia). Female fructifications are cones consisting of megasporophylls (modified leaves), each bearing two (or sometimes two rows) of seeds. In the Yorkshire Jurassic four leaf genera are ascribed to cycads and both male (*Androstrobus*) and female fructifications (*Beania*) have been described.

Bennettitales became extinct in the Cretaceous. They resemble cycads in growth habit but their leaves differ in vein patterns and cuticle characters, and their fructifications are very different, superficially resembling a flower, which may be either bisexual or unisexual. Six leaf genera are ascribed to Bennettitales. Fructifications include *Williamsoniella*, which is bisexual, *Williamsonia*, which is female and *Weltrichia*, which is male.

Ginkgoales were a diverse group in the Jurassic but are now represented by the sole tree species, *Ginkgo biloba.* The distinctive characteristic is the stalked fan-shaped leaf with its dichotomous branching pattern and dichotomous venation. The female fructification is a stalk bearing at its tip two or three seeds; the male resembles a catkin. Leaves of four genera (including *Ginkgo*) have been recorded from the Yorkshire Jurassic and are locally common. The few fructifications found closely resemble those of *G. biloba*.

Czekanowskiales were probably trees. They are represented by two foliage genera (*Czekanowskia* and *Solenites*) and a genus of female fructifications (*Leptostrobus*).

Coniferales range from shrubs to forest trees bearing leaves in the form of needles or scales. Conifer fossils are common in the Yorkshire Jurassic but mostly as detached sterile twigs with foliage that are difficult to assign to a family. Reproduction is by separate male and female cones, several of which have been recorded and assigned to living families, including the monkey puzzle family, Araucariaceae, the wood from members of which is reported to be the source of jet. The yews (*Taxus* and other genera such as the fossil *Marskea*) are often treated as a separate order, Taxales.

Selected Fossil Genera of the Yorkshire Jurassic

Bryophytes: *Hepaticites*

Pteridophytes
Sphenopsids: *Equisetum*
Filicopsids:
Marattiales – *Marattia, Angiopteris*
Osmundales – *Cladophlebis, Osmundopsis, Todites*;
Filicales –
  Matoniaceae: *Phlebopteris, Matonia*
  Dipteridaceae: *Clathropteris, Dictyophyllum*
  Dicksoniaceae: *Coniopteris*
  Thelypteridaceae: *Aspidistes*

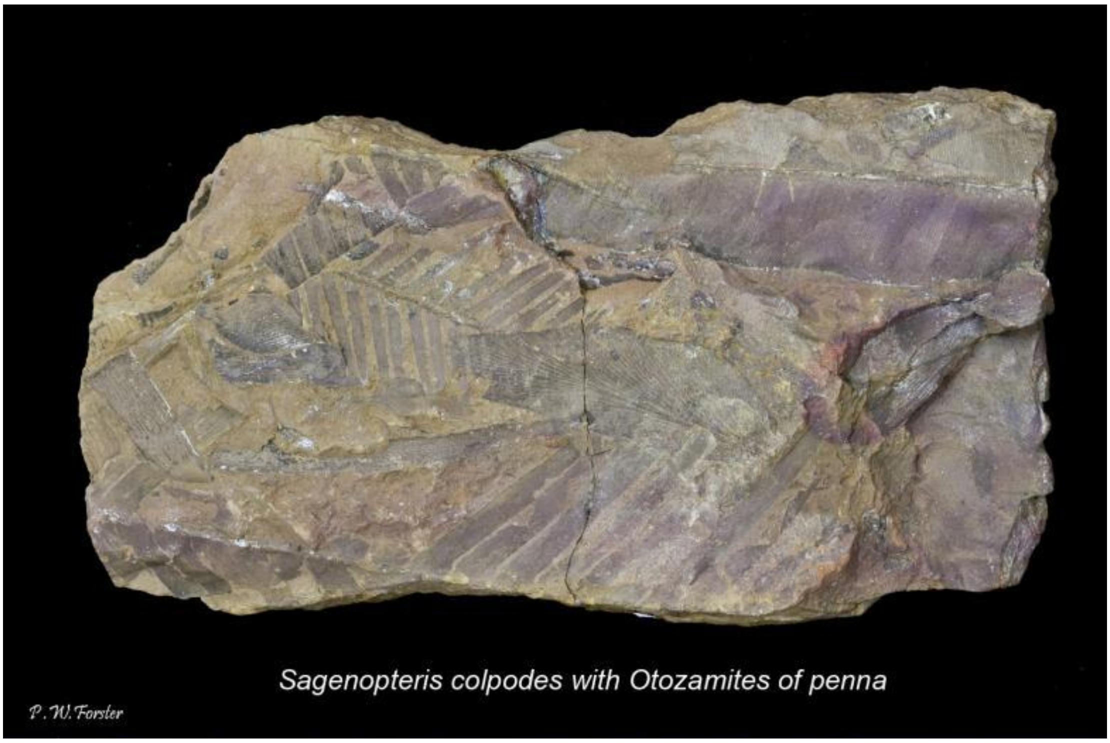
Gymnosperms
Pteridosperms (leaf genera) – *Ctenozamites, Pachypteris, Stenopteris*
Caytoniales – *Caytonia* (female fructification), *Caytonanthus* (male), Sagenopteris (leaf)
Cycadales -
  Leaf genera – *Ctenis, Pseudoctenis, Paracycas, Nilssonia*
  Female fructification - *Beania*
  Male cone - *Androstrobus*
  Note*: Nilssonia compta* (the commonest species), *Beania gracilis* and *Androstrobus prisma* are probably from the same plant species.
Bennettitales –
  Leaf genera – *Anomozamites, Otozamites, Nilssoniopteris, Pterophyllum, Ptilophyllum, Zamites*
  Fructifications – *Williamsonia* (female), *Weltrichia* (male), *Williamsoniella* (bisexual)
  Note: *Nilssoniopteris vittata* and the bisexual *Williamsoniella coronata* are from the same plant species.
Ginkgoales –
  Leaf genera – *Baiera, Eretmophyllum, Ginkgo, Sphenobaiera*
  Fructifications – *Ginkgo*
Czekanowskiales –
  Leaf genera – *Czekanowskia, Solenites*
  Female fructification – *Leptostrobus cancer*
  Note: *Leptostrobus cancer* and *Solenites vimineus* are probably from the same plant species.
Coniferales –
  Foliage genera – *Bilsdalea, Brachyphyllum, Cyparissidium, Elatides, Elatocladus, Geinitzia, Marskea, Pagiophyllum, Pityocladus*
  Families with cones –
  Araucariaceae: *Brachyphyllum mammillare,* male and female
  Cheirolepidiaceae: *Brachyphyllum crucis,* male and female
  Pinaceae: *Pityocladus scarburgensis,* female only
  Podocarpaceae: *Cyparissidium blackii*, male and female

Taxaceae: *Marskea jurassica*, male and female
Unassigned foliage form genus – *Taeniopteris*, pinnate leaves or entire leaves with pinnate venation (thought probably to include foliage of ferns, pteridosperms, Cycadales and Bennettitales)

Taeniopterios vittata

Ptillophyllum pecten

Ptilophyllum hirsutum



Sagenopteris colpodes with Otozamites of penna

Ptilophyllum pecten