

UNIVERSITY OF BIRMINGHAM  
 School of Geography, Earth and Environmental Sciences  
 & Birmingham Institute of Forest Research

**The Permian vegetational Pompeii – significance of a tropical forest ecosystem preserved by volcanic ash**

Professor Jason Hilton

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**Research undertaken in collaboration with (amongst others)**



**Nanjing Institute of Geology, Palaeontology and Stratigraphy (Chinese Academy of Sciences)**  
 Professor Jun Wang – project leader  
 Dr Weiming Zhou  
 Dr Dandan Li  
 Professor Shi-Jun Wang

**Excavation and specimen-based research team:**  
**Nanjing Institute of Geology, Palaeontology and Stratigraphy (Chinese Academy of Sciences)**  
 Many, many individuals (who are gratefully thanked!)

**University of Pennsylvania**  
 Professor Hermann Pfefferkorn


**Czech palaeobotany and palynology “consortium”**  
 Jiří Bek, Stanislav Opluštil, Josef Pšenička, Milan Libertin, Jana Frojdová

**Significant collaborations and conceptual contributions:**  
 Mario Coiro & Leyla Seyfullah, (University of Vienna)  
 Lu Jing, Shao Longyi, Ye Wang, Peixin Zhang, Kai Zhou (China University of Mining and Technology)

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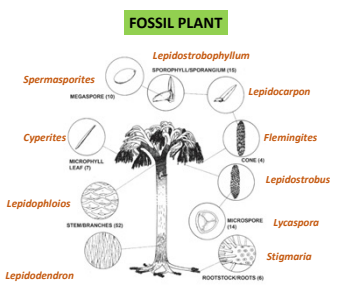
**Disarticulation and fragmentation is the norm!**

Ontogeny      Preservational bias      Palaeobotanical sampling  
 Animal activity      Reproductive dispersal  
 Taphonomic and sedimentary processes      Death and decay



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**Reconstructing fossil plants as once-living organisms**




- Fossil plants typically fragmentary in the fossil record
- Typical vascular land-plant consists of **10–12 definable organs**
- For necessity, each part has its own name, and reconstructed plants have their own name
- Finding one part does not necessarily mean the fossil plant species had all the same parts
- Reconstructing fossil plants laborious process

Bateman & Hilton (2009, *Taxon* 58: 1254–1280)

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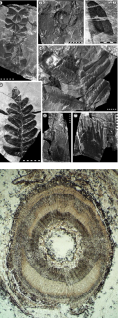
**“Text book” view of Carboniferous Coal Swamp communities**



National Museums of Scotland

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**Early Permian floras of North China – previous information**



**Compression floras**


- Abundant, fragmentary, often transported
- Limited palaeoecology and evolutionary utility
- Challenging to reconstruct source floras and forests

**Coal ball floras**

- Limited occurrences but preserve cellular detail
- Preserves in-situ peat
- Mostly fragmentary, lots of decay
- Limited palaeoecology utility

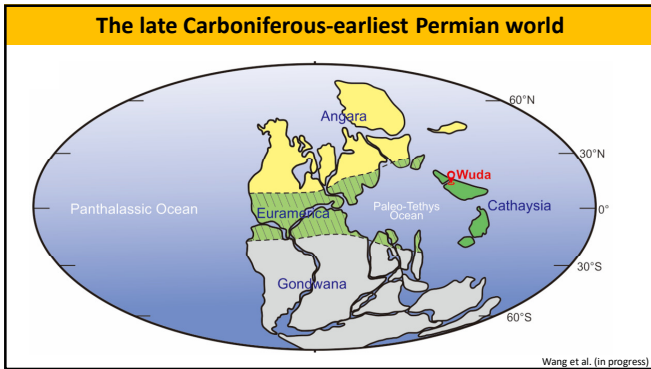
**Volcanic tuffs**

- Extremely rare
- Exquisite morphological and anatomical preservation
- Fragmentary, transported
- Limited ecological utility
- Can't reconstruct source floras

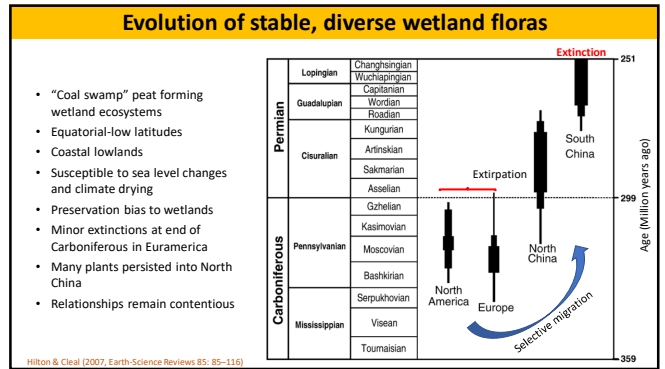


Hilton et al. (2001, *Rev. Pal. Palaeobot.* 114: 175–189)

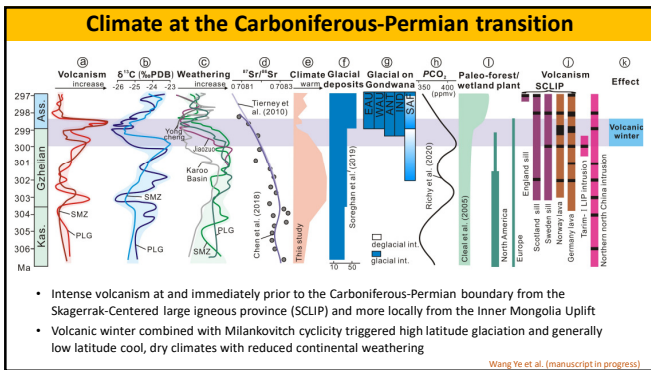
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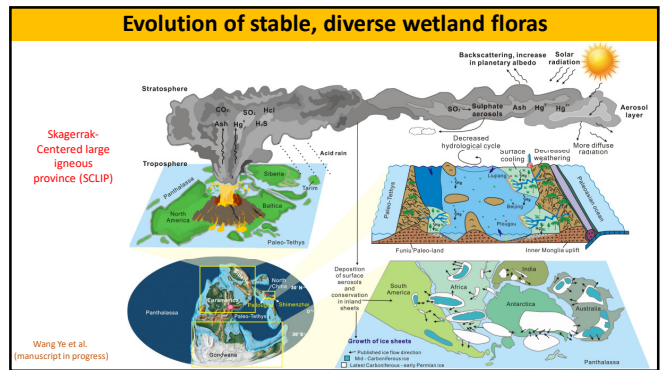
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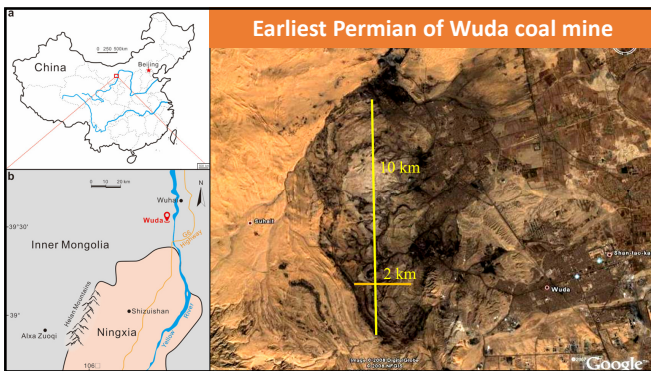
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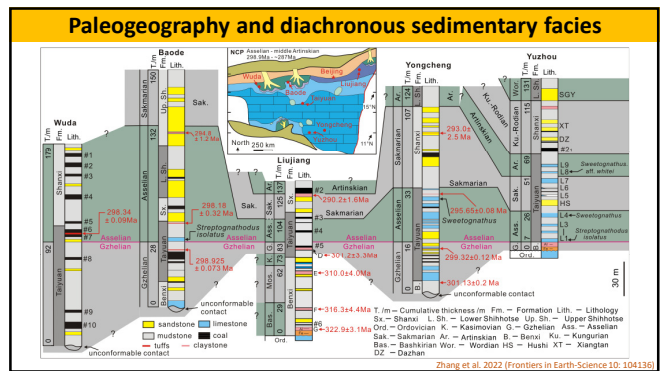
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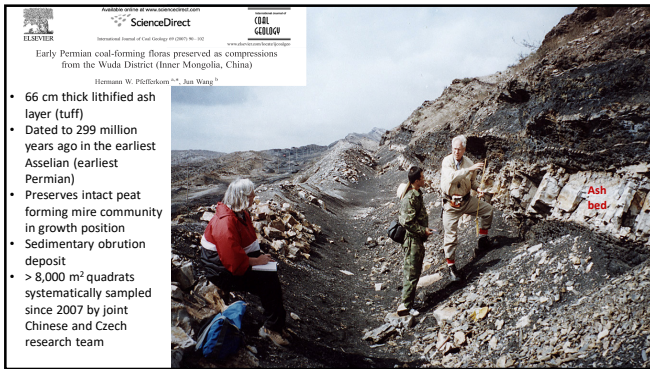
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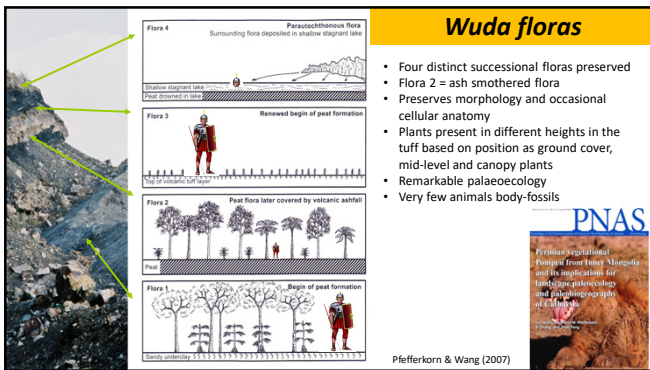
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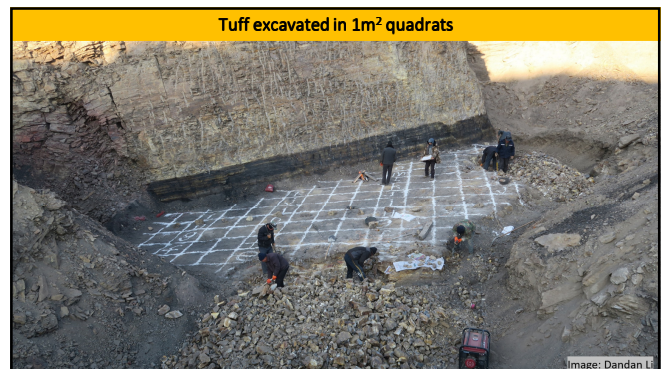
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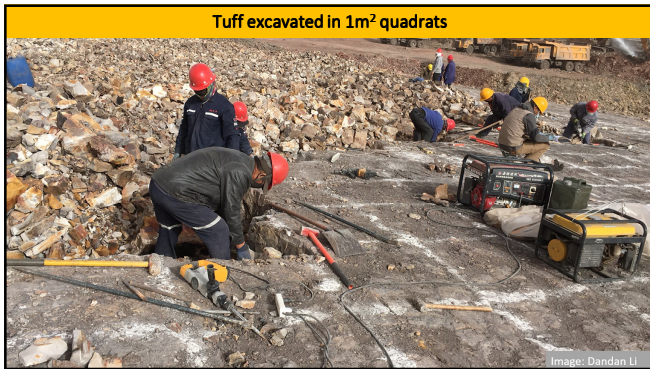
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### Wuda Noeggerathiales

- Noeggerathiales affinity elusive since first recognized in early 1900's in Europe
- In Wuda, two species of *Paratingia* one species of *Tingia*
- Multiple entire plants preserved as well as shed organs in leaf-litter
- Entire plants preserved after falling over from ash inundation alongside upright broken trunks
- Trees typically 4-6 m tall with long, naked trunks
- Apical portions of trees with vegetative and fertile zones
- Reconstruction with morphology and anatomy allows the affinity of this previously enigmatic group of plants to be determined for the first time

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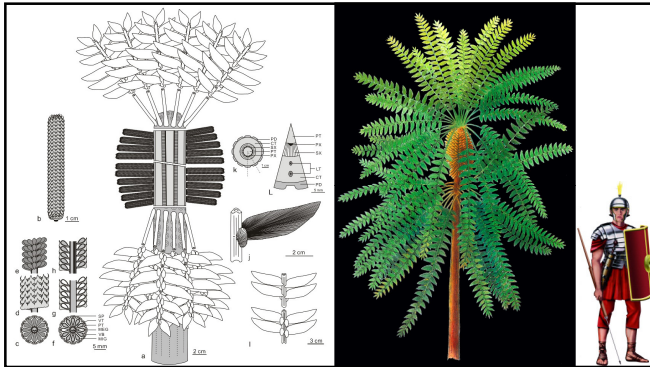


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### "Strobilus"

- Bilateral organisation with  $\Omega$  shaped vascular bundle
- Homologous to leaf rachis – both have  $\Omega$  shaped vascular bundles and born in same relative position on stem
- Sporangium bearing structures are modified pinnules, bearing multiple sporangia

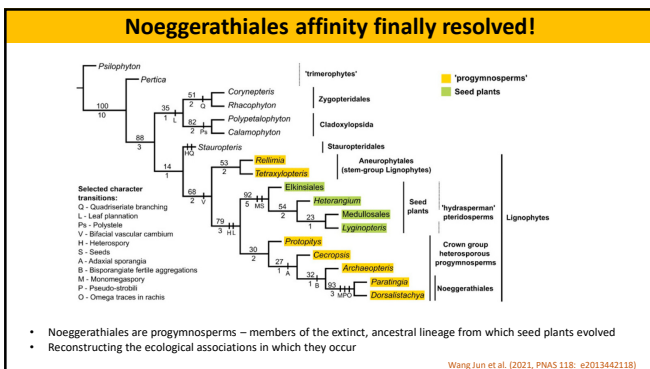
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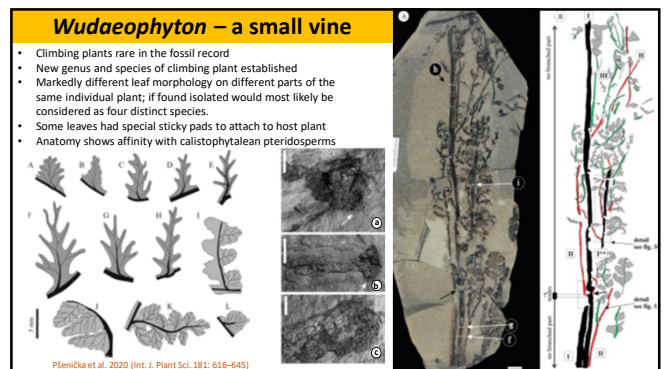
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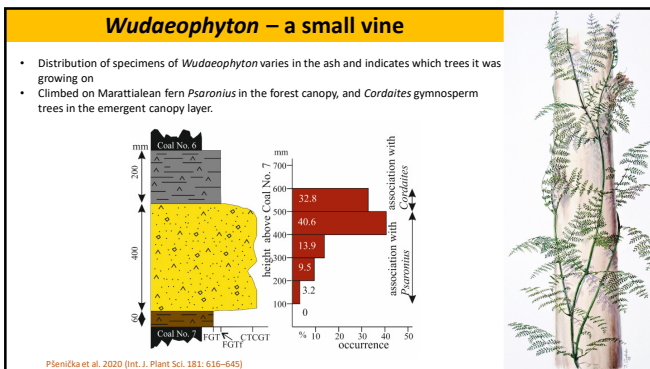
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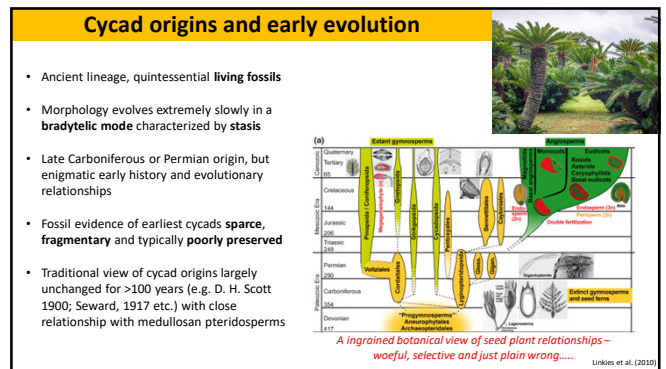
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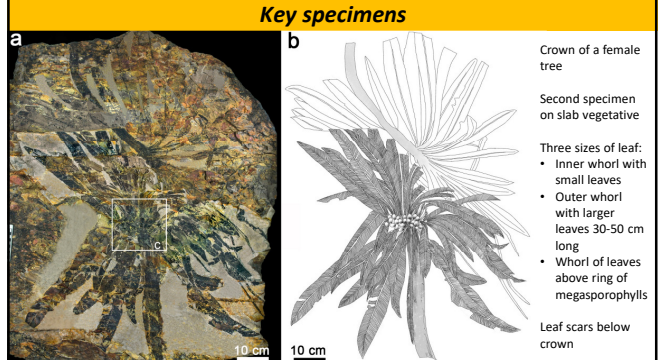
### New family, genus and species of cycad



- Long (2.5-5.5m), slender trunk
- Crown of up to 36 helically inserted leaves
- Leaf scars on stem below crown
- Entire leaves of *Taeneopteris* Brongniart
- Leaves with thick, tapering midrib and straight lateral veins that bifurcate once near midrib, sometimes again near margin
- Overall architecture similar to some living species of *Cycas* (e.g. *C. media* R. Br.)

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### Key specimens



**a** **b**

Crown of a female tree

Second specimen on slab vegetative


Three sizes of leaf:

- Inner whorl with small leaves
- Outer whorl with larger leaves 30-50 cm long
- Whorl of leaves above ring of megasporophylls

Leaf scars below crown

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### Fertile leaves (sporophylls) and ovules

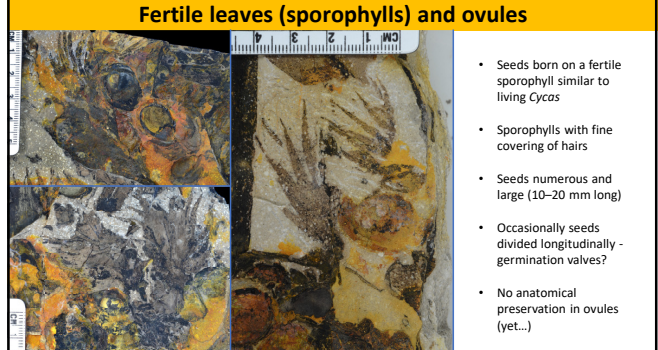


**Holotype - female tree**

- Megasporophylls on stem and not cone forming
- Long, narrow, axis-like vegetative structures on stem with megasporophylls interpreted as cataphylls.
- Individual megasporophylls difficult as obscure each other

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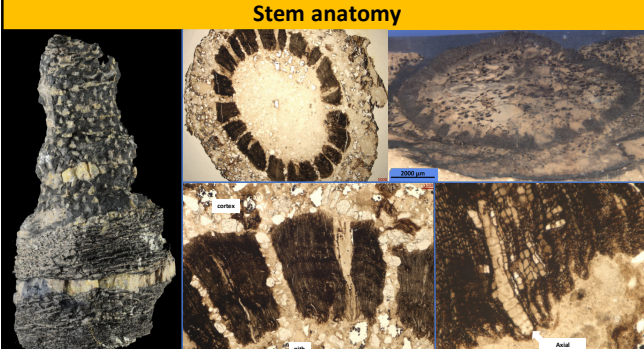
### Fertile leaves (sporophylls) and ovules



- Seeds born on a fertile sporophyll similar to living *Cycas*
- Sporophylls with fine covering of hairs
- Seeds numerous and large (10-20 mm long)
- Occasionally seeds divided longitudinally - germination valves?
- No anatomical preservation in ovules (yet...)

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### Stem anatomy



3000 µm

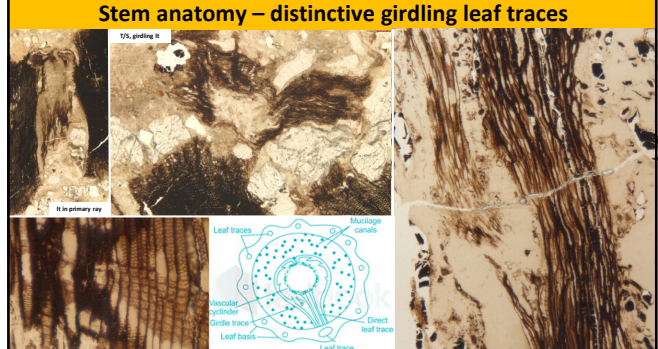
cortex

pith

axial parenchyma

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### Stem anatomy – distinctive girdling leaf traces



1/5, girdling R

It is primary ray

1/5, axial parenchyma

1/5, girdling R

Leaf traces

Mastige canals

Leaf bases

Dried leaf trace

Leaf trace

1/5, axial parenchyma

1/5, girdling R

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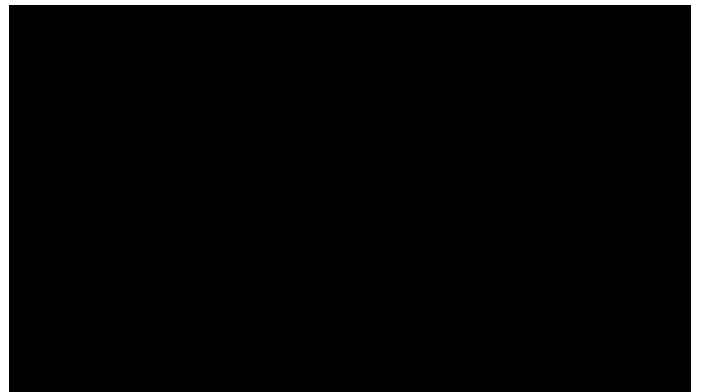
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**Examples of other reconstructed species**

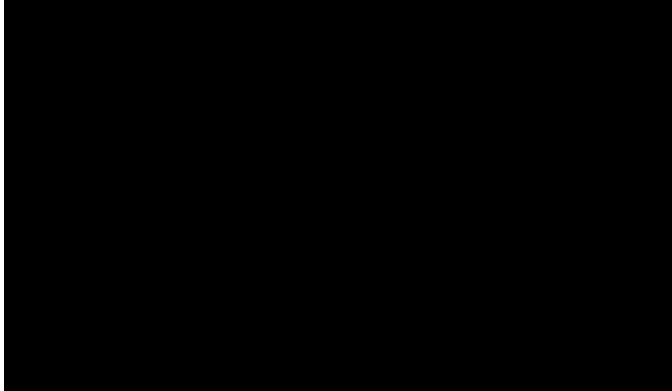
- New whole plant species of marattialean and zygopterid ferns
- *Scolecapteris libera* (Psaroniaceae) about 2m tall

Images: Dandan Li

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### Conclusions

- Wuda flora presents an unrivalled view into an early Permian terrestrial ecosystem which is revolutionizing our understanding of:
  - floral composition in the early Permian Cathaysian flora
  - morphological and anatomical evolution of major plant groups
  - palaeoecology and spatial distribution of early Permian floras
  - relationships of the equatorial Euramerican and Cathaysian floras
- Carboniferous-Permian boundary was a time of immense change with volcanic driven climate change and astronomical cycles combining to trigger a shift into glacial conditions
  - advance of high latitude glaciations in Gondwana
  - global sea level drop (regression) and aerial exposure of former continental shelf environments
  - Cooler and drier equatorial climates

Volcanic cooling usually short lived – so why did it last so long at the C-P boundary?

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### Ongoing studies....

- Continued work excavating new parts of the forest
- Continued study documenting and reconstructing new species
- Individual species interpreted for ecological adaptations
- Investigating population and community structures from quadrat data
- Investigating macroecological relationships
- Reconstructing how species interact with each other and their environment
- Analysing biogeographic patterns and processes
- Evaluating long-term floral response to climate change

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### Rescue Palaeontology, and environmental dilemmas

#### Site context:

- Fossils exposed in a working open cast coal mine
- Mining progressively exposes the fossiliferous horizon throughout the basin
- Company has rights to extract all the coal, with massive national demand
- Coal mining supports local community
- **But extraction and use of fossil fuels causes massive global environmental issues (greenhouse gas emission, acid rain, pollution of water courses, particulate air pollution etc.)**

#### Excavation and study:

- Local government support – purpose-built museum in progress as national amenity
- Coal company support for excavations
- Academic community involvement
  - unique fossil assemblage – best preserved and most intact late Paleozoic forest
  - highest quality fossils available for research – In Paleozoic importance second to Rhyndie chert
  - **if left unstudied, fossils destroyed to expose and extract coal below**

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