

Research Questions

How many different leaf types are present in the Early Cretaceous Tevshii Govi fossil flora, what are the distinguishing characteristics of these leaves and leaves from Tugrug, and how are they related to known gymnosperms and ferns?

Background

Mongolia has numerous coal deposits from the Carboniferous, Permian, Jurassic, and Cretaceous Periods. The Early Cretaceous of Mongolia was selected for study because it should provide evidence for some of the earliest angiosperms as part of an extensive diversification of flowering plants. Many Early Cretaceous deposits are found in eastern Mongolia. These deposits are lignite coal rather than the older bituminous or anthracitic coals found farther west¹. Coal mines in these lignite deposits provide a means of collecting bulk mesofossil samples for study (Fig. 2).

Bulk samples were collected from Tevshii Govi and Tugrug by Pat Herendeen and collaborators (Fig. 1). However, the samples are primarily characterized by gymnosperms, ferns and other groups. The gymnosperm samples include many unidentified specimens that need to be studied in order to understand and reconstruct this Cretaceous flora. Among these are abundant leaves with well-preserved epidermal anatomy.

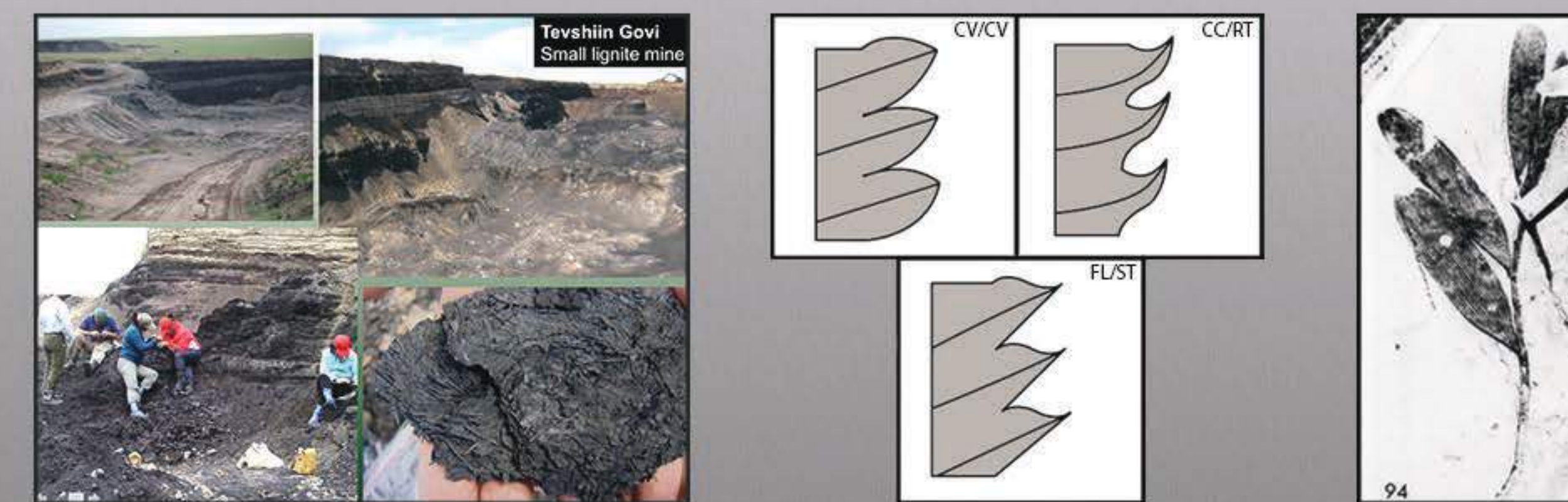
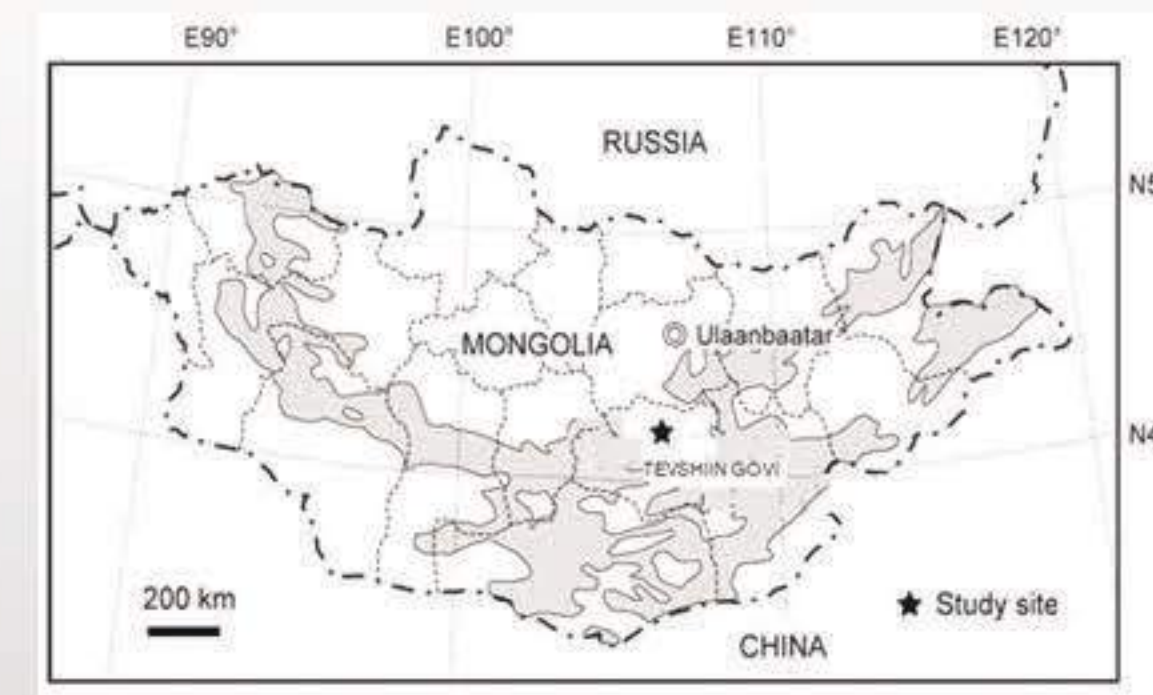


Fig. 1: Map of Mongolia showing collection site of Tevshii Govi (From Ichinnorov *et al.*).



Methods

- Bulk samples from Tevshii Govi and Tugrug of lignified plant material were disaggregated in water and cleaned with HCl and HF. The samples were picked through to isolate well-preserved specimens.
- Leaf specimens were separated into morphotypes: groups with a unique set of morphological and epidermal characters.
- Leaves were photographed and prepared for light (bleaching, staining, and mounting) or scanning electron microscopy (mounting on pin stubs and coating with gold). Micrographs were taken of each morphotype.
- Images were analyzed to describe each morphotype's distinguishing features.
- Morphotypes were compared with known gymnosperm groups⁴ and a leaf morphology manual⁵.

Fig. 2 (left): Lignite mine at Tevshii Govi. **Fig. 3** (center): Tooth shapes found in Morphotype 7: CV/CV (convex/convex), CC/RT (concave/retroflexed), FL/ST (flexuous/straight) (From Ellis *et al.*). **Fig. 4** (right): *Podozamites* sp. (From Krassilov 1982).

Results (cont.)

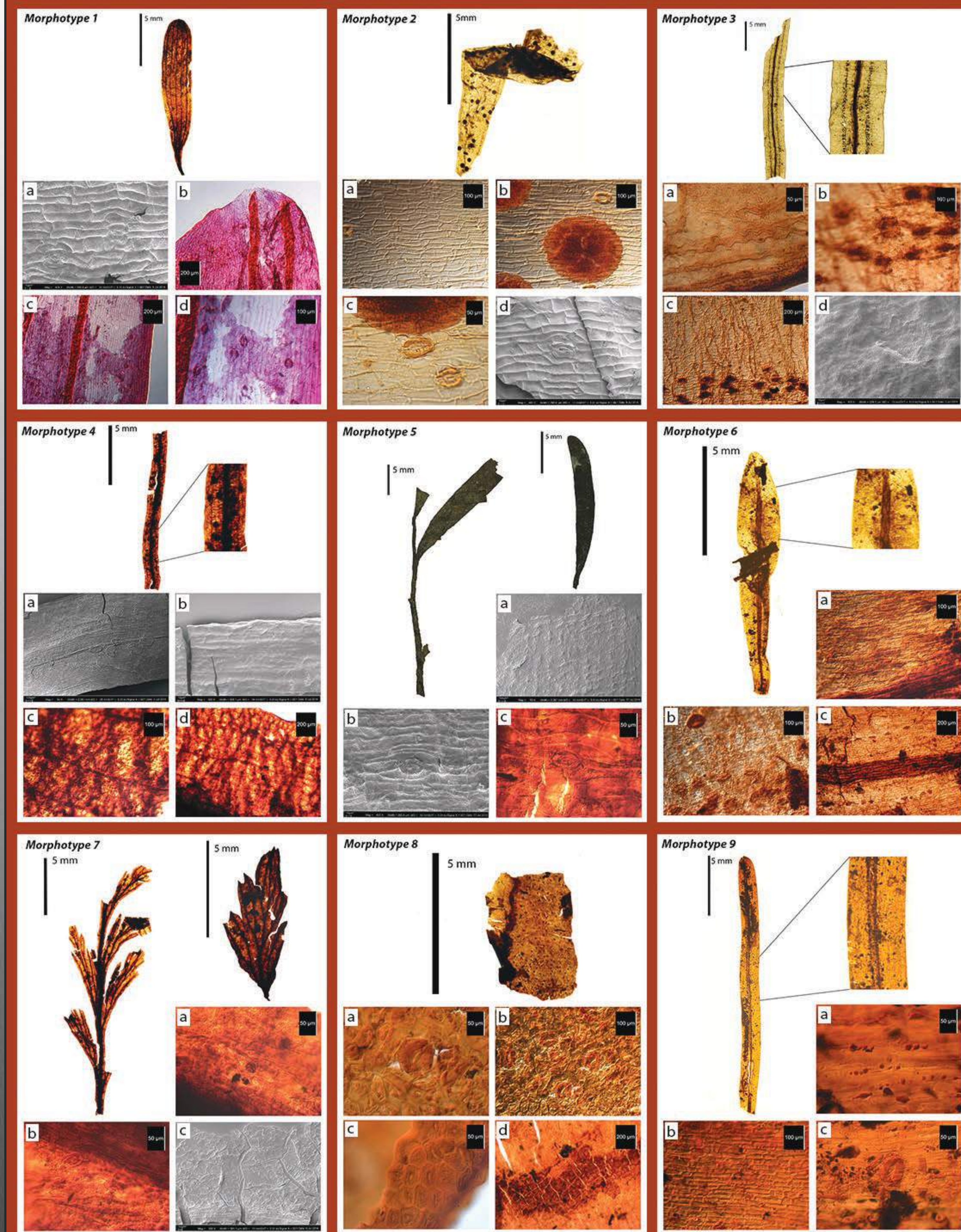


Fig. 5: Images of each morphotype and epidermal anatomy. **Morphotype 1**, *Tevshii Govi*, a) epidermal cell walls and stomata (400x), b) epidermal cell walls and resin canals, c) stomatal orientation, d) stomatal detail. **Morphotype 2**, *Tevshii Govi*, a) epidermal cell walls, b) large black spot, c) stomatal detail, d) stomatal detail (400x). **Morphotype 3**, *Tevshii Govi*, a) epidermal cell outlines, b) detail of line of stomata, c) stomata and secondary vein framework, d) trichome bases (500x). **Morphotype 4**, *Tevshii Govi*, a) black spot outlines (50x), b) epidermal cell outlines (500x), c/d) exmedially ramified tertiary vein fabric. **Morphotype 5**, *Tevshii Govi*, a) equidistant rows of stomata (50x), b) epidermal cell outlines and stomatal detail (400x), c) stomatal detail. **Morphotype 6**, *Tevshii Govi*, a) epidermal cell walls, b) line of single stomata, c) midvein and stomata lines. **Morphotype 7**, *Tevshii Govi*, a) stomatal detail, b) midvein and stomata?, c) epidermal cell outlines (300x). **Morphotype 8**, *Tugrug*, a) stomatal detail, b) stomatal orientation, c) epidermal cell walls, d) vein. **Morphotype 9**, *Tugrug*, a/b) epidermal cell walls, c) stomatal detail.

Results

Table 1: Characters of each morphotype. Unless noted, all morphotypes are untoothed, unlobed, attached marginally, and medially and basally symmetrical with anomocytic stomata.

Morphotype	Laminar Size	Laminar LW ratio	Laminar Shape	Apex Angle	Apex Shape	Base Angle	Base Shape	Primary Vein Network	Number of Primary Veins	Major 2 nd Vein Framework	Perimarginal Veins	Epidermal Cell Shape	Stomata parallel to long axis of leaf?	Other	Teeth	Affinity
Morphotype 1	Nanophyll	3:1	Obovate	Obtuse	Rounded	Acute	Straight	Parallelodromous	4-8			Elongated and rectangular	Yes, some acutely angled away from axis	Resin canals		
Morphotype 2	Microphyll		Obovate	Obtuse	Rounded	Acute		Likely parallelodromous	0		Intramarginal secondary veins	Elongated and rectangular	Yes	Irregular, large, black spots		
Morphotype 3	Nano-Microphyll	6:1	Ovate/Oblong	Acute		Obtuse	Rounded	Pinnate	1	Craspedo/Cladodromous	Fimbrial vein	Undulating outlines	Yes, in one row on each side of midvein	Trichome bases throughout lamina		Pentoxylales?
Morphotype 4	Nano-Microphyll	~20:1	Oblanceolate	Acute	Straight/Acuminate	Acute	Decurrent	Pinnate	1	Parallelodromous	Fimbrial Vein	Rectangular	Yes	Irregular, large, black spots; exmedially ramified tertiary vein fabric		Voltziales, Cupressaceae?, Pinaceae?
Morphotype 5	Microphyll	10:1	Oblong	Acute to Obtuse	Rounded	Convex	Straight	Parallelodromous (veins recurved at tip of apex)	13-20			Rectangular	Yes, in equidistant rows	Leaf attachment petiolate; arrangement alternate; asymmetrical basal width		<i>Podozamites</i> sp.
Morphotype 6	Nanophyll	10:1	Obovate	Acute	Convex	Acute	Straight	Pinnate	1	Craspedo/Cladodromous		Narrow and rectangular	Yes, in one row of single stomata on each side of midvein	Stomata small		Pentoxylales?
Morphotype 7	Nano-Microphyll	3:1	Oblong					Pinnate	1	Craspedo/Cladodromous		Undulating outlines?	Teeth apes darkened; pinnatisect lobation; serrate margins; stomata type unknown	Irregular spacing of three orders of teeth; rounded sinuses; tooth shapes CV/CV, CC/RT, FL/ST (Fig. 3); principal vein present, terminates at apex of tooth		Fern
Morphotype 8								Possibly pinnate				Polygonal, isodiametric	No, various orientations	From Tugrug; stomata are darkened		
Morphotype 9	Microphyll	20:1	Linear	Obtuse	Convex			Pinnate	1	Parallelodromous		Rectangular	No	From Tugrug		

Discussion/Conclusions

Seven distinct morphotypes were found from Tevshii Govi as well as two from Tugrug (Fig. 5). The seven Tevshii Govi morphotypes represent the entirety of the leaf diversity present in the samples thus far picked through from this site. The Tugrug morphotypes represent only a fraction of the leaf types present in the samples from this locality. The morphotypes were defined by a number of traits, some of which were not visible for each leaf type (Table 1). Venation and stomata arrangement were the primary differentiating features of the morphotypes.

- Morphotypes 1, 2, 8, and 9 have too few features to identify.
- Morphotypes 3 and 6 have distinctive bands of stomata on either side of the midvein, as well as perpendicularly oriented secondary veins leading away from the midvein, as are found in the Pentoxylales.
- Morphotype 4 appears similar to the Voltziales with its needle-like leaves, but could also be a member of the Cupressaceae or Pinaceae families.
- Morphotype 5, with its broad oblong shape, rounded apex, and many veins, is likely a member of the *Podozamites* spp. as described in Krassilov (1982) (Fig. 4).
- Morphotype 7 has fern-like venation but is only found in small fragments and is thus difficult to identify.

In order to fully understand the flora of these Cretaceous localities, more individuals of these morphotypes need to be found and studied to provide missing information. The remaining leaf types from various localities including Tugrug need to be described and compared to known families. Additionally, epidermal anatomy from the morphotypes can be compared with that of other plant fossil fragments in order to provide whole plant reconstructions.

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