IMPLICATIONS OF A NEW WATER FERN FROM THE CRETACEOUS DAKOTA FORMATION OF WOODBURY COUNTY, IOWA, U.S.A.

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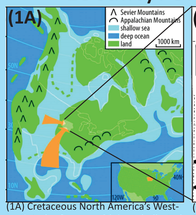
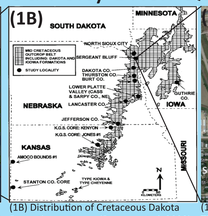
Abstract

A new fern megaspore recovered from exposures of the mid-Cretaceous Dakota Formation in northwest Iowa indicates a greater abundance and richness of ferns than previously documented. Bulk samples of a dark brown-gray, poorly consolidated clay were collected from the Sioux City Brick Quarry in Woodbury County, Iowa (N 42 24.517, W 096 21.267). Litho- and palynostratigraphy indicate that this unit falls within the Woodbury Member of the Dakota Formation, dated as late Albian - early Cenomanian (±99.6 Ma). The sediments were deposited in a large, fluvial-deltaic system along the eastern margin of the Western Interior Seaway of North America. Charcoalified debris was extracted using standard paleobotanical processing techniques and a 63 µm sieve. Exploratory study of the resulting residue under reflected light microscopy has produced >50 specimens of the new fern megaspore. The new megaspore consists of a main spore body (mean equatorial diameter = 253.04 µm, sd = 27.14, n = 23) whose smooth surface is decorated by tube like appendages (mean length = 75.61 µm, sd = 20.88; mean number of appendages = 15.22, sd = 3.42, n = 23). The spore body is crowned with an acrolamellae (a ridged, tapered, flamelike structure) with a mean height of 272.17 µm (sd = 37.52, n = 23). The new megaspore's morphology suggests a close affinity to the extinct genus *Arcellites*, a member of the heterosporous water fern family, Marsileaceae. The genus *Arcellites* currently consists of sixteen species, in which the two species most similar to Sioux City Brick specimens (*A. disciformis and A. hexapartitus*) are differentiated primarily by characteristics of the megaspore. To determine if the new megaspore is taxonomically distinct, we will thin section some specimens and use transmitted light and scanning electron microscopy to describe thickness and microstructure of the exoexine, exine, and intexine. When taken in context of a recent paleoecological assessment of the Woodbury Member's palyno-flora, the addition of an abundant Marsileaceaous megaspore tentatively identified as Arcellites supports the interpretation that ferns continued to repre-sent an important component of mid-Cretaceous plant communities even as angiosperms diversified.

Locality: Sioux City Brick Quarry, Woodbury County, Iowa



(1A) Cretaceous North America's West-ern Interior Seaway with Iowa indicated (modified from White et al., 2001)



(1B) Distribution of Cretaceous Dakota Formation outcrops (Brenner et al. 2000). Study site indicated at Sergeant Bluff,

(1C) Sample site in new pit at Sioux City Brick & Tile Quarry near Sergeant Bluff (Imagary c 2014 DigitalGlobe, USDA, Map data c 2014 Google).

-Sample material collected at Sioux City Brick (SCB) Quarry in Woodbury County, Iowa (N 42°24.517, W 096°21.267);
- SCB Quarry preserves fluvial-deltaic sediments deposited on eastern margin of Cretaceous Western Interior Seaway;
- Ludvigson et al. (2010) assigned SCB exposures to Woodbury Member of Dakota Formation (Cretaceous) with palynology-based biostratigraphy.

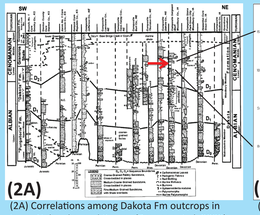
Stratigraphy and Sedimentology

-Woodbury Member (Dakota Fm) considered to be latest Albian (possibly earliest Cenomanian) (Ludvigson et al. 2010);

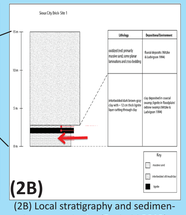
-Claystone bulk collected from base of quarry road exposure in June 2012 (Drehobl 2012);

-Light grey semi-consolidated clay lens bracketed by 10-20cm thick lignite layers above and below;

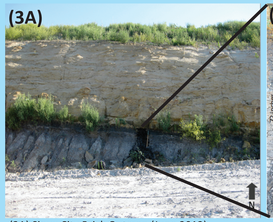
-Depositional environment interpreted as meander cutoff or oxbow swamp on coastal floodplain with generally stagnant water except during storm events (Witzke & Ludvigson 1994).



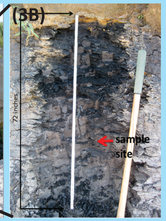
(2A) Correlations among Dakota Fm outcrops in Iowa, Nebraska, and Kansas (Brenner et al. 2000).



(2B) Local stratigraphy and sedimen-tology at study site (Drehobl 2012).



(3A) Sioux City Brick Outcrop (June 2012).



(3B) Sioux City Brick Sample Site

Field and Laboratory Methods

-Bulk samples collected from fresh, unweathered outcrop;
-Claystone air-dried in lab and then disaggregated using stan-dard paleobotanical methods (Jones & Rowe 1999);
-Sample material soaked in series of water, hydrogen peroxide, and 10% HCl until minerals disaggregated;
-Disaggregated sample was washed gently with water through a fine sieve (250 µm) to cull fusainized plant fragments;
-Material retained in sieve was air-dried, stored with dessicant, and sorted under a Leica M205C stereo dissecting microscope;
-All informative specimens accessioned to the University of Iowa Paleontology Repository.

Megaspore from Sioux City Brick Quarry, Iowa

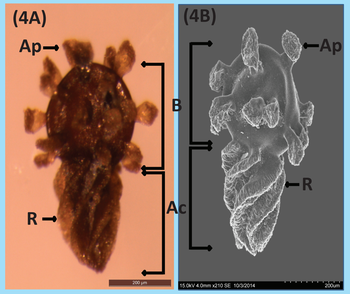


Fig. 4. *Arcellites* megaspore with prominent acro-mella (Ac) at proximal end. Megaspore body (B) spherical, trilete, with smooth surface. The spore body is comprised of three layers (outer, middle, and inner) detailed in Fig. 5B. Appendages (Ap) distributed across megaspore surface. Appendage surface pitted at tips but smooth toward base. Acromella consists of six separate leaves (R) joined together and dextrally twisted with possible at-tachment of microspores between fused leaf ridges. Trilete mark positioned within spore body at point where acrolamella joins the spore body.

(5A) Magnification of appendage tip (Ap in Fig. 4). Appendage surface pitted at tips but smooth toward base.
(5B) Section through broken megaspore exposing three layers: outer wall (O), middle wall (M), and inner wall (I). Mean width of spore wall = 8 µm.
(5C) Acrolamella (arrow B in Fig. 4) con-sists of six leafy appendages fused to-gether to form a dextrally-twisted, spiral structure.
(5D) Magnification of acrolamella ridge (R in Fig. 4).
(5E) Magnification of smooth megaspore surface of SCB specimen.
(5F) Pitted megaspore surface of *A. disci-formis* (from Batten et al. 1996).

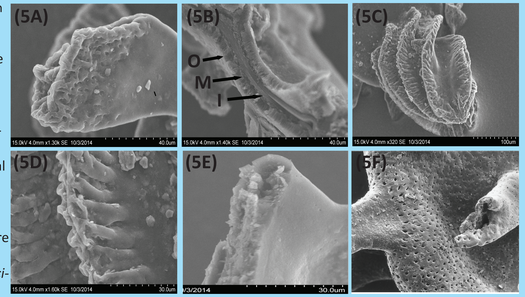
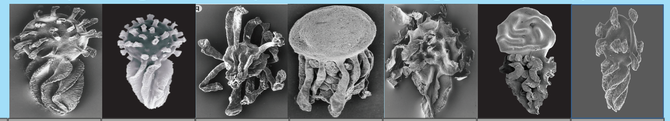


Table 1. Morphological Comparisons among *Arcellites* species



	Arcellites disciformis (Batten et al., 1996)	*Arcellites hexapartitus* (Batten et al., 1996)	*Arcellites medusus* (Batten et al., 1996)	*Arcellites santacrucensis* (Batten et al., 1996)	*Arcellites vectis* (Batten et al., 1996)	*Arcellites punctatus* (Friis et al., 2014)	*Arcellites unkown*
Wall Width (µm)	6.5	8.5-12	8-18	7.8-12	16-17.5	16-26	8
Outerwall layer	Granular	Granular	Granular	Granular	Granular	Punctate-perforate	Needs further SEM work
Middle wall layer	Finely granular	Granular	Granular	Granular	Granular-spongy	Granular-fibrous	
Inner wall Layer	Perforated	Perforated	Granular	Perforated	Perforated	Solid	
Surface Sculpture	Pitted and Smooth	Perforated	Rugulate	Pitted and Smooth	Scabrate-rugulate	Smooth, finely perforated, and rugose	Smooth
Acrolamella	Dextrally Twisted	Twisted	Straight	Dextrally twisted	Straight	Twisted, each section is infolded, horseshoe shaped	Dextrally Twisted
Appendages	Numerous and short	Numerous and short	Numerous and long	10-12, long	Numerous and long	Lacking appendages	Numerous and short
Ages	Barremian-Cenomanian	Late Barremian	Late Valanginian	Late Aptain-early Albian	Barremian	Late Barremian-Early Aptian	Middle Cenomanian

Preliminary identification: The new megaspore from the Sioux City Brick Quarry is known from ≥60 specimens. It shares more morphological characteristics with *Arcellites disciformis* Miner emend. Ellis et Tschudy than with any other species of *Arcellites*. However, the SCB megaspore appears to be significantly larger than the range reported for *A. disciformis* by Batten et al. (1996) and has a smooth megaspore body surface (vs. pitted of *A. disciformis*). Future work using SEM and TEM will focus on these issues and describing structure of spore wall layers.

Systematic Paleobotany

Plantae
Pteridophyta
Polypodiopsida
Salviniales
Marsileaceae
Arcellites sp.

Ellis and Tschudy (1964) attributed the extinct genus, *Arcellites,* to the Marsileaceae, a clade of heterosperous ferns (3 extant genera, 50-80 spe-cies) that are dominated by aquatic and semi-aquatic forms (commonly known as pepperwort or water-clover). Two extinct Cretaceous genera (*Molaspora*, *Arcellites*) have been atributed to Marsileaceae.

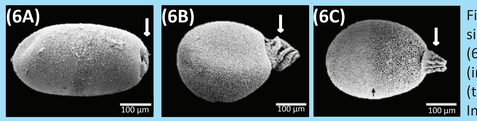


Fig. 6. Megaspores from three extant genera of Mar-sileaceae: *Marsilea vestita* (6A), *Regnellidium dyphyllum* (6B), and *Pilularia americana* (6C). Acrolamella (indicated with arrow) is moderately to highly reduced (to form a hilium in *M. Vestita*) relative to *Arcellites*. Images from Lupia et al. (2000).

Conclusions

-Ecology and habitat preferences (aquatic to semi-aquatic, Fig. 8) of *Arcellites'* closest living relatives consistent with sedimentological interpretation of SCB site and Dakota Fm as oxbow swamp on coastal floodplain;

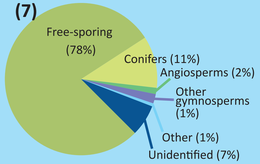
-Drehobl (2012)'s analysis indicated SCB palynoflora (Fig. 7) was dominated by free-sporing plants including ferns (75% of 300 grain count) but did not identify *Arcellites*;

-The unknown SCB *Arcellites* megaspore was probably not recovered by Drehobl (2012) due to its large size, emphasizing impact that sieve size has on reconstructions of paleocommunity composition and diversity;

-Ravn and Witzke (1995) identified *Arcellites disciformis* megaspores from their "upper Sergeant Bluff" outcrop sample (~500m away and stratigraphically lower relative to the current study) preserved with affiliated microspores of *Crybelosporites bursatus*;

-Future work (including analyses of Drehobl [2012] residues and additional SEM and TEM work) should allow us to determine if the new SCB *Arcellites* megaspores represent a new species, indicating that the SCB paleocommunity contains an even greater diversity of ferns than previously thought.

(7)



(8)

Acknowledgements

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References

Batten, D. et al. 1996. Cretaceous Research 17:39-65.
Brenner et al. 2000. Journal of Sedimentary Research 70:868-878.
Drehobl, M. 2012. PhD thesis in Geoscience, The University of Iowa.
Ellis and R. Tschudy. 1964. Micropaleontology 10:73-79.
Friis, E. et al. 2014. Grana 53:91-102.
Larson, G. 1992. Western wetland flora. USDA NRCS Wetland Sci. Inst.
International Commission on Stratigraphy. 2014. International Stratigraphic Chart.
Kovach and D. Dilcher. 1998. Palynology 12:89-119.
Ludvigson, G. et al. 2010. Current Research in Earth Science Bulletin 258, part 2.
Lupia, R. et al. 2000. International Journal of Plant Sciences 161:975-988.
White, T. et al. 2005. Geology 33:13-19.
Witzke, B. and G. Ludvigson. 1994. Geological Society of America Special Paper 287.