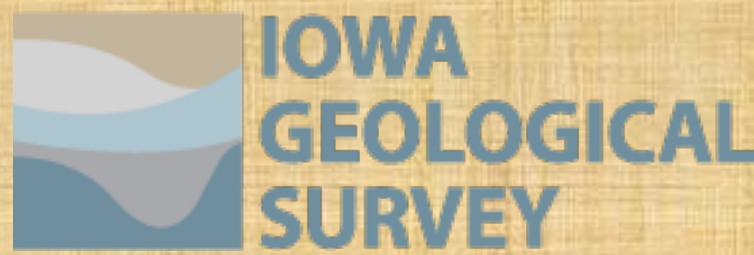


The Winneshiek Shale and the Decorah impact structure: Windows into the Sauk – Tippecanoe Megasequence Boundary



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1. Introduction

The Middle Ordovician (Darriwilian) Winneshiek Shale is a 17 to 27 m thick greenish brown to dark gray laminated sandy shale that occurs near the city of Decorah, northeast Iowa (Fig. 1). It is only known to be preserved within the mostly subsurface Decorah impact structure, a meteorite crater of approximately 5.6 km diameter (Fig. 2). The Winneshiek Shale hosts the Winneshiek Lagerstätte which is characterized by many well-preserved fossils including some soft body and tissues (Fig. 3).

The fossil component indicates that the Winneshiek fauna lived in a special marine environment, and was dominated by non-shelly taxa, especially conodonts, arthropods, and algae. Investigations of the Winneshiek fauna and the Decorah impact structure have not only opened a new window of the mid-Ordovician life, but the crater-fill sequence also revealed the potential to reconstruct a portion of the missing geologic record represented by the Sauk – Tippecanoe megasequence boundary in the inboard region of the cratonic interior, northern Midwest U.S.A.

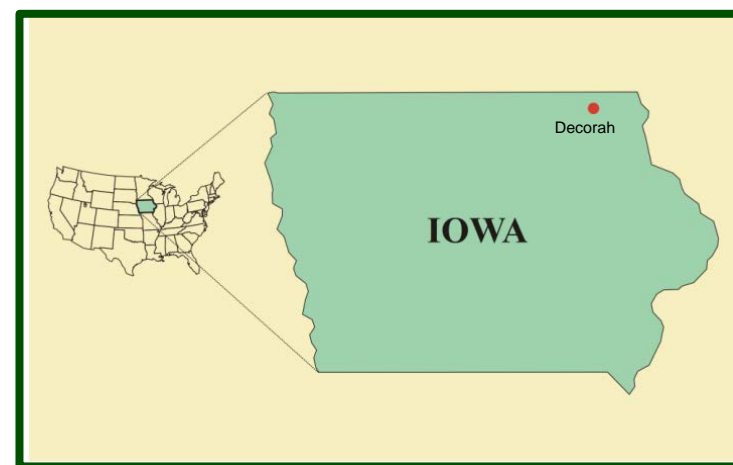


Fig. 1: Location of the Winneshiek Lagerstätte in northeastern Iowa, USA.

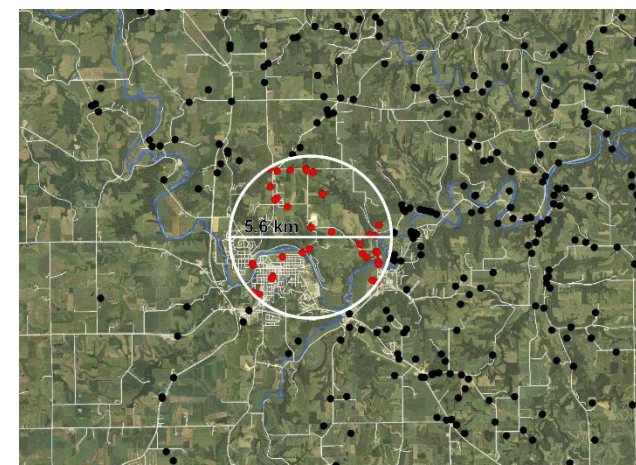


Fig. 2: Outline of the Decorah impact structure which was first inferred by the deposits in wells.



Fig. 3: The reconstructed oldest eurypterid and some selected fossils from the Middle Ordovician Winneshiek Lagerstätte.

2. The Sauk – Tippecanoe megasequence boundary and the Decorah crater-fill succession

The Sauk – Tippecanoe megasequence boundary is a major stratigraphic gap or hiatus of approximately 20 m.y. (~460 – 480 Ma) of record in the Midwest USA including Iowa, Minnesota, and Wisconsin (Sloss, 1963; Taylor et al., 2012). In Iowa, this hiatus represents the unconformity between the St. Peter Sandstone (late Darriwilian and Sandbian) and the Shakopee Formation (late Tremadocian) (Fig. 4A). Results from recent studies suggest that the Decorah impact structure was formed in the Early to Middle Ordovician (460 – 483 Ma) and it had an original diameter of about 6 km and a depth about 200 m (Fig. 4B; French et al., 2018). Because the Decorah crater-fill succession including the Winneshiek Shale was deposited within the age of the regional stratigraphic hiatus, these strata offer a unique opportunity to explore heretofore unknown geologic records which are regionally absent across the Sauk – Tippecanoe megasequence boundary.

Global Stages (2017/02)	Laurentia Series	Megasequence (Taylor et al., 2012)	Typical Stratigraphy	Decorah Crater-fill Succession
Ma				
453				
458	Sandbian	Mohawkian (part)	St. Peter Sandstone	St. Peter Sandstone
467	Darriwilian	Whiterockian		Winneshiek Shale
470	Dapingian			unnamed breccia
478	Floian			lower shale
485	Tremadocian	Ibexian		breccia ?
490	Stage 10			any other deposits and/or post-Shakopee Fm breccia clasts?
494	Jiangshanian	Millardian	Shakopee & Oneota fms	
497	Paibian		Jordan Sandstone	
500	Guzhangian		St. Lawrence Fm.	
505	Drumian	Lincolnian	Lone Rock Fm.	
			Wonewoc Fm.	
			Eau Claire Fm.	
			Mt. Simon Fm.	
			Precambrian	

Fig. 4: Stratigraphic successions of the region and the Decorah impact structure. (A) Typical stratigraphic successions of the region where the Sauk – Tippecanoe megasequence boundary omits the geologic record between the Shakopee through the St. Peter Sandstone formations, but where the Decorah crater-fill deposits represent at least a portion of the missing stratigraphic and biologic history (Note: the crater-fill units may not match the ages shown in the table). (B) Comparison of gamma survey logs showing the stratigraphic difference between region's regular sequence (left) and the succession preserved within the Decorah structure as documented examination of water well drill cuttings from IGS well 53572 located off-center of the structure (right).

3. Other coeval crater-fills in the Midwest

In addition to the Decorah crater, other two meteorite structures, the Ames impact structure in Oklahoma and the Rock Elm impact structure in Wisconsin, have been recognized in the Midwest USA (Fig. 5A), and similar shale deposits and coeval fossils, including conodonts, eurypterids, and phyllocarids, have been reported from these crater-fills (Figs. 5B & C; Repetski, 1997; Peters et al., 2002).

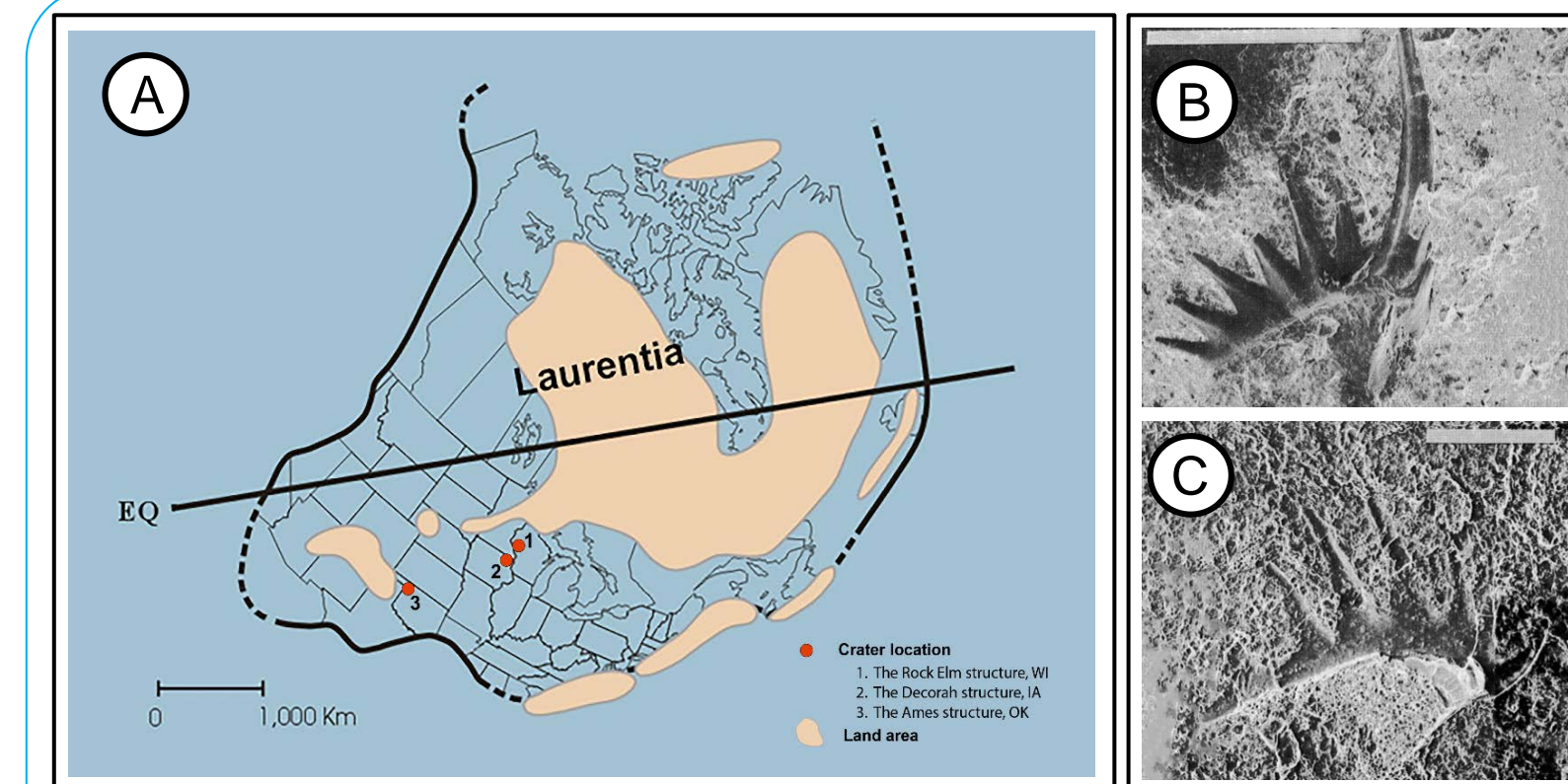


Fig. 5: Locations of the three Middle Ordovician meteorite craters found in Midwest USA (Fig. 5A; Laurentia paleogeographic map from Witzke, 1990), and conodonts from the Ames structure (Figs. 5B & C; from Repetski, 1997).

4. Discussion

- 1) The three meteoritic structures in the Midwest preserve similar deposits and fossils, suggesting that the comparable environments and similar faunas were widespread in Laurentia during the Middle Ordovician.
- 2) The significant erosion between the Sauk and Tippecanoe sequences removed all coeval geologic records except the strata preserved in some unique places such as meteorite craters.
- 3) Information from such crater-fill materials can provide direct geologic and paleobiologic evidence concerning reconstruction of the regional earth history which was destroyed by the regional erosion.
- 4) To achieve this goal, in addition to current data, drilling a corehole through the Decorah impact structure and completing a study of the core sequence is necessary and attainable.

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This research was funded by NSF (Award # 0921245 and 0922054).