DATING THE STE. GENEVIEVE LIMESTONE IN WEST-CENTRAL INDIANA USING SR-ISOTOPE STRATIGRAPHY

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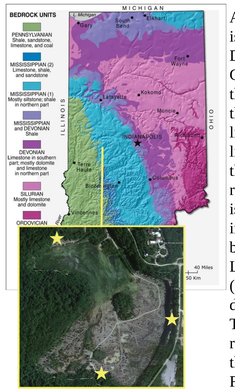
ABSTRACT

A section of Mississippian limestone is exposed in quarry walls at the DePauw Nature Park in Greencastle, Indiana, but its precise age is not known. This research project aimed to date the exposed wall using $^{87}Sr/^{86}Sr$ isotopic ratios to determine the absolute age. Ten samples of brachiopods and ooids were collected at various levels along the stratigraphic column. Isotope ratios were measured in these samples at ALS Scandinavia using a Neptune Plus MC-ICP-MS. Those ratios were then placed on a LOESS seawater Sr-isotope curve (McArthur, 2020) to determine the absolute age range for each sample. Whereas several samples were contaminated by matrix or had recrystallized, placing them completely out of stratigraphic order on the LOESS curve, three of the samples yielded valid results, bracketing a section of the quarry wall to 333.2 –332 Ma. All three valid samples fall on the LOESS curve in stratigraphic order and are clustered together in a way that is to be expected with their stratigraphic proximity within the sampling area. Thin sections of each valid sample showed no signs of recrystallization. Additionally, two of the valid samples sampled from superjacent beds yielded identical ratios with small standard deviations, decreasing the chance of both samples being contaminated. Our new absolute ages constrain the age of the basal Ste. Genevieve Limestone in Indiana. With additional sampling and dating along the quarry wall, we could calculate the sedimentation rate and the full range of ages for the Ste. Genevieve Limestone exposed in the Nature Park quarry.

INTRODUCTION



A section of Mississippian limestone is exposed within quarry walls in the DePauw Nature Park, located in Greencastle Indiana (Figure 1). Whereas the general age (Mississippian) is known, there is no precise date tied to the limestone. An absolute age for this limestone would provide a constraint for the basal Ste. Genevieve Limestone in this region. Brachiopods preserve $^{87}Sr/^{86}Sr$ isotopic ratios of the sea water they grew in. When these ratios are measured in a brachiopod fossil and matched to the LOESS seawater Sr-isotope curve (McArthur, 2020) they can be used to determine an absolute age for the fossil. This study aims to use the Sr-isotopic ratios of brachiopod fossils to determine the absolute age of the Ste. Genevieve Formation in the Nature Park quarry.

Figure 1: The DePauw Nature Park marked on a map of Indiana (IGWS, n.d.). The stars mark sample sites.

BACKGROUND & FIELD AREA

The limestone in the DePauw Nature Park belongs to the lower portion of the Ste. Genevieve Formation. In this part of Indiana, the Fredonia Member contains thinly bedded biomicrite interbedded with calcareous shale. Beds in the Fredonia Member thicken upward. The Spar Mountain Member is a cross-bedded oolitic grainstone (Indiana Geological & Water Survey, 2024). The Levias Member is fossil-poor oomicrite. The Levias Member is only observable at the top of the quarry and the Spar Mountain Member is not accessible for sampling. Samples could not be collected in straight stratigraphic order, but rather in three different sites (Figure 1) along the quarry floor and rim that were correlated with one another. The majority of sampling was near the bottom of the Fredonia Member, in biomicrite beds where brachiopods are plentiful.

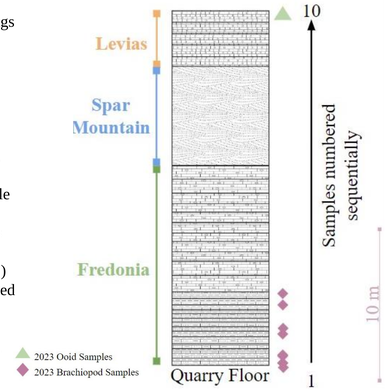


Figure 2: A stratigraphic column of the DePauw Nature Park with units and samples marked. The samples are numbered sequentially, with one as the oldest.

METHODS

Samples were collected from three sites within the DePauw Nature Park. Brachiopods and ooids were collected from various levels of the stratigraphic column for analysis. The methods used in this study are briefly summarized in the flow chart below.

1.) Drill powder from brachiopods for isotope analysis

Brachiopods had powder from shell collected for analysis using a dental drill. Tools and samples were cleaned prior to extraction to avoid contamination.

2.) Samples sent for isotope analysis

The prepared samples were then sent to ALS Scandinavia for analysis of $^{87}Sr/^{86}Sr$ isotopic ratios using a Neptune Plus MC-ICP-MS.

3.) Create thin-sections & check for recrystallization

Thin sections were created from the brachiopods to ensure the ratios from each sample were showing the original age of the brachiopods. This step would ideally occur before step 2 but due to timing and funding had to occur after the fact.

4.) Correlate

The $^{87}Sr/^{86}Sr$ isotopic ratios were placed on a LOESS seawater Sr-isotope curve (McArthur, 2020) to determine the absolute age range for each sample.

RESULTS

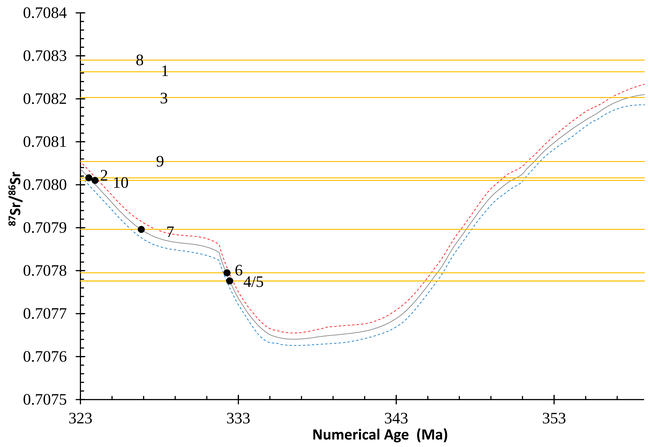


Figure 3 (Above): The Mississippian segment of the LOESS curve (McArthur, 2020), with ratios collected from samples applied. The yellow lines mark the ratios of each sample, and the black points mark where each of the ratios intersect with the late Mississippian leg of the curve. All of the points fall out of stratigraphic order except for 7, 6, 4, and 5.

Sample Number	$^{87}Sr/^{86}Sr$	2 σ error
1	0.708263	$2.2x10^5$
2	0.708016	$2.0x10^5$
3	0.708203	$2.1x10^5$
4	0.707776	$2.0x10^5$
5	0.707776	$1.9x10^5$
6	0.707795	$2.4x10^5$
7	0.707896	$2.4x10^5$
8	0.70829	$2.0x10^5$
9	0.708054	$2.2x10^5$
10	0.70801	$1.6x10^5$

Figure 4 (Above): Table with original $^{87}Sr/^{86}Sr$ ratios and their standard deviations measured by ALS Scandinavia.

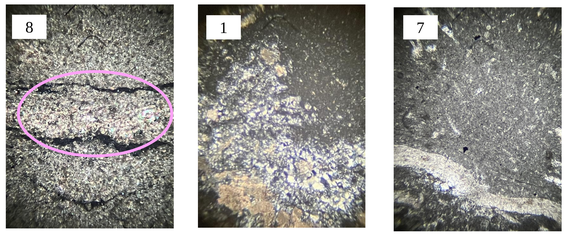


Figure 5 (Above): Representative thin-section photomicrographs from some rejected samples plotted in Figure 3. Sample 8 has been completely micritized, including the brachiopod circled in pink, which explains why its $^{87}Sr/^{86}Sr$ ratio does not lie on the LOESS curve. The presence of chert and micrite in Sample 1 explains why its ratio appears so far out of stratigraphic order. Whereas Sample 7 has no signs of recrystallization, and the sample is in stratigraphic order, the gap between 7 and 6 has led us to infer that it was contaminated by matrix, and the ratio does not represent seawater Sr at the time of deposition.

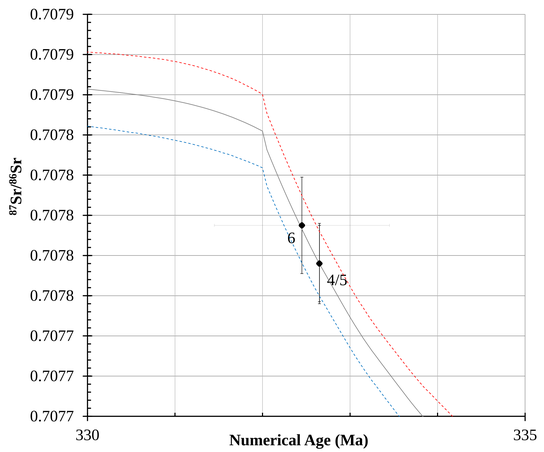


Figure 7 (Above): A close up of points 6, 4, & 5 from Figure 3 and their error bars based on 2 standard deviations. To further calculate the absolute age range for each of these points, where the lower error bar meets the red line provides the upper confidence level, and where the upper error bar crosses the blue line provides the lower confidence level.

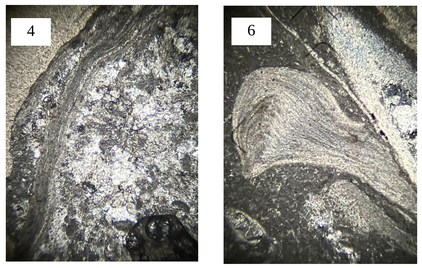


Figure 6 (Left): Representative thin-section photomicrographs from the valid samples plotted in Figures 3 and 7. Samples 4 and 5 came from two separate superjacent beds, and they yielded the same ratio and virtually the same standard deviation. Sample 4 exhibits variable recrystallization, but the brachiopod itself retains its original texture. Both samples yield the same $^{87}Sr/^{86}Sr$ ratio for an appropriate age. Sample 6 exhibits no recrystallization— the growth lines within the brachiopod are still visible. The $^{87}Sr/^{86}Sr$ ratio of Sample 6 matches the stratigraphic ordering.

CONCLUSIONS & FUTURE WORK

The goal of this project was to attain an absolute age range for the rocks in the DePauw Nature Park. This research has produced the following conclusion:

The middle layers of the DePauw Nature Park are 333.15-332.05 Ma

Several samples were contaminated by matrix when originally collected or had recrystallized, placing them completely out of stratigraphic order on the LOESS curve. Despite this hurdle, three of the samples yielded valid results, placing a section of the quarry wall at 333.15-332.05 Ma. All three valid samples fall on the LOESS curve in stratigraphic order and are clustered together in a way that is to be expected with their stratigraphic proximity within the sampling area. Thin sections of each valid sample showed no signs of recrystallization. Additionally, two of the valid samples from superjacent beds yielded identical ratios with small standard deviations, decreasing the chance of both samples being contaminated.

Issues faced during the research included a lack of brachiopods at the top of the column to use for $^{87}Sr/^{86}Sr$ dating, contamination of samples with surrounding matrix while preparing them for testing, unnecessary testing of Sr-ratios, and being unable to collect in a straight line up the stratigraphic column due to safety and accessibility..

Although the collecting issues cannot be resolved, contamination issues can be by more methodically drilling the brachiopod to ensure no matrix is collected.

Future work may involve obtaining a full age range for the Nature park rather than just an interval within the stratigraphic column. Additionally, with enough samples and dating along the quarry wall, the sedimentation rate for Ste. Genevieve Formation exposed in the DePauw Nature Park could be calculated.

By understanding the age range of the Ste. Genevieve Limestone, we can better understand the ages of the superjacent formations. Additionally, if we eventually calculate the sedimentation rate based on the ages, we can then gain a better understanding of the environment Ste. Genevieve was deposited in and how it was regularly changing.

Figure 8: Samples 4, 5, and 6 plotted on the stratigraphic column, and the corresponding age range calculated for each sample.

ACKNOWLEDGEMENTS AND REFERENCES

Scan for references

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