LIGHT ISOTOPE ANALYSIS AND BIOGEOGRAPHY OF LATE CRETACEOUS METHANE COLD-SEEPS OF THE PIERRE SHALE, SOUTH DAKOTA

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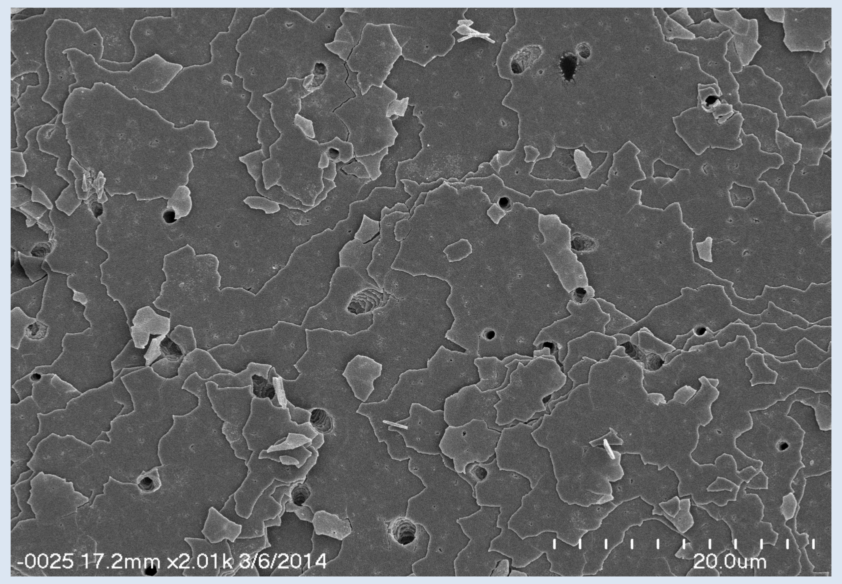
Abstract: Methane cold-seeps from the Late Cretaceous in the Pierre Shale of South Dakota tend to have dense faunal communities including baculites and inoceramids. These communities depend on intricate relationships between the geochemically driven formation of the seep substrate, pressure gradients allowing for methane migration, anaerobic oxidation of methane combined with sulphate reduction, and interactions between fauna and micro-organisms. These functions are necessary to sustain life within the cold-seep community. American Museum of Natural History (AMNH) loc. 3520A, South Dakota, was gridded into 24 quadrants each approximately 4' by 4', mapped out, and specimens were collected for light isotope analysis, $\delta^{18}O$ and $\delta^{13}C$, and faunal analysis. Nacre from inoceramids and baculites were extracted from larger samples, coated with Au and Pd, and imaged using a Hitachi S4700 FE- scanning electron microscope to determine the preservation index, (PI; quality of preservation). Samples with a preservation index of 3 or greater were sent out for $\delta^{13}C$ and $\delta^{18}O$ isotope analysis. The distribution of fauna with respect to the central pipes at the seep and location in the mound were examined for any relationships. There was no correlation found between the preservation index of the samples and the distance from the main conduit of the cold-seep. Baculites were found in a greater concentration from the central conduit of the methane-seep and became scarcer moving away from the main conduit. Inoceramids are well distributed throughout the seep. AMNH loc. 3520A does not appear to have a concentric distribution of fauna around the central conduit as frequently mentioned in the literature. Light isotope readings were consistent with baculite samples, both proximal and distal to the main conduit. Inoceramid species isotope readings were variable and reflect no spatial patterns.

GOOD PRESERVATION | POOR PRESERVATION



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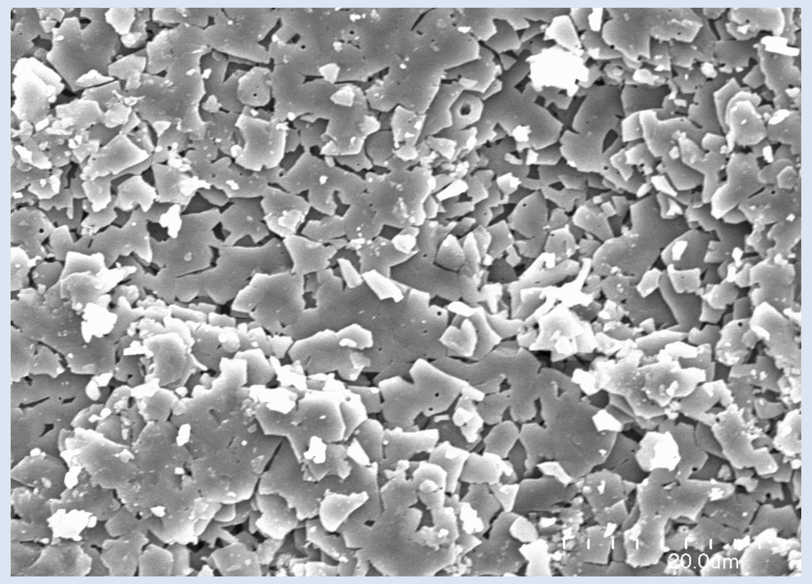
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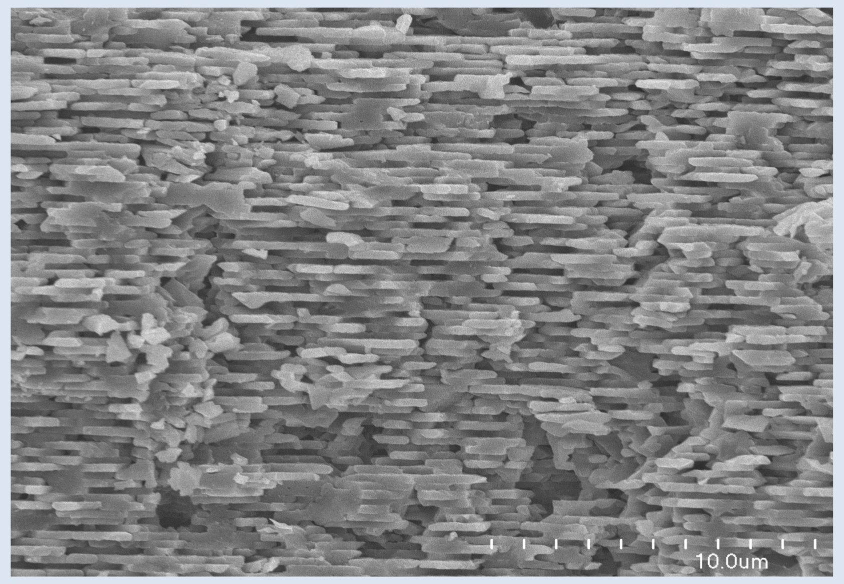

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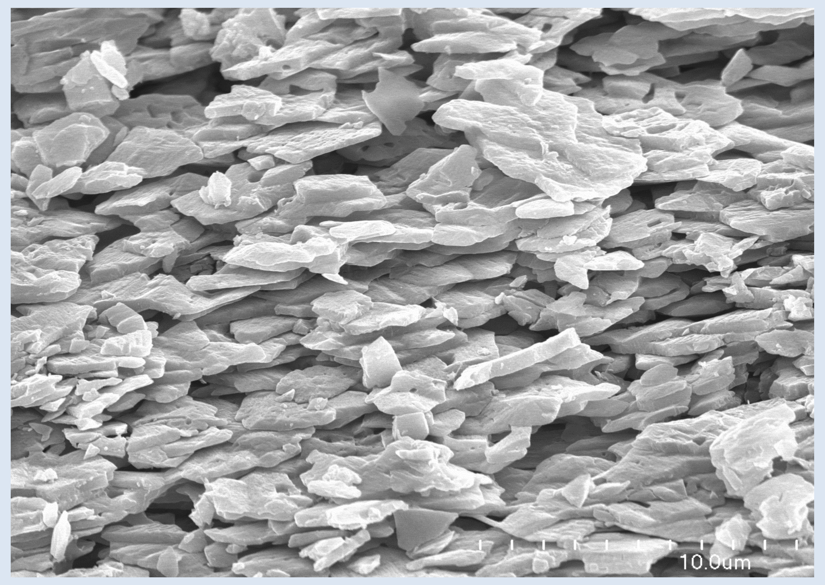

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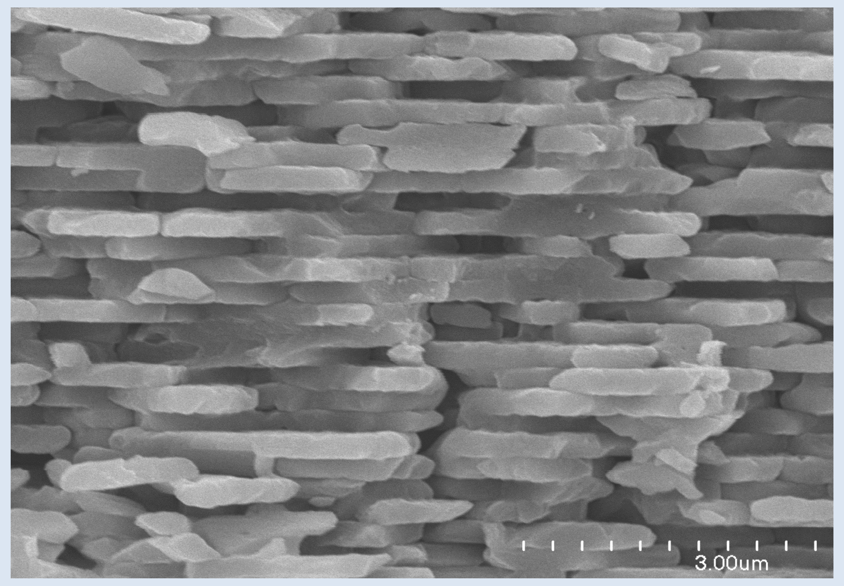

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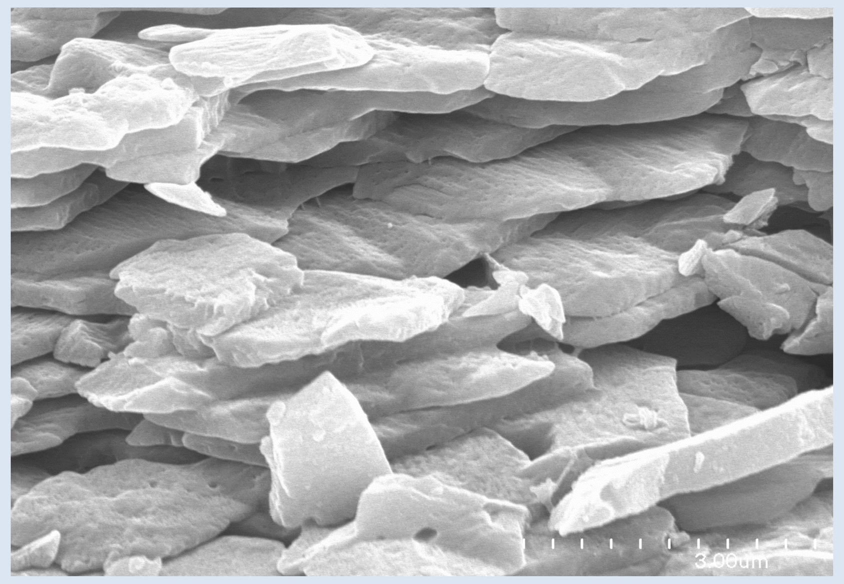
Profile: 15K

Figure 1 – Good and poor reservation examples of nacre samples from AMNH loc. 3520A imaged at 2k, 5k, and 15k to determine PI. Good preservation, left, was determined to have a PI of 4. Poor preservation, right, was determined to have a PI of 1.5.

Methods

Pieces of shell nacre were chipped off baculites and inoceramids and were coated with Au and Pd ions. This is to ensure that there is no charge when they are put into the scanning electron microscope. Each sample was imaged in the Hitachi S-4700 Field emission scanning electron microscope at 2,000X for the top view. The profile was imaged at 5,000X, 10,000X, and 15,000X. From these images each sample was given a PI number; 5 being the best preserved and 1 being the worst preserved. All samples with a preservation index of 3 and higher were sent out for carbon and oxygen isotope analysis to the Paleoenvironmental and Environmental Stable Isotope Laboratory at the University of Kansas.

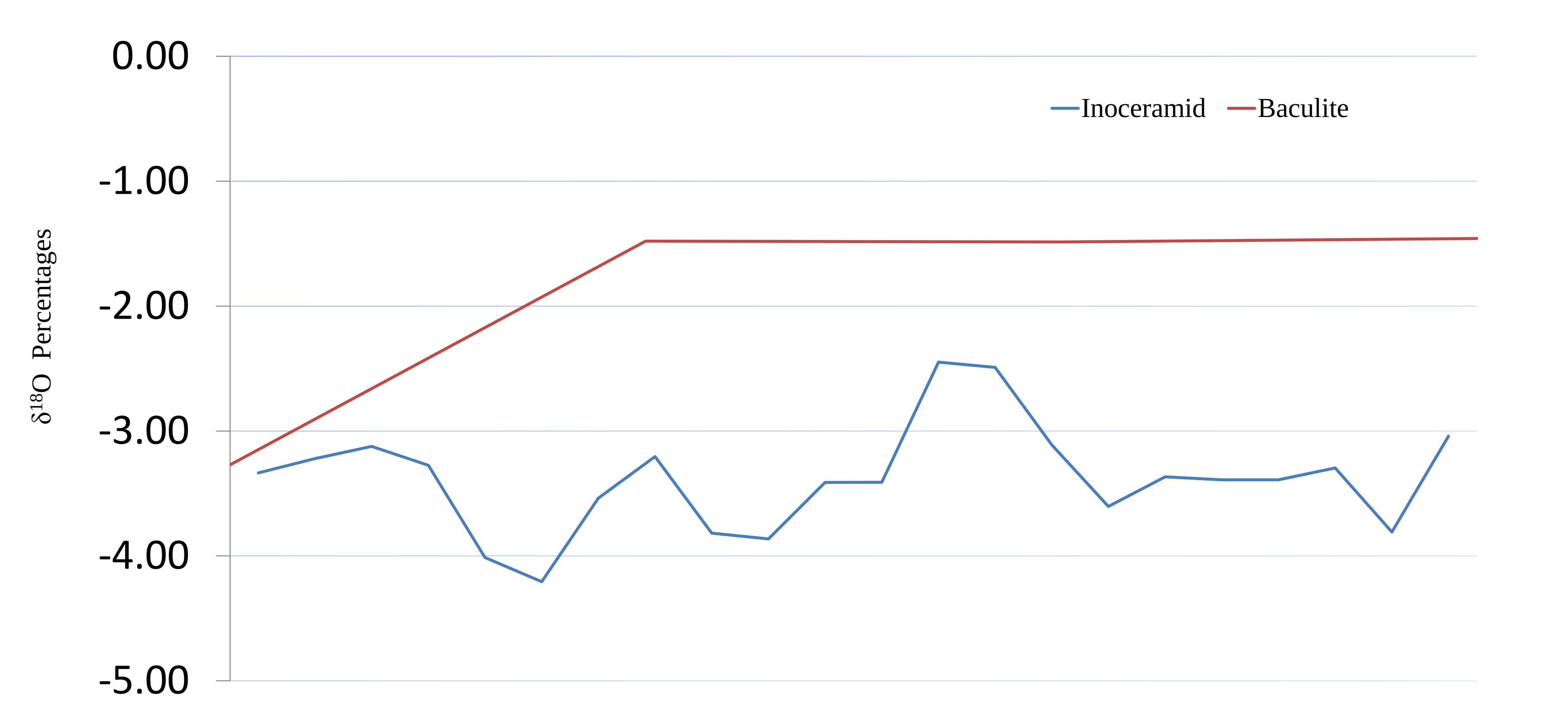

Figure 2: $\delta^{18}O$ for Inoceramids and baculites

Conclusions

Baculites have $\delta^{13}C$ values ranging from -2.09% to -6.75% and are distal to the main conduits of the methane cold-seep shown in Figure 3. The $\delta^{13}C$ indicate that these baculites incorporated methane derived carbon and must have lived near archaea (methanogens) and sulphate reducing bacteria undergoing anaerobic oxidation of methane (Landman et al., 2012). $\delta^{18}O$ values are shown in Figure 2 for baculites ranging from -1.46% to -3.27% while inoceramids show even lighter $\delta^{18}O$ values ranging from -2.54% to – 4.21%. Inoceramid species show a wide range of $\delta^{13}C$ values ranging from -8.06% to 5.18%. Inoceramids at this seep show $\delta^{13}C$ values, indicated by the shaded areas of Figure 4. These $\delta^{13}C$ values coupled with such $\delta^{18}O$ values, it is indicated that inoceramids did not secrete their shells in isotopic equilibrium with the seawater which is in agreement with the findings of Landman et al. (2012).

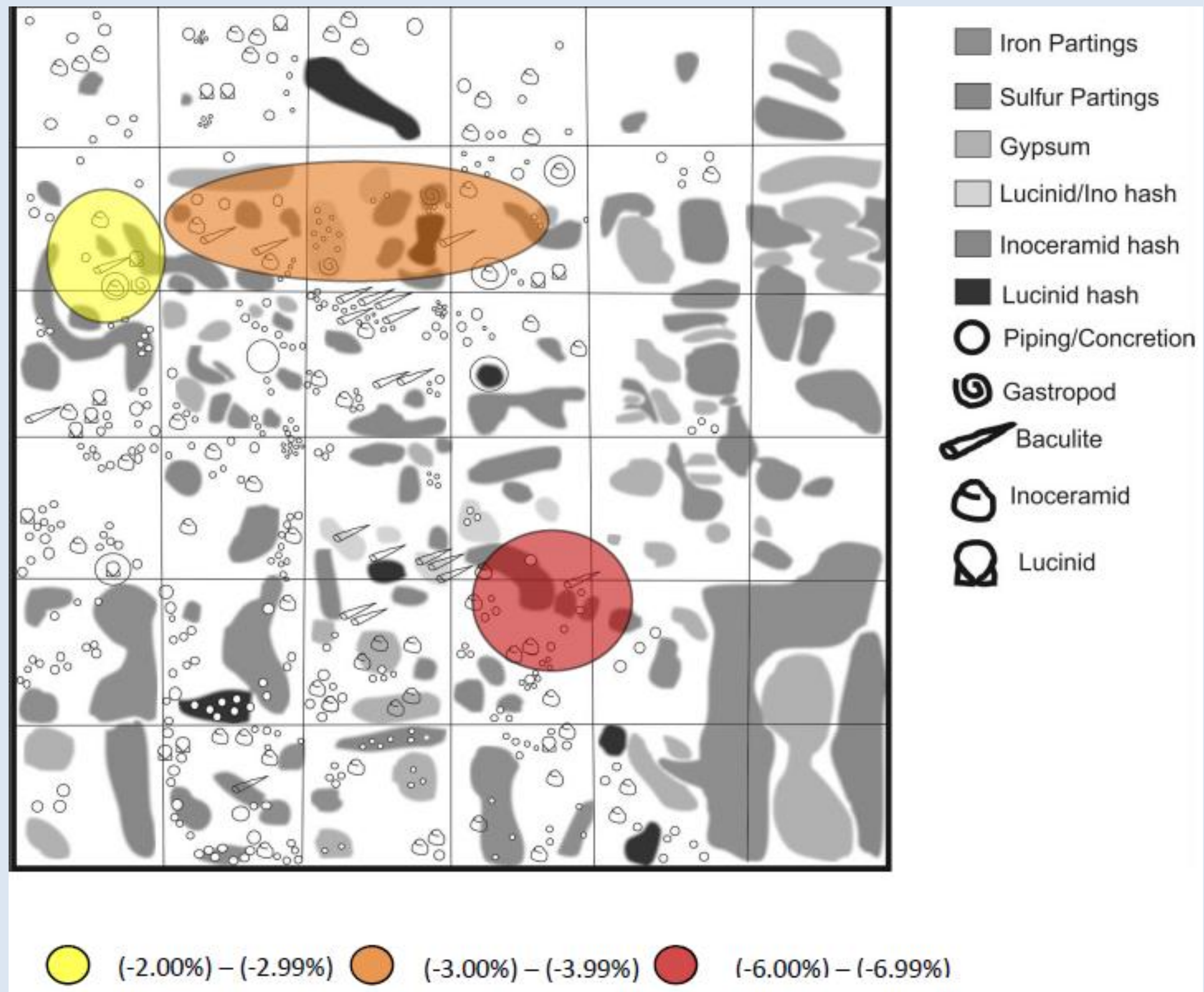

Figure 3 – Baculite $\delta^{13}C$ distribution at AMNH local 3520A

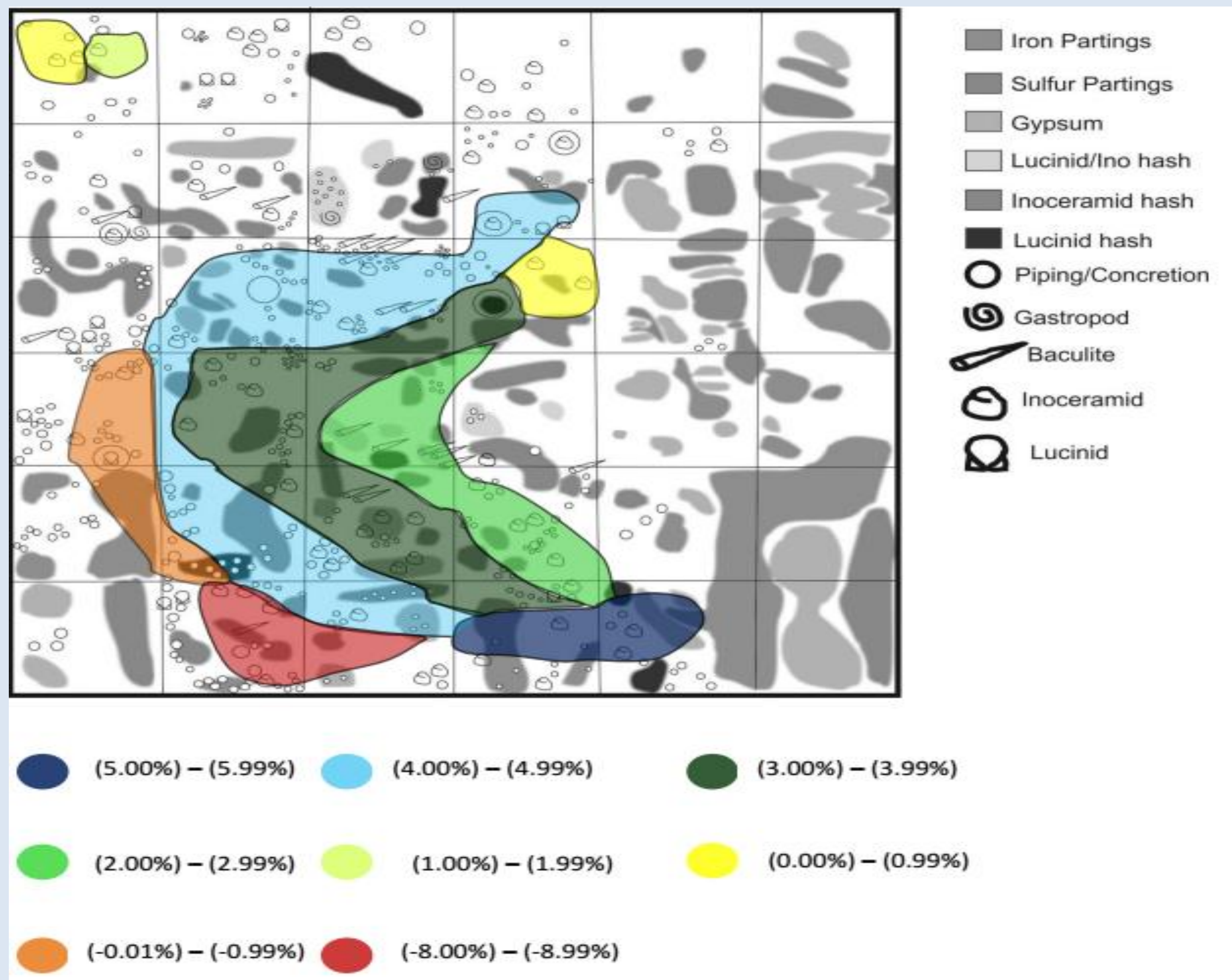

Figure 4 – Inoceramid $\delta^{13}C$ distribution at AMNH local 3520A

References:
Neil H. Landman, J. Kirk Cochran, Neal L. Larson, Jamie Brezina, Matthew P. Garb, and Peter J. Harries, 2012, Methane seeps as ammonite habitats in the U.S. Western Interior Seaway revealed by isotopic analyses of well-preserved shell material: Geology, v. 40, p. 507-510, First published on April 10, 2012, doi:10.1130/G32782.1

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