

Gao, Y., Henkes, G.A., Cochran, J.K., and Landman, N.H., 2021, Temperatures of Late Cretaceous (Campanian) methane-derived authigenic carbonates from the Western Interior Seaway, South Dakota, USA, using clumped isotopes: GSA Bulletin, <https://doi.org/10.1130/B35846.1>.

## Supplemental Material

**Figure S1.** A scanned billet of methane derived authigenic carbonate AMNH loc. 3528 #102525A. The area inside the red dash line is the region that was subsampled (#1 is the subsampling ID) for carbonate clumped isotope measurements. Subsample #1 is homogenous micrite cement. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface.

**Figure S2.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3528 #102534A. The areas inside the red dash lines are the regions that were subsampled for clumped isotope measurement. Subsample #1 is micrite, and #2 is an example of vein (part of the same feature as the horizontal vein that crosses the subsampled area). Transmitted light and cathodoluminescence microscopy images of #2 can be seen in Fig. 2. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface.

**Figure S3.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3528 # 102525F (N-S). The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #2 is an example of nodule (similar to the feature shown in Fig. S6a). Another subsample was taken right above #2, but it was not measured for clumped isotopes in this study. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface. Scale units in this figure are in centimeters.

**Figure S4.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3528 # 102534A. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #4 is an example of “darker micrite”. The #4 subsample (before being microdrilled) resembled the area inside the maroon dotted line shown in the middle of the hand sample. Another subsample was taken on the left edge of the billet, but it was not measured for clumped isotopes in this study. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Some circular saw cut marks can be seen running across the samples surface on the lower part of the billet.

**Figure S5.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3528 # 102534A (F). The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #2 is an example of “darker micrite”. The #2 subsample (before being microdrilled) resembled the area inside the maroon dotted line in the middle of the hand sample in Fig. S4. Two other subsamples were taken on the left part of the billet, but they were not measured for clumped isotopes in this study. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Scale units below the billet are in centimeters. Circular saw cut marks can be seen running across the samples surface.

**Figure S6.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3528 # 102536B. The areas inside the red dash lines in (b) are the regions that were subsampled for clumped isotope measurements. Subsample #1 is homogenous micrite. Subsample #2 is an example of a diagenetic nodule. (a) is the back of the 102536B billet, which shows an example of the original texture of these so-called diagenetic nodules before sampling. Transmitted light and cathodoluminescence microscopy images of #2 can be found in Fig. 2. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Scale units in S6 (a) are also in centimeters.

**Figure S7.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3545 # 102511B. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #1 is homogenous micrite. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet.

**Figure S8.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3545 # 102524. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #1 is homogenous micrite. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface.

**Figure S9.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3545 # 102533A. The areas inside the red dash lines are the regions that were subsampled for clumped isotope measurements. Subsample #1 is micrite, and #2 is an example of darker micrite. This sample show unique features among micrites sampled, with fluid-like textural variations between blocks of the darker micrite. Transmitted light microscopy images of #2 can be found in Fig. S18, as this region does not show any sign of luminescence. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface.

**Figure S10.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3545 # 102533B. The areas inside the red dash lines are the regions that were subsampled for clumped isotope measurements. This sample shows similar features as AMNH loc. 3545 # 102533A (Fig. S9). Subsample #1 is micrite, and #2 is an example of darker micrite. Details about the sample

morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface.

**Figure S11.** Scanned billets of methane derived authigenic carbonate AMNH loc. 3418 # 79017E. The areas inside the red dash lines are the regions that were subsampled for clumped isotope measurement. Both subsamples are very hard homogeneous micrites. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Scale units in this image are in centimeters. Some circular saw cut marks can be seen running across the samples surface.

**Figure S12.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3418 # 79159A. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #1 is micrite. The entire hand sample surrounded by notably lighter edges that were avoided during microdrilling. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface.

**Figure S13.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3418 # 79017F. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #1 is micrite. Another subsample was taken at the upper right corner of the hand sample, but it was not measured for clumped isotopes in this study. Scale units in this image are in centimeters. Some circular saw cut marks can be seen running across the samples surface.

**Figure S14.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3418 # 79159B. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. Subsample #1 is micrite. Two other subsamples were taken on both right and left side of #1, but they were not measured for clumped isotopes in this study. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Circular saw cut marks can be seen running across the samples surface.

**Figure S15.** Scanned billets of methane derived authigenic carbonate AMNH loc. 3440 # 102535B. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. #1 is an example of micritic coquinite. The scan in (b) is a more representative coquinite (with shell fragment embedded) from the same sample hand sample. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Scale units in this image are in centimeters. Some circular saw cut marks can be seen running across the sample surface in (a).

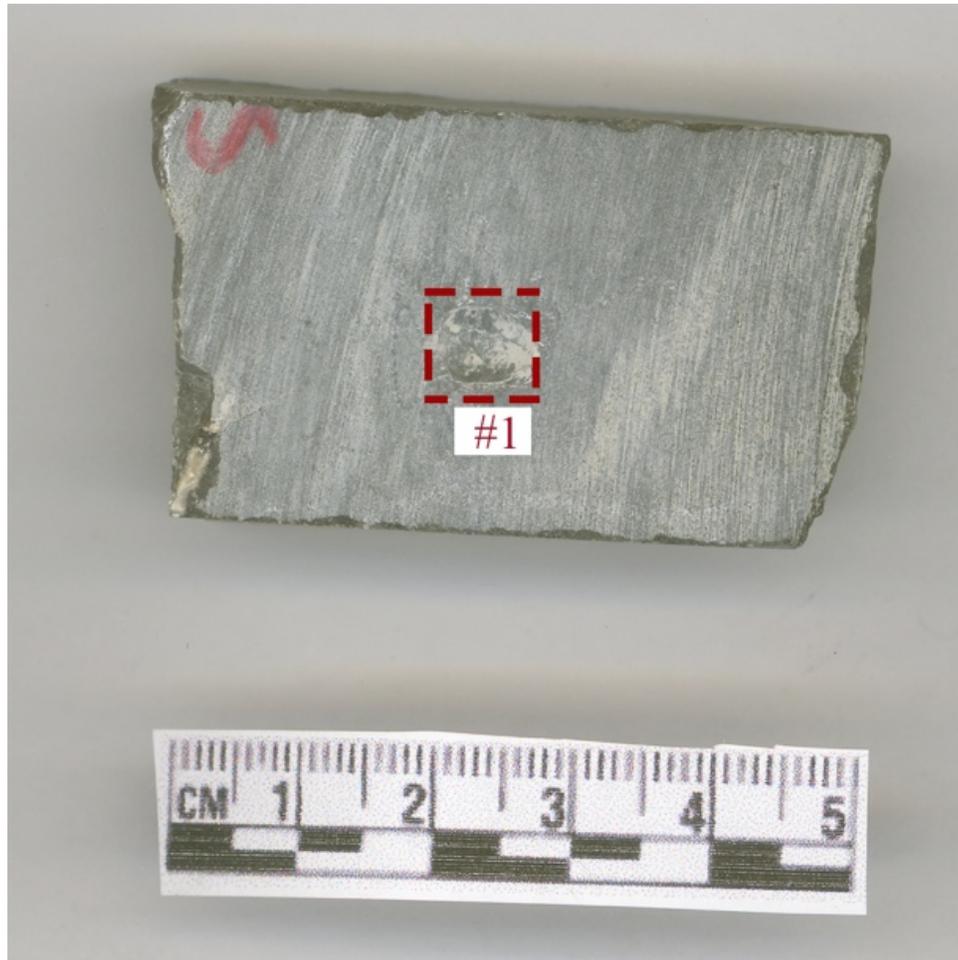
**Figure S16.** Scanned billet of methane derived authigenic carbonate AMNH loc. 3529 # 64436B. The area inside the red dash line is the region that was subsampled for clumped isotope measurement. This sample is an example of fossiliferous platy carbonate that contains a great number of fossil shell fragments. Subsample #1 was taken horizontally and in parallel with the

lineation of embedded shell fragments, though we cannot rule out that some cement was included with the shell fragment carbonate during micro-drilling. Details about the sample morphologies and isotopic results can be found in Table 1 and supporting data spreadsheet. Scale units in this image are in centimeters.

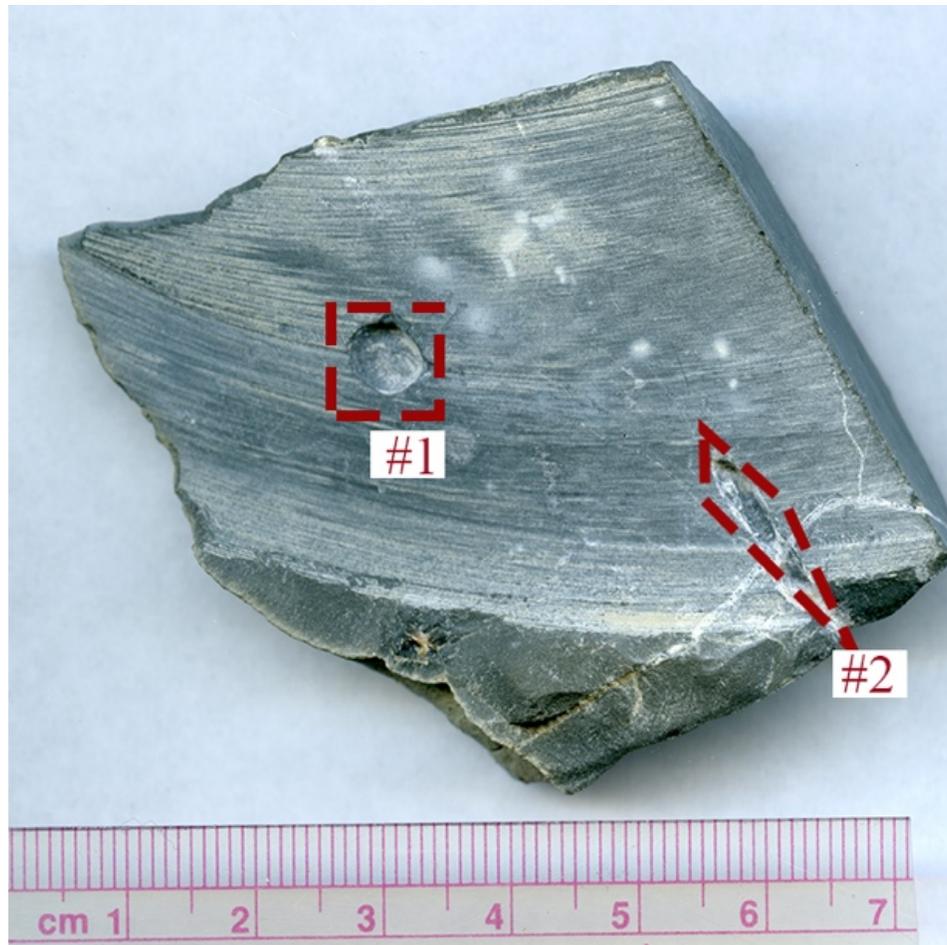
**Figure S17.** Transmitted light (a, c) and cathodoluminescence (b, d) microscopy images (a, c) of samples from AMNH locality 3418: 79159 A (a & b), and 79159 B (c & d). Both samples contain unique sedimentary features that we've described as diagenetic nodules. Color and brightness were slightly adjusted on the transmitted light image to enhance contrast. The variation in luminance around the edge of the nodules and imbedded features (*i.e.*, zoning) may reflect varying fluid chemistry during diagenetic modification. See Fig. S6a for a scanned sample billet that shows a diagenetic nodule visible to the naked eye.

**Figure S18.** Transmitted light microscopy image of sample 102533A from AMNH loc. 3545 (massive seep carbonate). It is the only sample measured that did not show any luminescence during cathodoluminescence microscopy. The entire thin section is composed of micritic cement, though shows a blocky macrotexture with darker micrite apparently filled in by lighter cement.

**Figure S19.** X-ray diffraction spectra generated from three WIS authigenic carbonate samples: (a) AMNH loc. 3418 79017F #1, micrite (Fig. S13). (b) AMNH loc. 3528 102534A #2, vein (Fig. S2). (c) AMNH 3545 102533A #2, darker micrite (Figs. S2 and S9). Peaks (marked using grey dash lines along the x-axis) are from Match! Software reference libraries for magnesium calcite (#96-721-4219 for a & c, and #96-721-4218 for b).



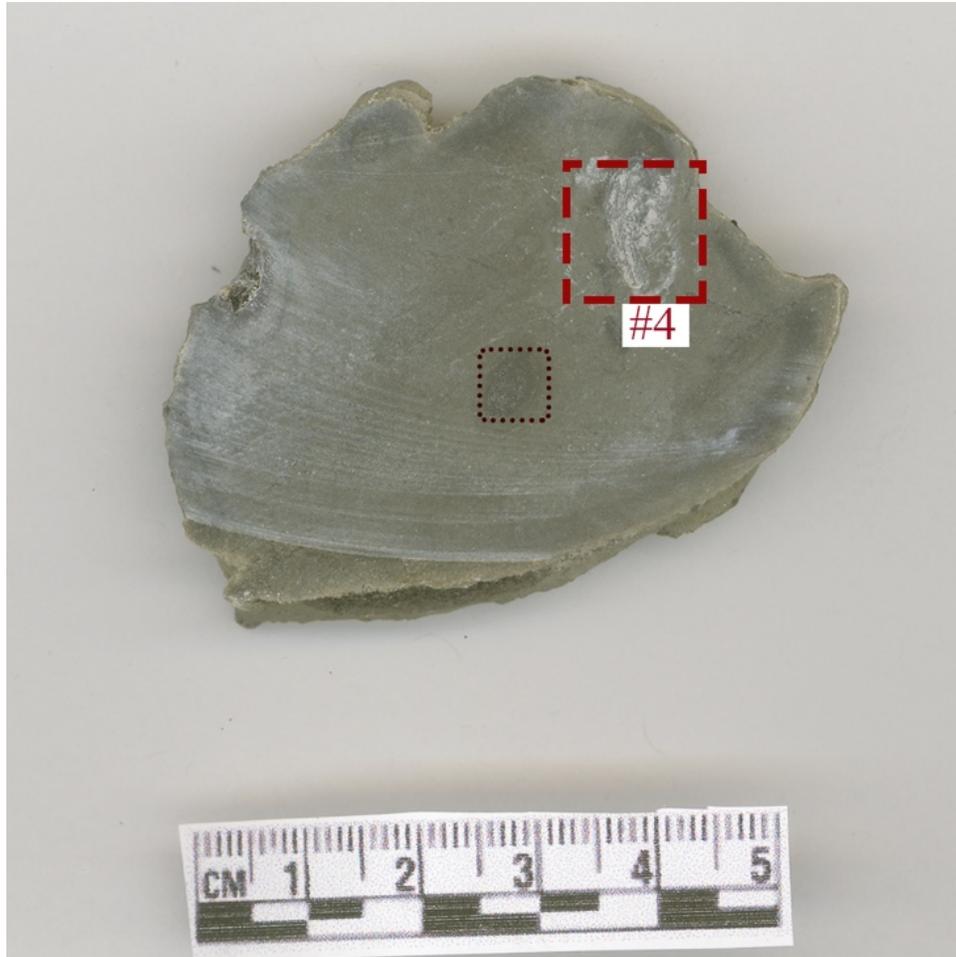
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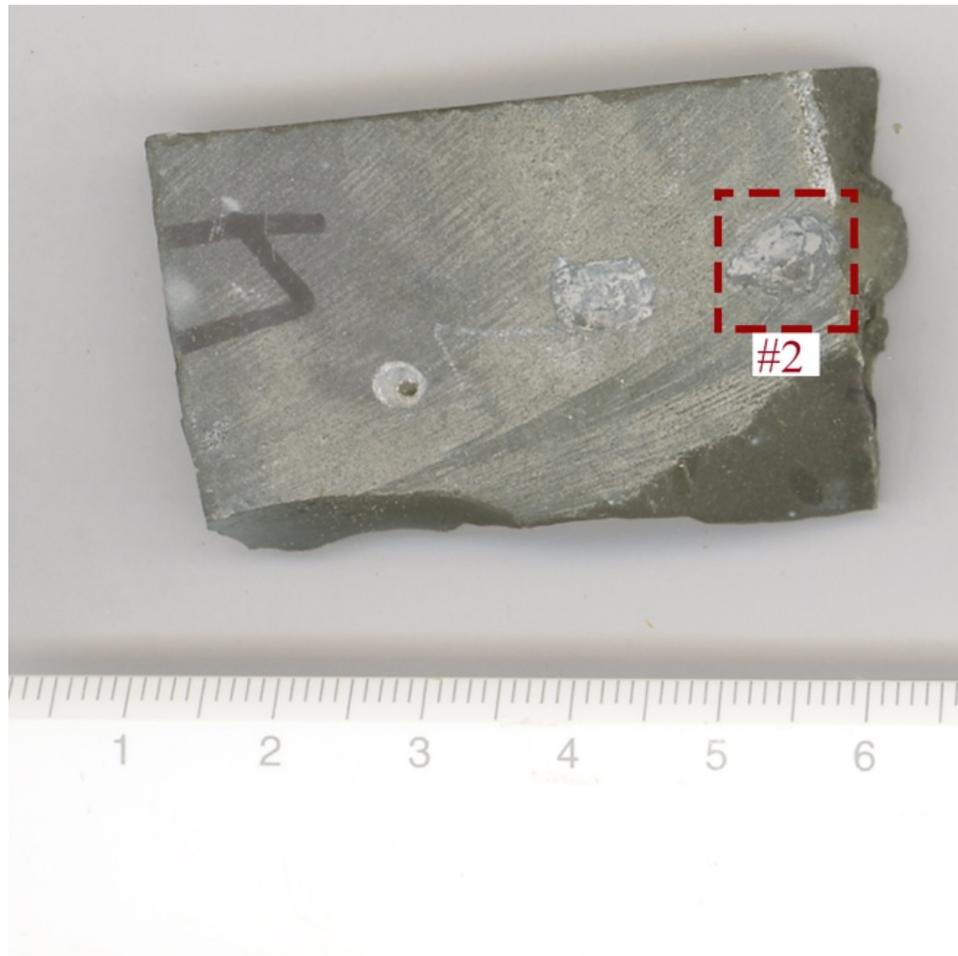
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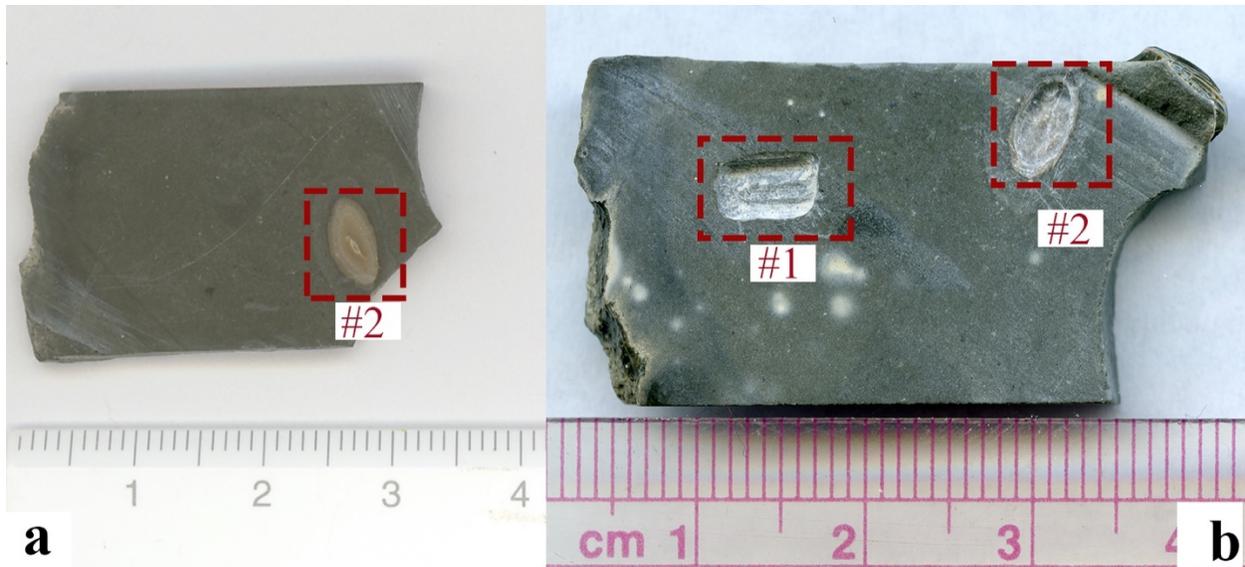
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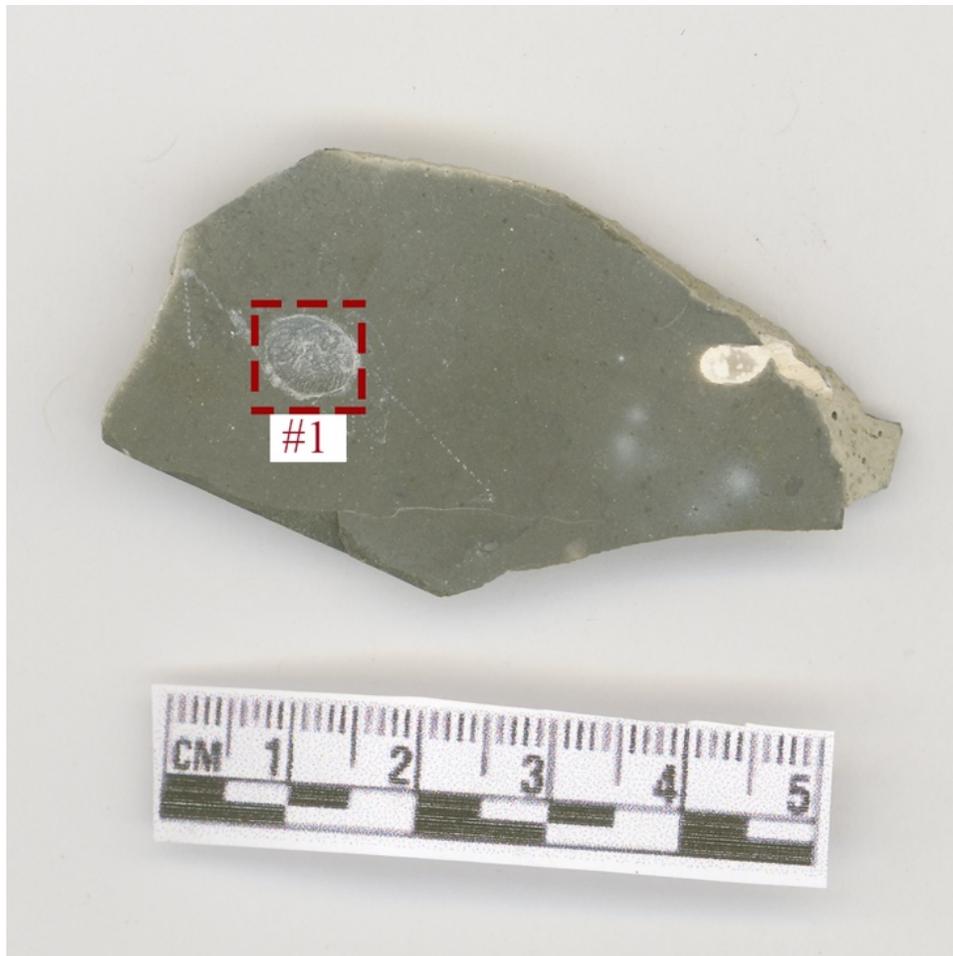
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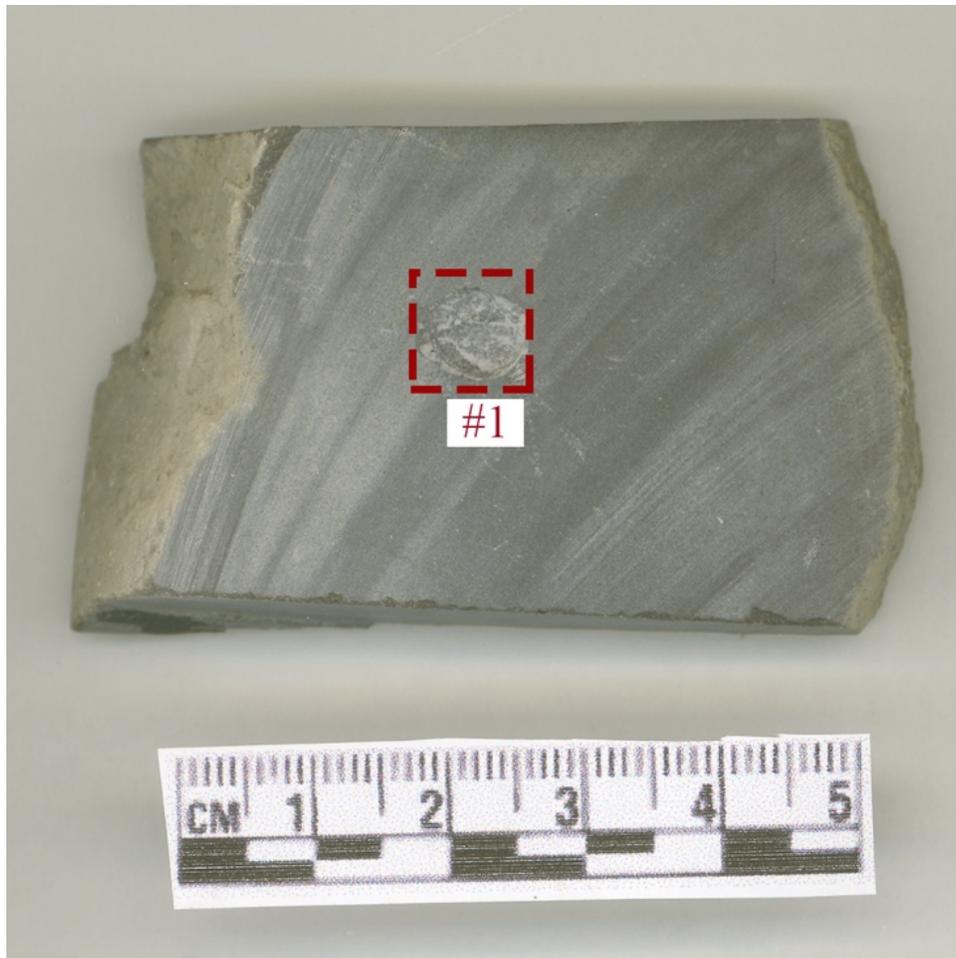
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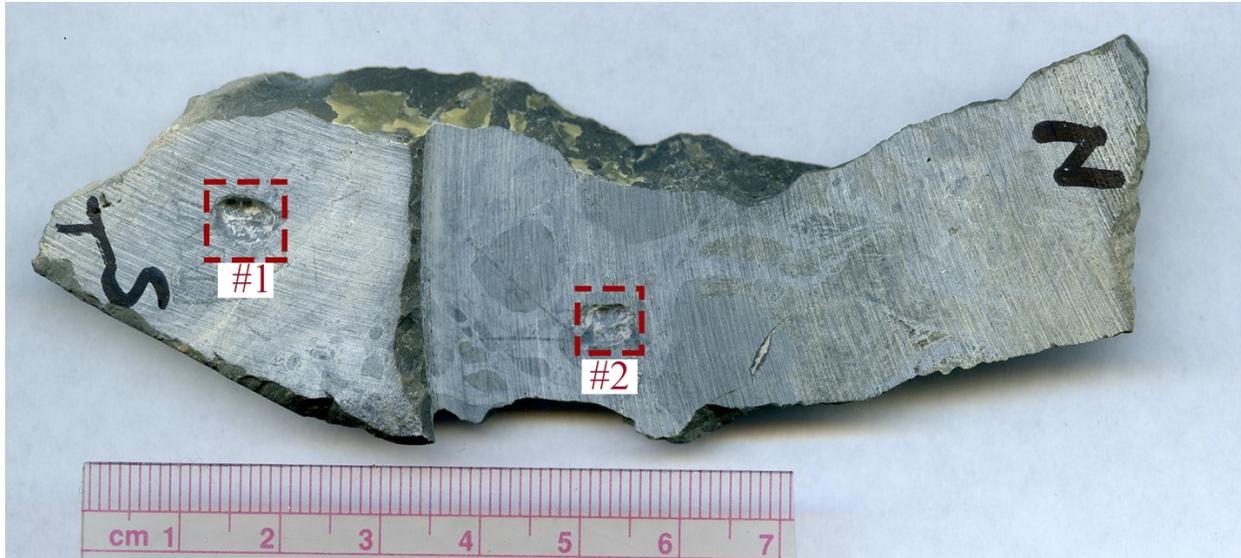
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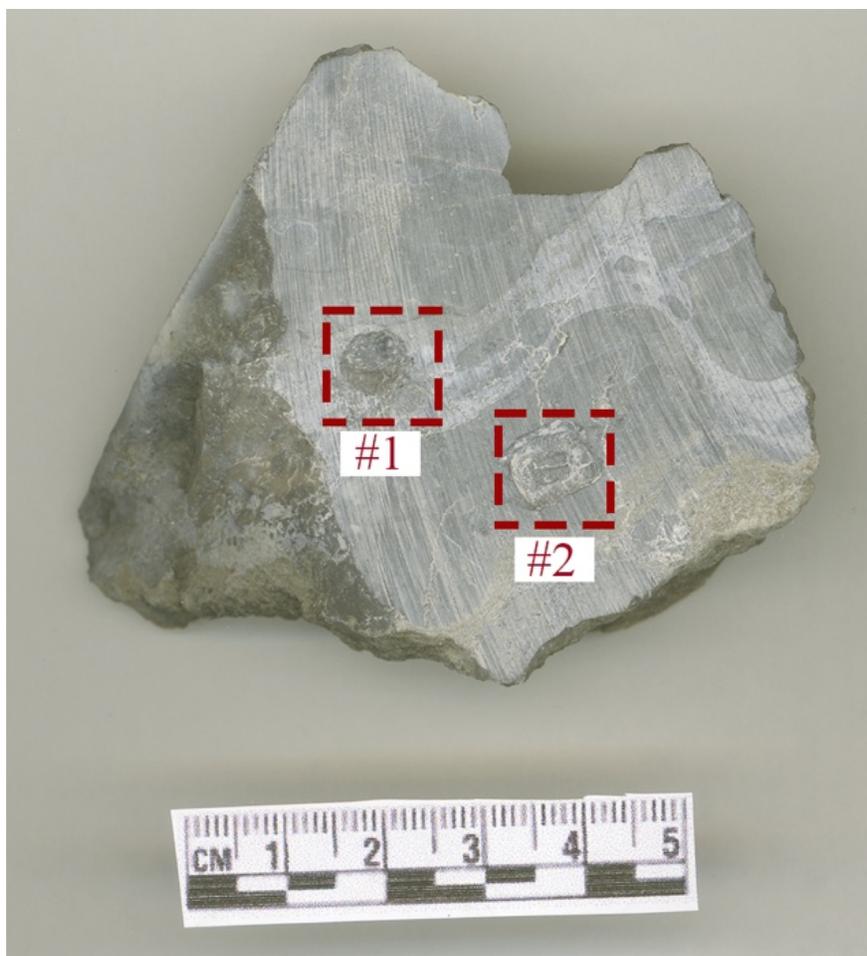
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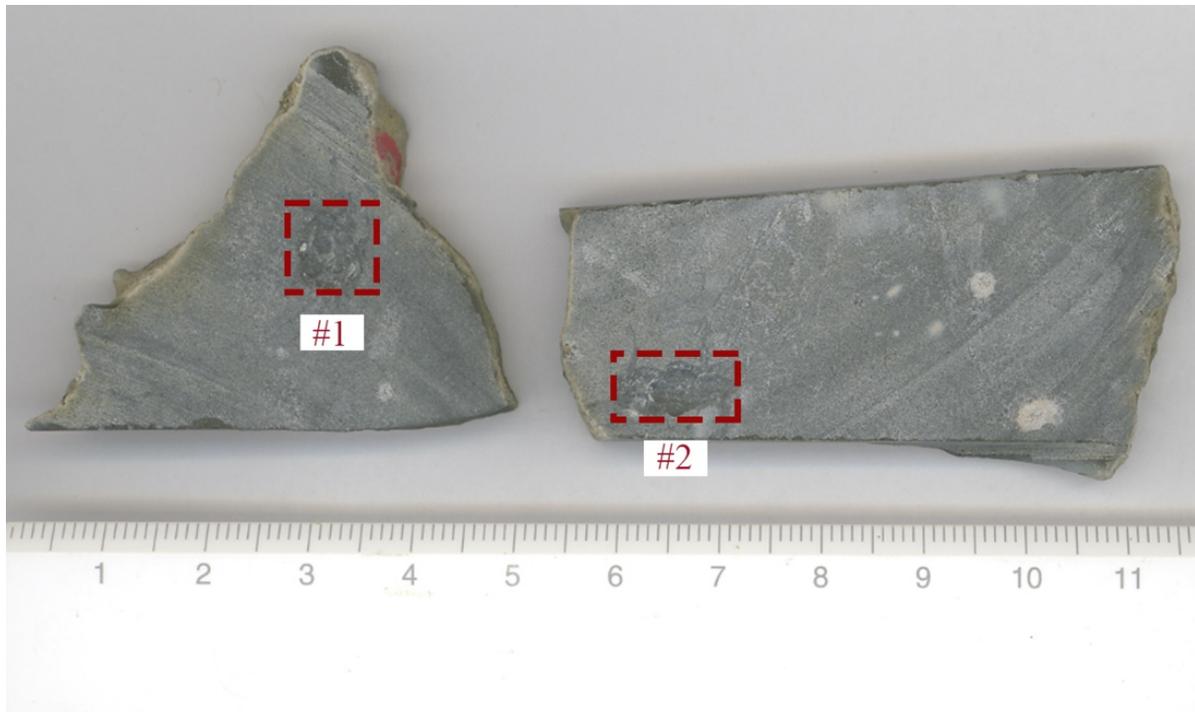
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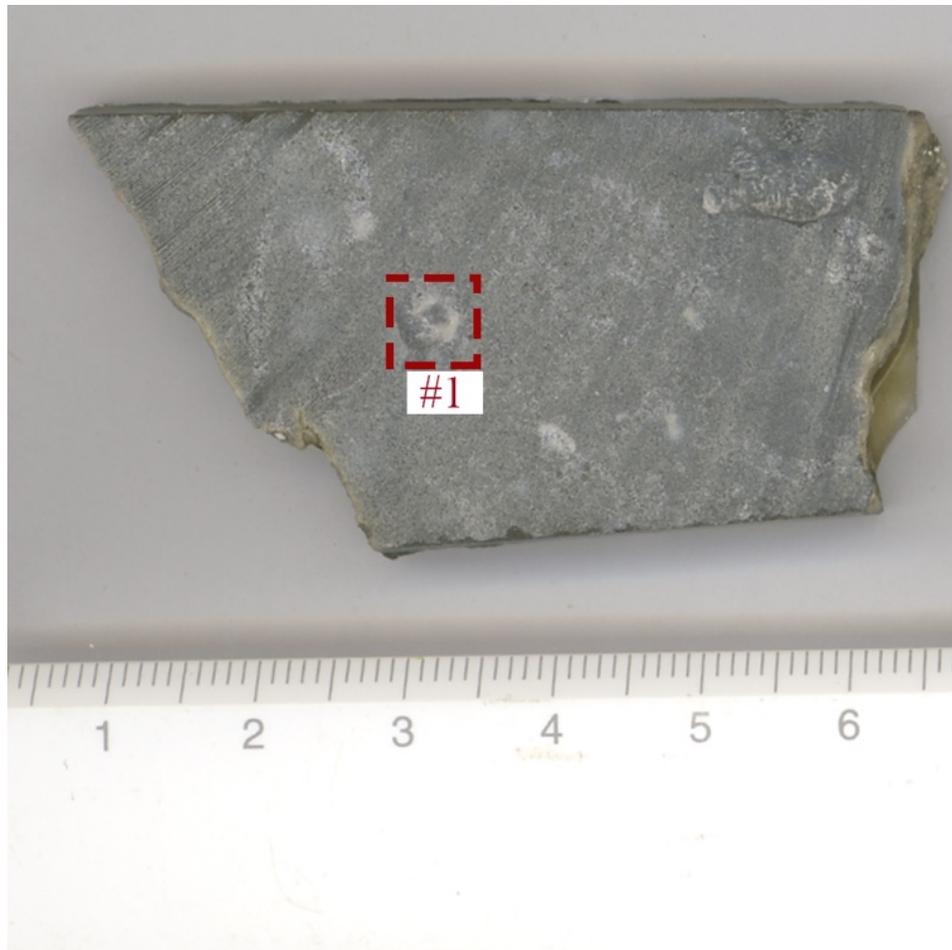
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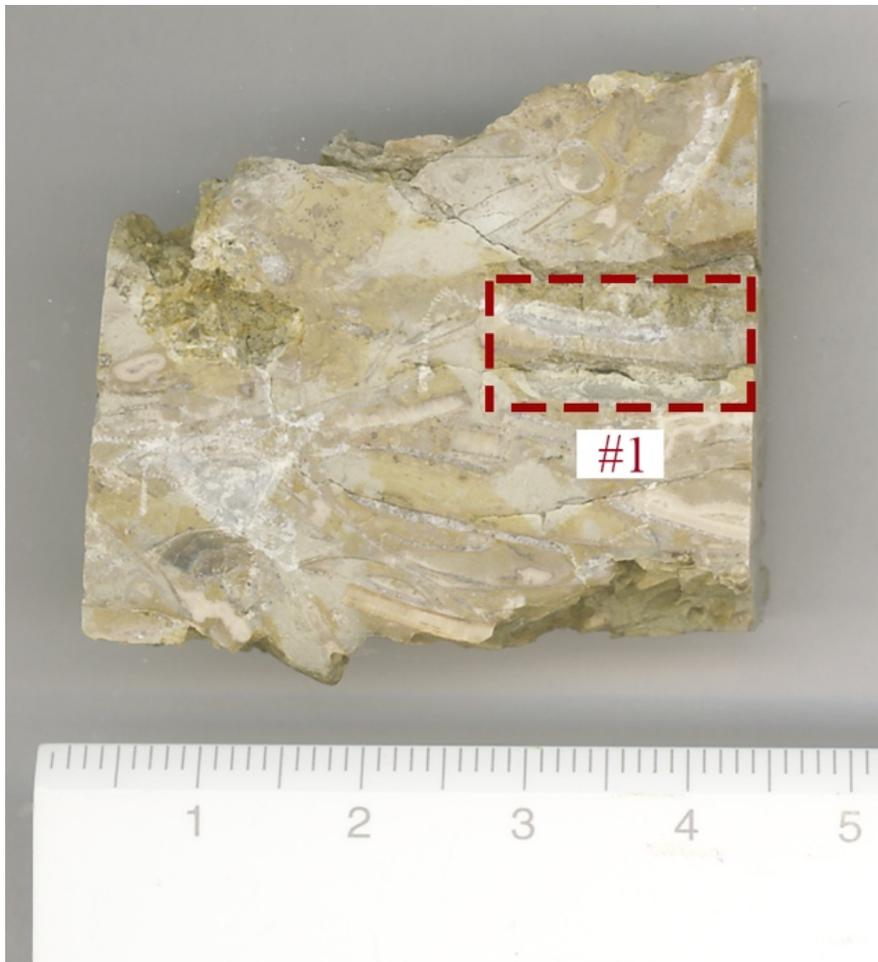
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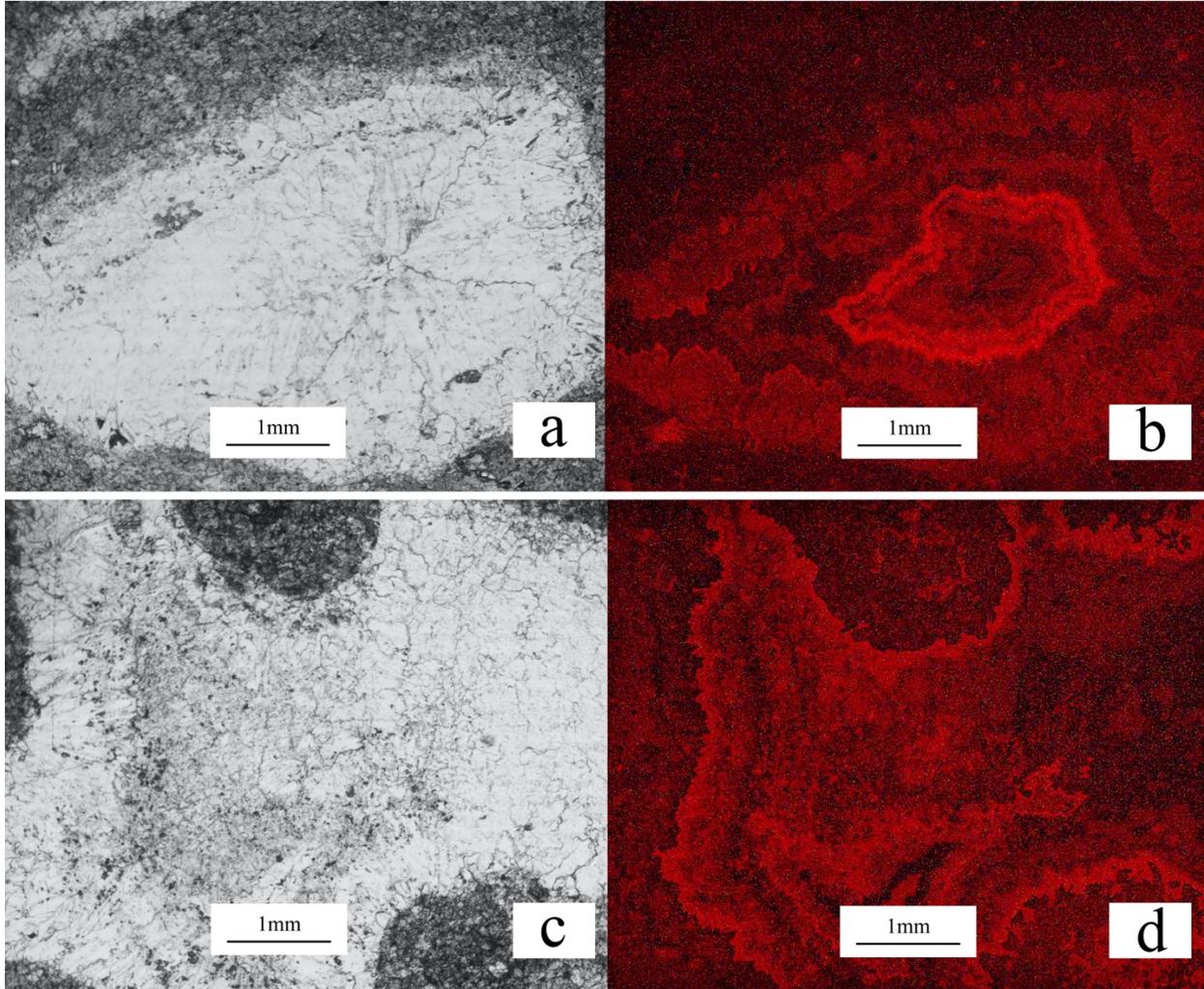
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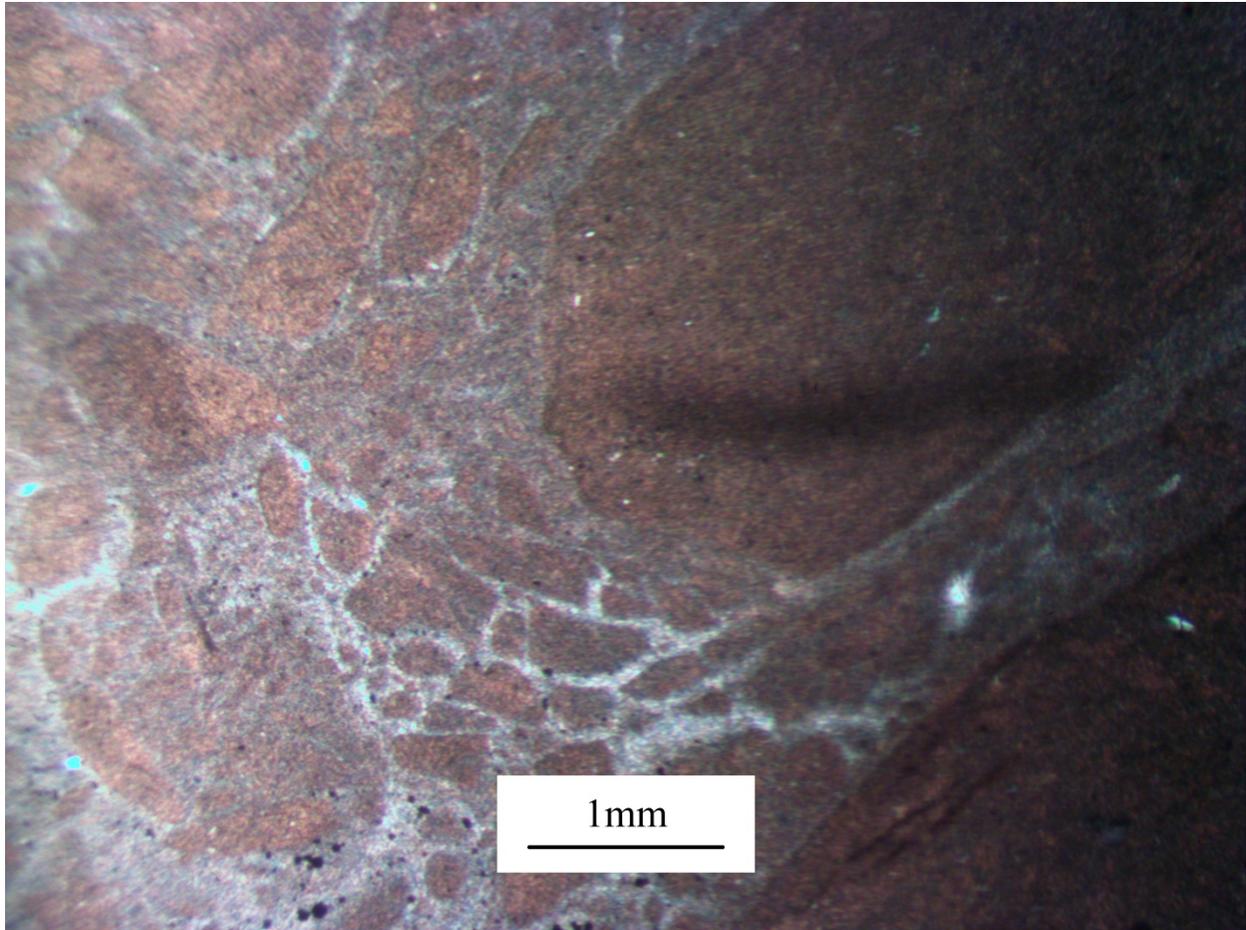
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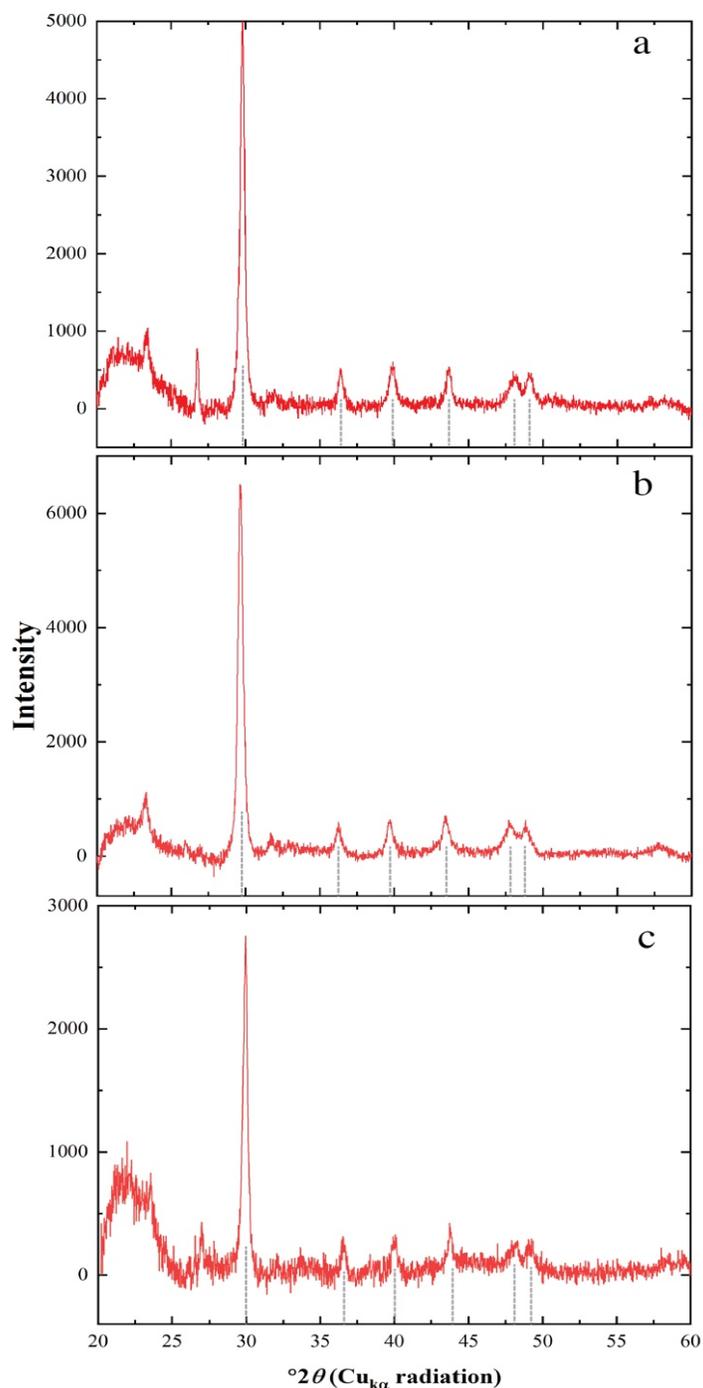
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