# Supplement 3-Supplemental Data

## Syntaxial Cementation Examples

### High resolution images of the specimen in Fig. 4

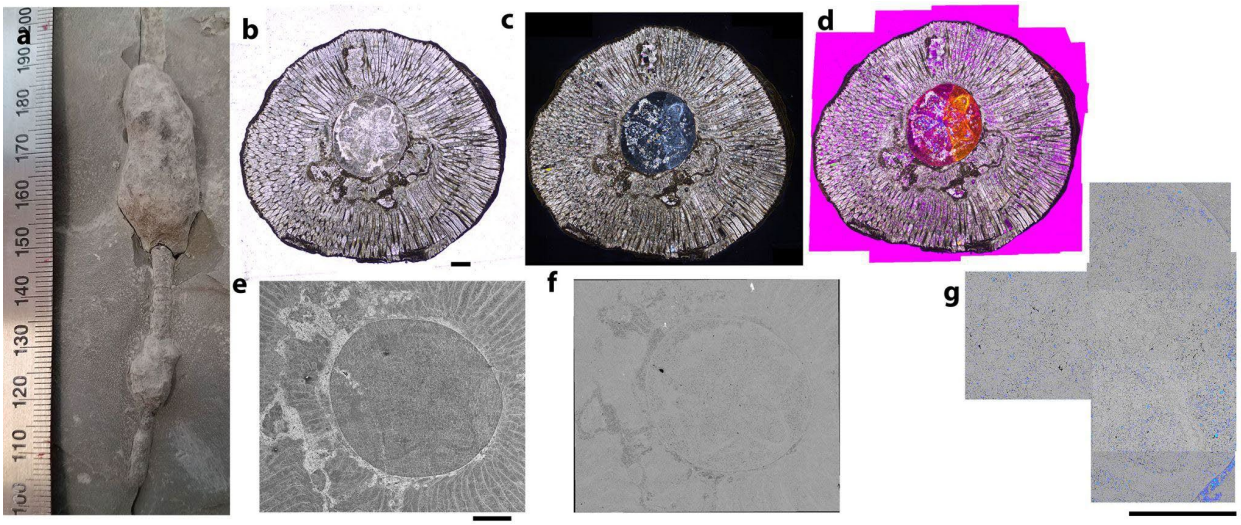


Fig. S3-1. High resolution mosaic images of figured specimen. **A.** Whole specimen in context for reference. Photo scale in mm. **b-g.** Cross section taken from within the large encrusting bryozoan in the top part of the picture. **b.** Plane polarized light (PPL) view. **c.** Cross polarized light (XPL) view. **d.** XPL plus first order red. **e.** Scanning electron microscopy secondary electrons (SEM-SE) image of lightly etched surface. **f.** Back scattered electron (BSE) image. **g.** Larger mosaic of BSE images overlain with Mg map ("light blue, hue 206°) from electron dispersive spectroscopy (EDS) showing the coincidence of dark BSE spots with small dolomite crystals. All scale bars **b-g** are 1 mm.

## Extra Section of Column from Morrow

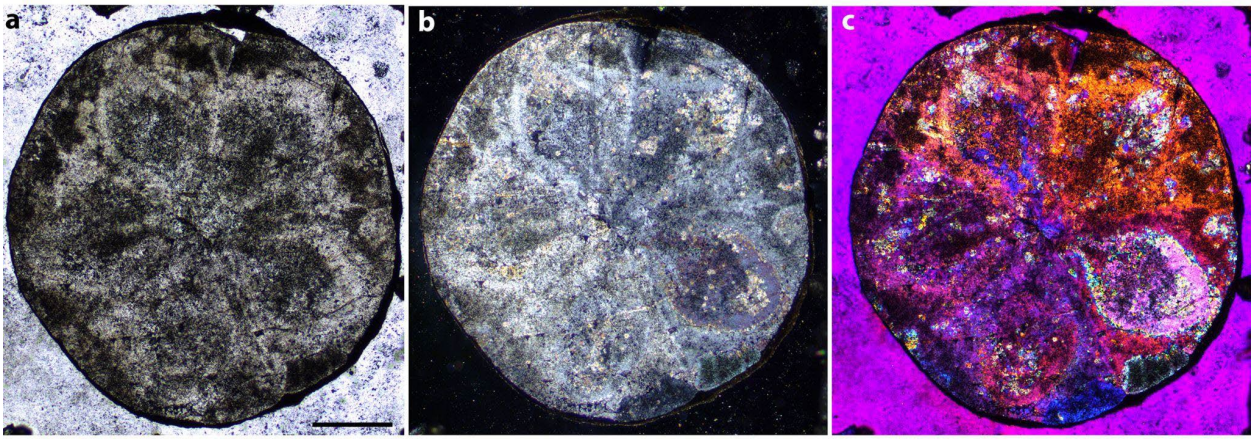


Fig. S3-2. High resolution optical microscope mosaic images of an additional columnal cross section from the Morrow specimen. **a.** PPL. **b.** XPL. **c.** XPL with First Order Red. Scale bar is 1 mm.

## Columnal Cross Section from Southgate Hill

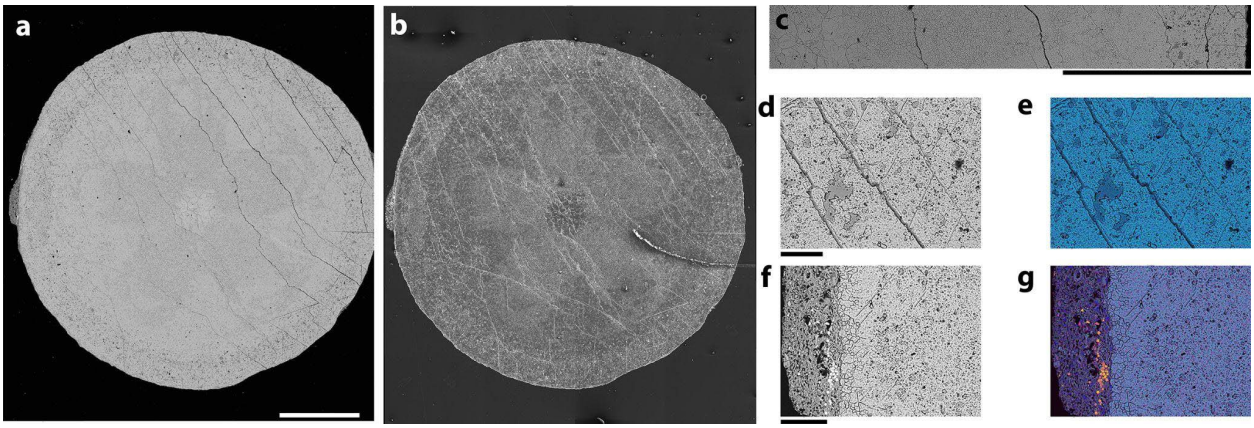


Fig. S3-3. High resolution optical microscope mosaic images of a columnal from Southgate Hill. All images of lightly etched specimen. **a-b.** images of the entire columnal cross section. Scale bar 1 mm. **a.** BSE. **b.** SE. **c.** Higher resolution strip of BSE across half of the columnal. Scale bar is 1 mm. **d-e.** Small area showing minute dolomite crystals. Scale bar is 100 μm. **d.** BSE. **e.** EDS

element map. **f-g.** Another small area showing dolomite and pyrite. Scale is 100 μm. **f.** BSE. **g.** EDS element map.

# Phosphatized Specimens

## Additional files of specimen in Fig. 5

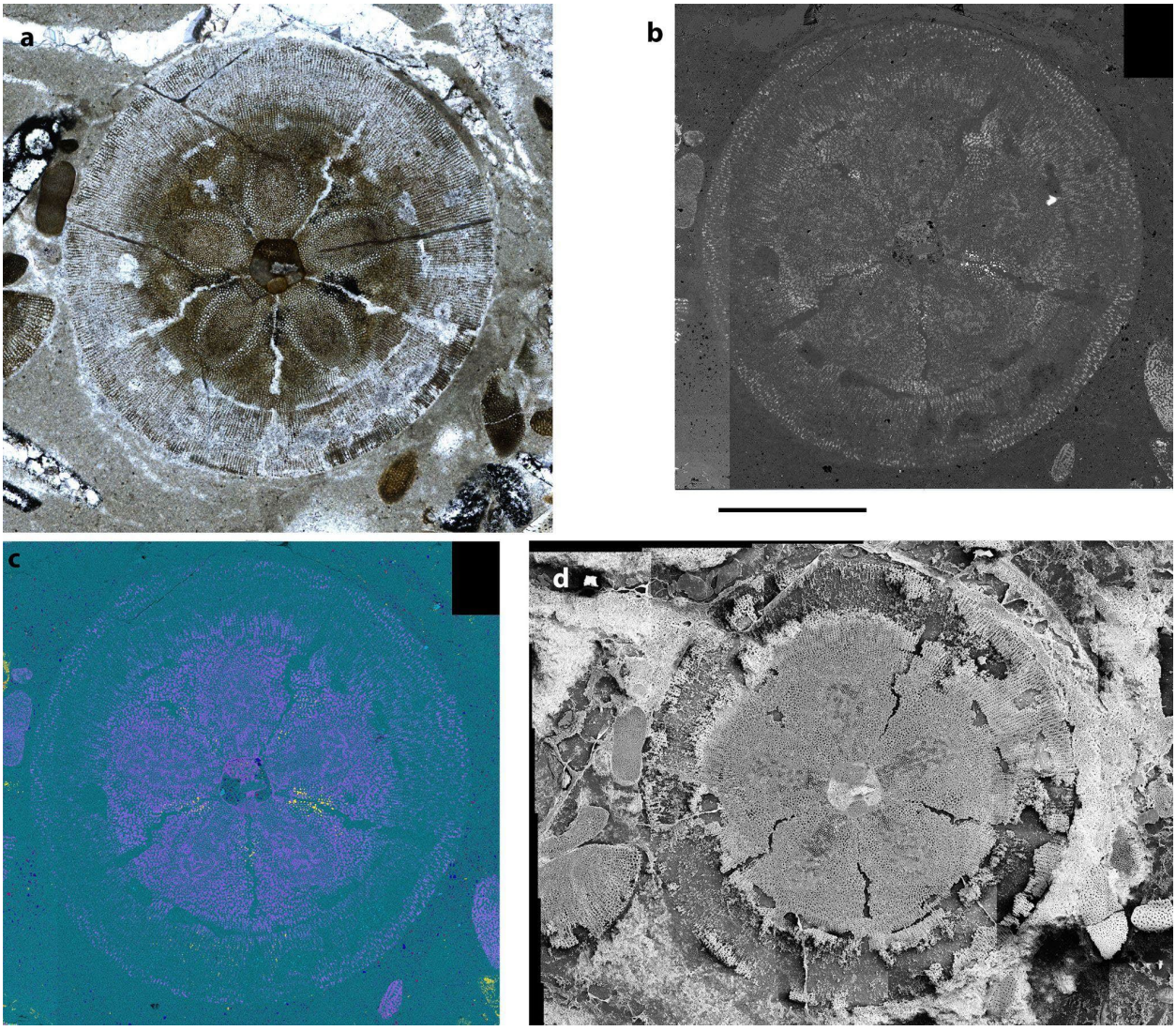


Fig. S3-4. Full mosaics and analyses of figured specimen on Fig. 5. **a-c**. Before etching. **a.** PPL. **b.** BSE. **c.** EDS element Map. **d.** SE after etching. Scale bar is 1 mm.

Other columnals from Milton

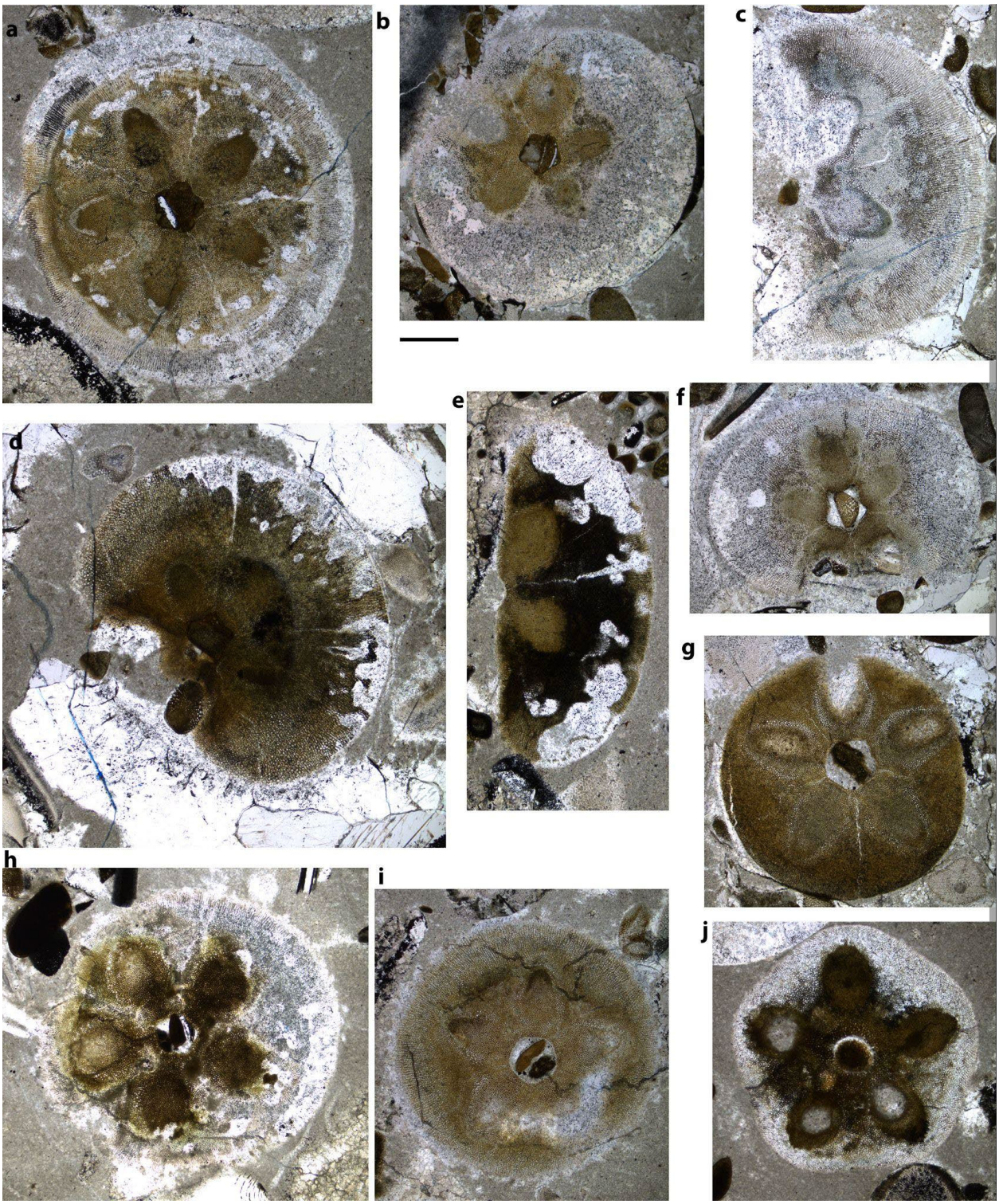


Fig. S3-5. Other Milton specimens in microphotomosaics. All plane polarized light. All come from bedding-parallel thin sections. Each image is a different columnal. **a.** Shows phosphatized facet but less phosphatized epifacet. Some development of early calcite cementation areas

(cleaner) blocking phosphate around perimeter of facet. Slight tilt with respect to section plane results in elongation UL-LR. **b.** Shows strong phosphatization of just the petal and crenularium with less phosphate outside of that. Tilt elongation UR-LL. Small spots of early calcite marking in the facet-epifacet boundary. **c.** Shows only slightest phosphatization of the crenularium, very little early calcite and more extreme tilt, resulting in elongation T-B forcing left side out of the plane of the section. **d.** Larger columnal showing almost complete phosphatization with dramatic areas of early calcite blocking phosphatization along the outer edge of the columnal. Strong tilt with UL-LR elongation and LL side out of plane. **e.** Completely phosphatized except for spectacular ealy calcite along the columnal edge and the sutures. Strongly tilted with the left side out of the thin section plane. **f.** Phosphatization restricted mostly to petals and crenularium and fading outward, strong tilt with L-R elongation revealing early calcite, in this view found only on the left and right edges of the columnal, where the section plane intersects the central disk central disk of the columnal around the edges. This central disk edge distribution of early calcite is common among columnals in this sample. **g.** Columnal showing only facet with plane of section intersecting near surface of columnal. Apparent convex shape of facet suggests *Cincinnaticrinus* "internodal" which alternates with every other columnal, fitting into the concave facets of the alternating columnals, and lacking epifacets. **h.** Strong phosphatization of the petals and crenularium again fading outward with early calcite along the edges. **i.** Glancing section of a well phosphatized ossicle that is only slightly tilted. Still the LR edge barely exits the plane of the thin section and the unevenness of the columnal surface shows. **j.** Petals and crenularium phosphatized with less phosphate outward. Plane of section is near surface of columnal. May also be an "internodal". Scale bar is 1 mm.

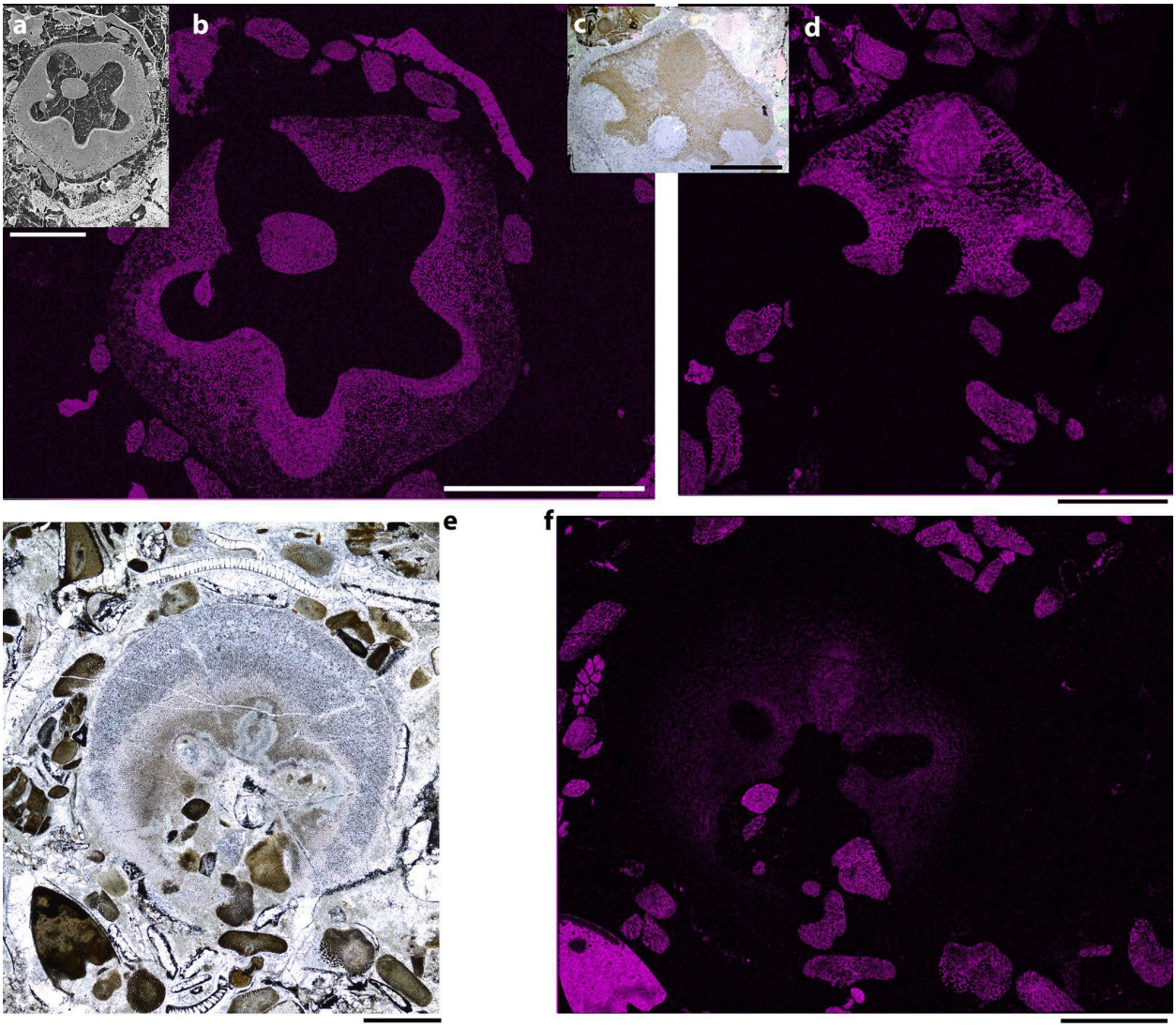


Fig. S3-6. Other Milton specimens with EDS element maps showing phosphorus (P, magenta, hue 300°). **a-b.** Unidentified echinoderm ossicle. Scale bar is 2 mm. **A.** PPL. **B.** EDS element map for phosphorus. **c-d.** Partial slice through pentagonal ossicle, possibly *Cincinnaticrinus*. Scale bar is 1 mm. **c.** PPL. **d.** EDS element map of phosphorus. **e-f**. Large *Cincinnaticrinus* ossicle, glancing cut, lightly phosphatized. Scale bar is 1 mm. **e.** PPL. **f.** EDS element map of phosphorous (P, magenta, hue 300°).

Lawrenceburg specimen

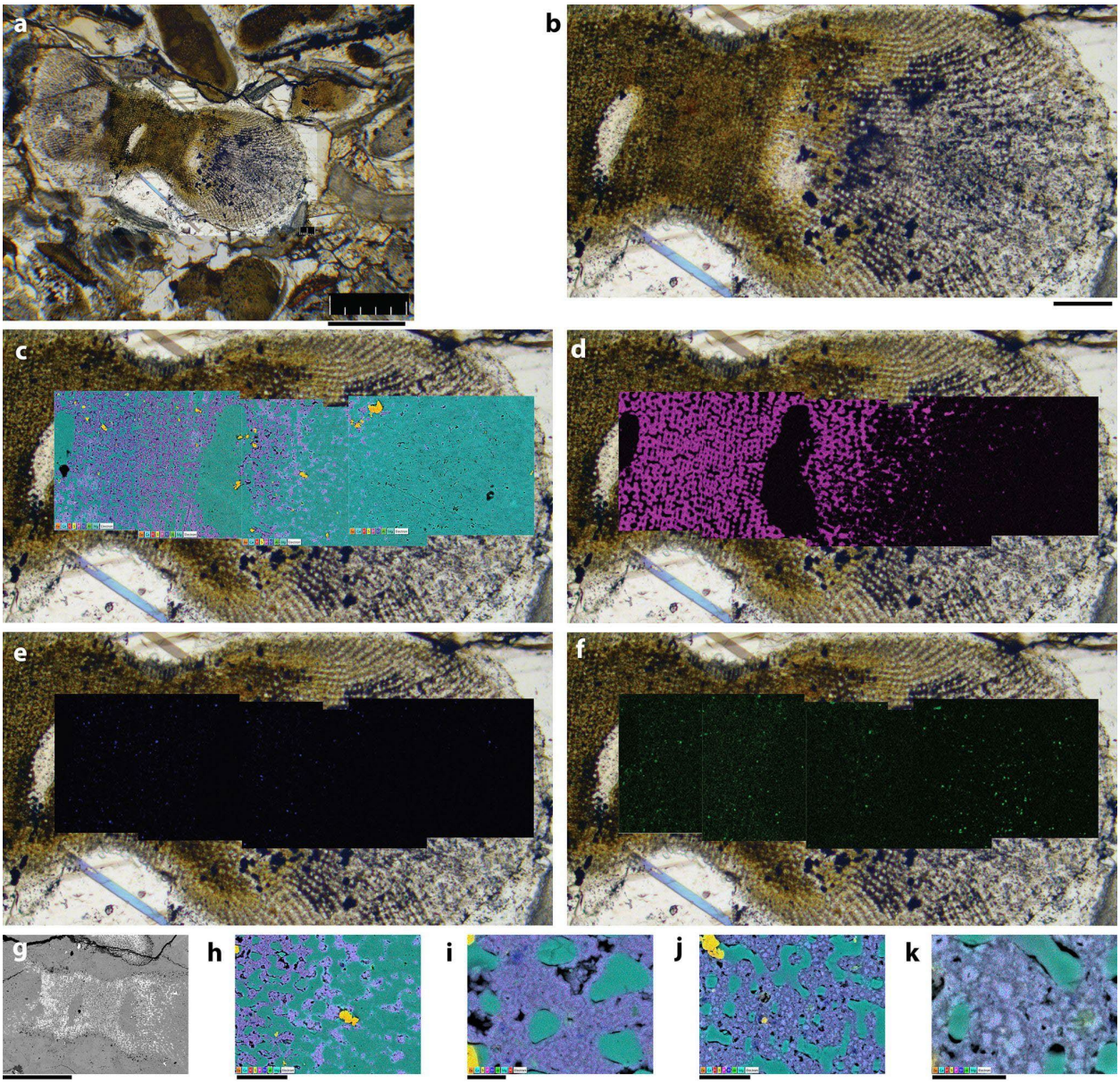


Fig. S3-7. Additional EDS study of a single columnal, possibly *Cincinnaticrinus*, from Lawrenceburg. **a.** PPL thin section view. Scale bar is 500 µm. **b.** Enlargement of the ossicle. Scale bar is 100 µm. **c.** SEM/EDS maps laid over PPL image showing elements Fe (orange, hue 30°), Ca (cyan, hue 180°) K (red, hue 0°), S (yellow, hue 60°), P (magenta, hue 300°), Si (blue, 240°), Al (green, hue 120°), Mg ("light blue", hue 206°). **d**. Phosphate only map. **e.** Silicon map. **f.** Aluminum map. **g.** BSE image of same ossicle. Scale bar is 500 µm. **h.** EDS element map.

Scale bar is 50 µm. **i.** Enlarged element map showing uniformity of calcite and siliciclastic inclusions in the "clotted" vuggy phosphate. Scale bar is 10 µm. **j.** EDS element map showing uniform skeletal calcite and siliciclastic inclusions in the "clotted" vuggy phosphate. Scale bar is 25 µm. **k.** Enlarged element map showing uniform skeletal calcite and siliciclastic inclusions in the "clotted" vuggy phosphate. Scale bar is 10 µm.

# Specimen from Bedford

## Element maps

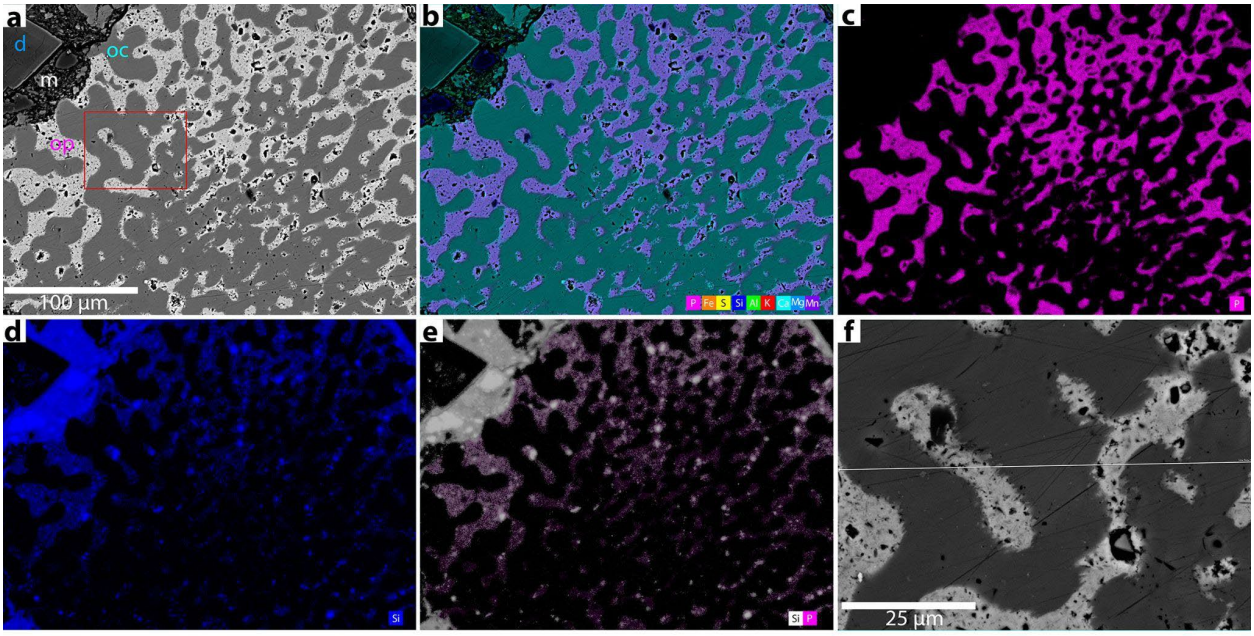


Fig. S3-8. SEM/EDS images of an ossicle fragment in a muddy matrix from Bedford showing the presence of detrital material in the phosphatic phase (upper left of images), and the absence of detrital material in the calcitic phase (compare Fig. 8). Annotations are as follows: d = dolomite rhomb (matrix); m = mud; oc = ossicle calcite; op = ossicle phosphate. **a.** BSE image with box inset for position of Fig. 6F. Note siliciclastic mud (m) in the upper left and upper right

corners, and the dolomite rhomb (d) in the upper left, dark spots in the lighter phosphatic areas (op), and relative uniformity of the darker calcitic areas (oc) of the ossicle. Scale bar is 100 μm. **b.** BSE image layered with EDS elemental maps of Ca (cyan, hue 180°), P (magenta, hue 300°), Si (blue, hue 240°), Mg ("light blue", hue 206°), Al (green, hue 120°), Fe (orange, hue 30°), S (yellow, hue 60°), Al (green, hue 120°), K (red, hue 0°), and Mn (violet, hue 270°). **c.** EDS map of P (magenta, hue 300°) standing in for CFA, showing inclusions of non-phosphatic materials as dark spots. **d.** EDS map of Si standing in for quartz, clays, and other aluminosilicates. Note the high intensity in the upper left siliciclastics, and penetration into the phosphatic areas of the ossicle, decreasing away from the external siliciclastics. **e.** EDS maps of Si (white) overlaid on P (subdued hue 300°) showing the almost exclusive association of Si with P within the ossicle, and its exclusion from the calcitic part of the ossicle (dark areas lacking P). **f.** Enlargement of inset box in **a**, showing the position of the linear analysis (Fig. S3-9).

# Line Scans

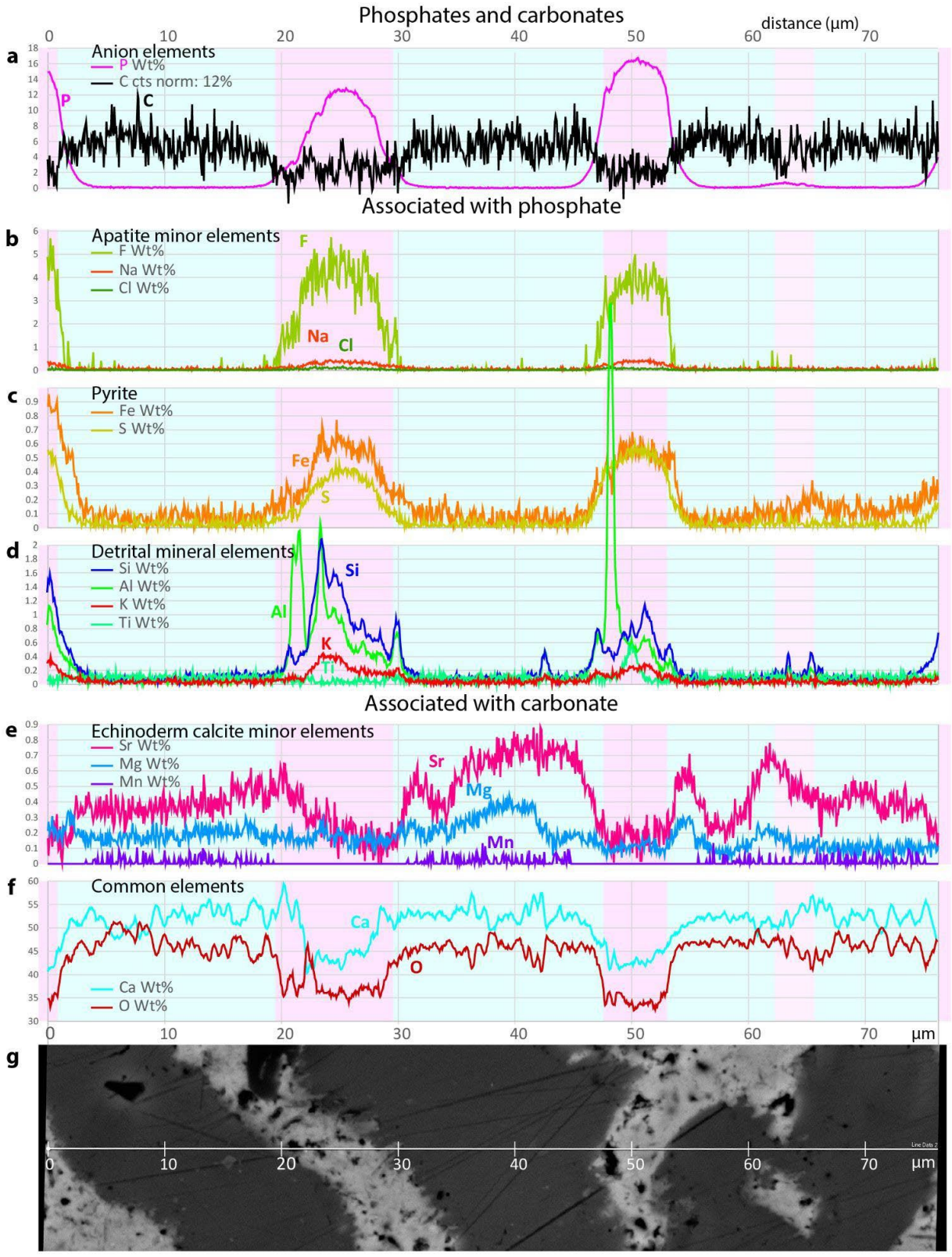
Phosphates and carbonates
distance (µm)
a
Anion elements
P Wt%
C cts norm: 12%
P
C
Associated with phosphate
b
Apatite minor elements
F Wt%
Na Wt%
Cl Wt%
F
Na
Cl
c
Pyrite
Fe Wt%
S Wt%
Fe
S
d
Detrital mineral elements
Si Wt%
Al Wt%
K Wt%
Ti Wt%
Si
Al
K
Ti
Associated with carbonate
e
Echinoderm calcite minor elements
Sr Wt%
Mg Wt%
Mn Wt%
Sr
Mg
Mn
f
Common elements
Ca
O
Ca Wt%
O Wt%
µm
g
µm

Fig. S3-9. Elemental distributions (compare Fig. 9) across the analytical line (Fig. S3-8), expressed as weight percent of all but carbon. Carbon is added as matrix-corrected counts normalized to 12 (average weight percent of carbon in calcite) for illustration purposes. **a.** The unique elements in the complex anions of apatite (P) and carbonates (C). **b.** Minor elements frequently found in CFA (F, Na, Cl). **c.** elements found in pyrite (Fe, S). **d.** Elements that mainly occur in detrital minerals, principally quartz, clays, and rutile (Si, Al, K, Ti). **e.** Minor elements associated with skeletal calcite (Sr, Mg, Mn). **f.** Major elements found in several phases. Line colors may be darkened slightly from map colors in Fig. S3-8 for better contrast against a white background. **g.** Detail of thin section in Fig. S3-8f showing position of line of analysis.