minerals

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# SUPPLEMENTARY INFORMATION

## Structural and geochemical assessment of the coralline alga *Tethysphytum antarcticum* from Terra Nova Bay, Ross Sea, Antarctica

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### Thin sections

Complementary to the SEM investigations, a further sample slice was cut perpendicular to the rock and algal crust, to examine the skeletal mineralogy and crystal orientation. In an EPOVAC chamber, the dry sample was vacuum-embedded in a two-component epoxy resin (Biresin L48 resin and hardener, 4:1), cured 48 hours, cut with a water-cooled PRESI Mecatome precision rock saw and grinded on a PRESI Minitech 300 SPI using diamond discs with 125 µm, 75 µm, 54 µm, and 18 µm graining. The surface was then glued with BIRESIN epoxy resin to a glass slide and ground to 20 µm final thickness using a G&N MPS 2 R300. Sections were photographed in normal and polarized translucent light with a Zeiss Axio Zoom.V16, equipped with a Zeiss Plan-NEOFLUAR Z 1x/0.25 FWD 56mm. The software Zeiss ZEN core 2.7.0 was used to produce high-resolution images via the tile stitching mode. All images were post-processed in Adobe Photoshop by means of sharpening, tonal value adjustment, and shadows/highlights adjustments.

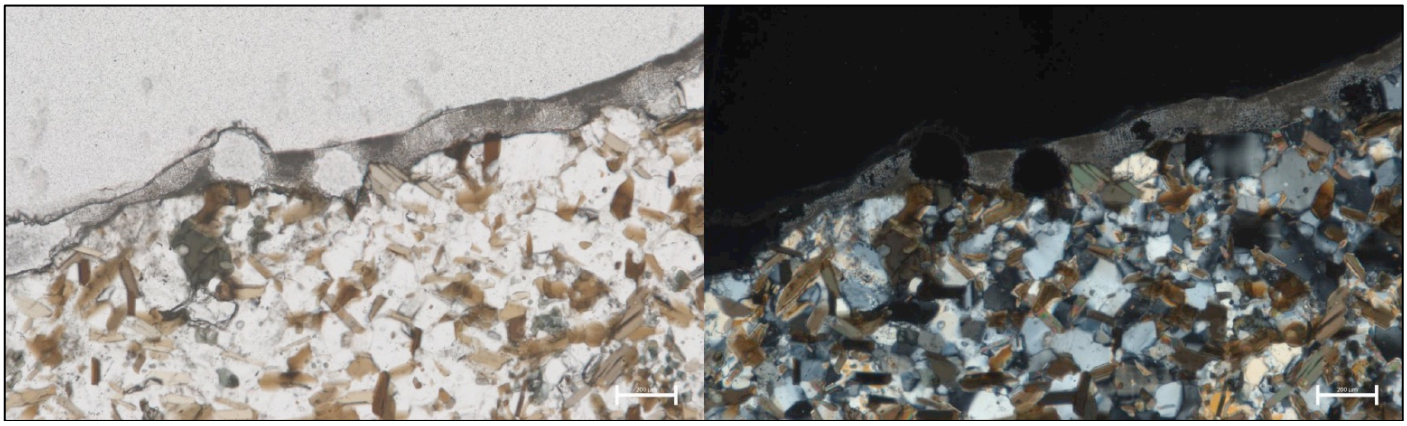

**Figure S1.** Thin section images with translucent light (left) and polarized light under crossed-nichols (right); the crystalline bedrock cobble is covered by a ~150 µm thin veneer of the calcareous coralline red alga *Thethysphytum antarcticum*. Two large conceptacles (sporangial cavities) in the center are embedded in the monomerous thallus. Electron-Microprobe map 3 is located between them. Scale bars: 200 µm.

### µRaman spectroscopy

The rock thin section was examined for its principal mineral composition at the University of Padova (Organic Chemistry Institute) with a ThermoScientific micro-Raman Spectroscope. The monochromatic 532 nm DXR laser was run at 3mW laser power, with a 25 µm aperture and a 50x LWD objective. Four replicates were taken for each spot measurement, with 30 s dwell time and Raman shift acquired between 50 and 3500 cm-1, at 900 lines/mm grating. Data were processed, background corrected and visualized (Fig. S2) with the OMNIC-software and compared to mineral reference spectra from the RRUFF-database (http://rruff.info). Principal peaks indicated orthoclase and phlogopite (Fig. S2).

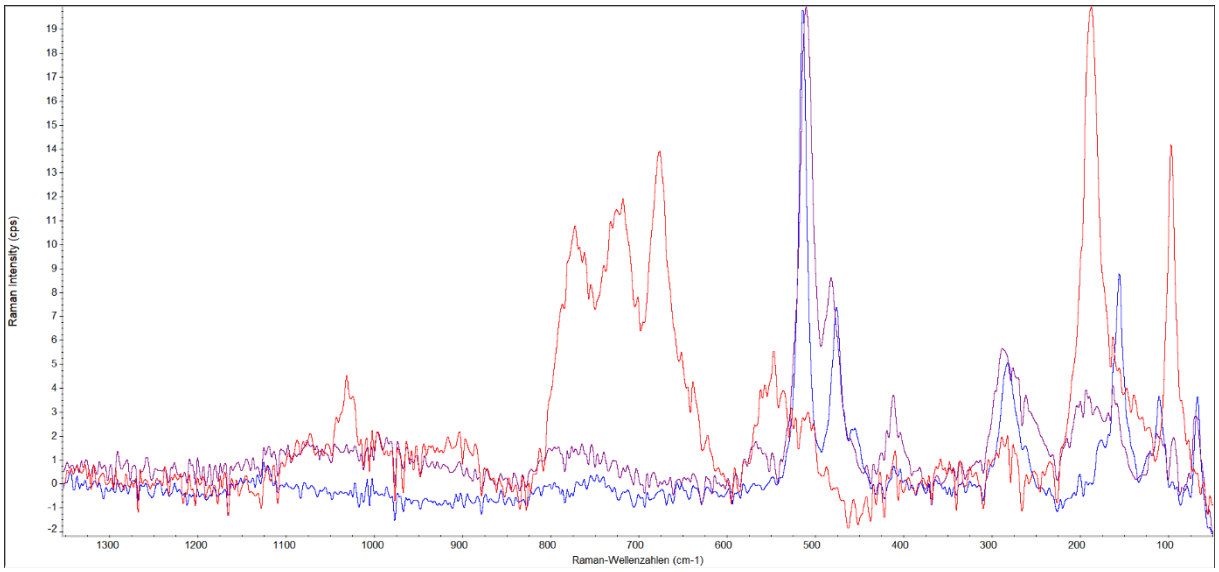


**Figure S2.** Raman spectra of two dominant minerals in the rock substrate beneath the algal crust are indicative of orthoclase (blue and purple) and phlogopite (red).

## X-ray powder diffractometry (XRD)

The XRD-diffractograms showed characteristic peaks for the (*hkl*)-surfaces at the 2Θ Cu $K_\alpha$ angles as follows: (*012*) at 23.22°, (*104*) at 29.63°, (110) at 36.23°, (113) at 39.70°, (202) at 43.47°, (018) at 47.89°, (116) at 48.88°, (112) at 57.84°. Refined Rietfeld unit cell parameters a, c and cell volume are given along with calculated MgCO3 (mol%) in Table S1. Calculations are based on regressions provided by Titschack et al. 2011 [42].

**Table S1.** Summarized unit cell parameters from Rietfeld refinement and $MgCO_3$ (mol%)

| **Sample ID** | ***a*** **(Å)** | ***C*** **(Å)** | **Volume (Å³)** | **Mg occ refined** | **mol% $MgCO_3$ (*a* - based)** | **mol% $MgCO_3$ (volume - based)** |
|---|---|---|---|---|---|---|
| Bulk powder 1 | 4.958 | 16.933 | 360.545 | 12.08 | 8.30 | 7.96 |
| Bulk powder 2 | 4.958 | 16.930 | 360.390 | 11.28 | 8.47 | 8.13 |
| Bulk powder 3 | 4.958 | 16.932 | 360.485 | 10.35 | 8.36 | 8.03 |
| | | | | | | |
| Average | 4.958 | 16.932 | 360.473 | 11.24 | 8.38 | 8.04 |
| Standard deviation | 0.0003 | 0.0011 | 0.0637 | 0.0071 | 0.0007 | 0.0007 |

**Table S2.** Quantitative EMP-spot measurements

| EMP-spot main-thallus | Distance (mm) | MgO (weight%) | CaO (weight%) | SrO (weight%) | $SO_2$ (weight%) | $CO_2$ (weight%) | Mg/Ca (mol/mol) | $MgCO_3$ (mol%) | Sr/Ca (mol/mol) | $SrCO_3$ (mol%) | $CaCO_3$ (mol%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TNB-1 | 0 | 3.266 | 51.676 | 0.239 | 0.598 | 44.221 | 0.0879 | 8.06 | 0.0025 | 0.23 | 91.71 |
| TNB-2 | 0.083 | 3.428 | 51.449 | 0.268 | 0.622 | 44.233 | 0.0927 | 8.46 | 0.0028 | 0.26 | 91.28 |
| TNB-3 | 0.255 | 3.786 | 51.085 | 0.216 | 0.597 | 44.316 | 0.1031 | 9.33 | 0.0023 | 0.21 | 90.46 |
| TNB-4 | 0.316 | 3.280 | 51.667 | 0.222 | 0.609 | 44.223 | 0.0883 | 8.10 | 0.0023 | 0.21 | 91.69 |
| TNB-5 | 0.390 | 2.907 | 52.032 | 0.284 | 0.647 | 44.129 | 0.0777 | 7.19 | 0.0030 | 0.27 | 92.53 |
| TNB-6 | 0.479 | 3.075 | 51.909 | 0.212 | 0.621 | 44.184 | 0.0824 | 7.60 | 0.0022 | 0.20 | 92.20 |
| TNB-7 | 0.543 | 3.015 | 52.031 | 0.176 | 0.577 | 44.200 | 0.0806 | 7.45 | 0.0018 | 0.17 | 92.38 |
| TNB-8 | 0.622 | 3.636 | 51.133 | 0.315 | 0.682 | 44.233 | 0.0990 | 8.98 | 0.0033 | 0.30 | 90.72 |
| TNB-10 | 0.717 | 1.468 | 53.855 | 0.190 | 0.538 | 43.948 | 0.0379 | 3.65 | 0.0019 | 0.18 | 96.17 |
| TNB-11 | 0.745 | 2.177 | 53.085 | 0.154 | 0.480 | 44.103 | 0.0571 | 5.39 | 0.0016 | 0.15 | 94.46 |
| TNB-12 | 0.858 | 3.710 | 51.206 | 0.238 | 0.509 | 44.337 | 0.1008 | 9.14 | 0.0025 | 0.23 | 90.64 |
| TNB-13 | 0.894 | 3.307 | 51.676 | 0.185 | 0.590 | 44.243 | 0.0890 | 8.16 | 0.0019 | 0.18 | 91.66 |
| TNB-14 | 0.927 | 3.099 | 51.952 | 0.142 | 0.592 | 44.215 | 0.0830 | 7.65 | 0.0015 | 0.14 | 92.21 |
| TNB-15 | 1.146 | 3.030 | 52.086 | 0.102 | 0.553 | 44.228 | 0.0809 | 7.48 | 0.0011 | 0.10 | 92.42 |
| TNB-16 | 1.190 | 3.520 | 51.327 | 0.317 | 0.577 | 44.259 | 0.0954 | 8.68 | 0.0033 | 0.30 | 91.01 |
| TNB-17 | 1.246 | 3.135 | 51.865 | 0.217 | 0.565 | 44.218 | 0.0841 | 7.74 | 0.0023 | 0.21 | 92.05 |
| TNB-18 | 1.379 | 3.248 | 52.060 | 0.036 | 0.240 | 44.417 | 0.0868 | 7.98 | 0.0004 | 0.03 | 91.98 |
| TNB-19 | 1.418 | 2.902 | 52.186 | 0.301 | 0.360 | 44.251 | 0.0774 | 7.16 | 0.0031 | 0.29 | 92.55 |
| TNB-20 | 1.546 | 2.819 | 52.441 | 0.057 | 0.427 | 44.256 | 0.0748 | 6.95 | 0.0006 | 0.05 | 92.99 |
| TNB-21 | 2.254 | 3.940 | 50.955 | 0.327 | 0.349 | 44.429 | 0.1076 | 9.68 | 0.0035 | 0.31 | 90.00 |
| TNB-22 | 2.371 | 3.764 | 51.286 | 0.255 | 0.229 | 44.467 | 0.1021 | 9.24 | 0.0027 | 0.24 | 90.51 |
| TNB-23 | 2.418 | 2.412 | 52.710 | 0.182 | 0.620 | 44.076 | 0.0637 | 5.98 | 0.0019 | 0.17 | 93.85 |
| TNB-25 | 2.742 | 3.401 | 51.480 | 0.307 | 0.567 | 44.245 | 0.0919 | 8.39 | 0.0032 | 0.29 | 91.31 |
| TNB-26 | 2.789 | 3.124 | 51.841 | 0.330 | 0.470 | 44.235 | 0.0839 | 7.71 | 0.0034 | 0.32 | 91.97 |
| TNB-28 | 3.067 | 3.083 | 51.871 | 0.285 | 0.567 | 44.194 | 0.0827 | 7.62 | 0.0030 | 0.27 | 92.11 |
| TNB-29 | 3.169 | 2.431 | 52.778 | 0.261 | 0.345 | 44.185 | 0.0641 | 6.01 | 0.0027 | 0.25 | 93.74 |
| TNB-30 | 3.300 | 3.756 | 51.282 | 0.182 | 0.358 | 44.423 | 0.1019 | 9.23 | 0.0019 | 0.17 | 90.59 |
| TNB-31 | 3.422 | 2.525 | 52.623 | 0.206 | 0.504 | 44.142 | 0.0668 | 6.25 | 0.0021 | 0.20 | 93.55 |
| TNB-32 | 3.579 | 3.328 | 51.586 | 0.387 | 0.415 | 44.283 | 0.0898 | 8.21 | 0.0041 | 0.37 | 91.42 |
| TNB-33 | 3.715 | 4.035 | 50.846 | 0.207 | 0.515 | 44.397 | 0.1104 | 9.92 | 0.0022 | 0.20 | 89.88 |
| TNB-34 | 3.801 | 2.740 | 52.366 | 0.187 | 0.542 | 44.166 | 0.0728 | 6.77 | 0.0019 | 0.18 | 93.05 |
| TNB-35 | 4.075 | 4.015 | 50.882 | 0.183 | 0.527 | 44.393 | 0.1098 | 9.88 | 0.0019 | 0.18 | 89.95 |
| TNB-36 | 4.242 | 3.770 | 51.193 | 0.155 | 0.523 | 44.358 | 0.1025 | 9.28 | 0.0016 | 0.15 | 90.57 |
| TNB-37 | 4.342 | 4.148 | 50.635 | 0.321 | 0.495 | 44.402 | 0.1140 | 10.20 | 0.0034 | 0.31 | 89.49 |
| TNB-38 | 4.535 | 4.266 | 50.579 | 0.276 | 0.410 | 44.469 | 0.1174 | 10.48 | 0.0030 | 0.26 | 89.26 |
| TNB-39 | 4.655 | 3.224 | 51.732 | 0.274 | 0.534 | 44.235 | 0.0867 | 7.96 | 0.0029 | 0.26 | 91.78 |
| TNB-41 | 4.888 | 3.174 | 51.716 | 0.334 | 0.582 | 44.193 | 0.0854 | 7.84 | 0.0035 | 0.32 | 91.84 |
| TNB-43 | 5.065 | 1.784 | 53.454 | 0.174 | 0.617 | 43.971 | 0.0464 | 4.43 | 0.0018 | 0.17 | 95.40 |
| TNB-45 | 5.336 | 3.491 | 51.390 | 0.334 | 0.503 | 44.283 | 0.0945 | 8.61 | 0.0035 | 0.32 | 91.07 |
| TNB-46 | 5.515 | 1.988 | 53.358 | 0.111 | 0.450 | 44.092 | 0.0518 | 4.92 | 0.0011 | 0.11 | 94.97 |
| TNB-47 | 5.600 | 3.006 | 52.062 | 0.239 | 0.452 | 44.241 | 0.0803 | 7.42 | 0.0025 | 0.23 | 92.35 |
| TNB-48 | 5.800 | 3.729 | 51.171 | 0.212 | 0.569 | 44.319 | 0.1014 | 9.19 | 0.0022 | 0.20 | 90.61 |
| TNB-49 | 5.945 | 4.585 | 50.232 | 0.243 | 0.410 | 44.531 | 0.1270 | 11.24 | 0.0026 | 0.23 | 88.53 |
| TNB-50 | 6.101 | 3.471 | 51.479 | 0.291 | 0.444 | 44.314 | 0.0938 | 8.55 | 0.0031 | 0.28 | 91.17 |
| TNB-51 | 6.203 | 3.811 | 51.060 | 0.277 | 0.503 | 44.349 | 0.1038 | 9.38 | 0.0029 | 0.26 | 90.35 |
| TNB-52 | 6.301 | 2.503 | 52.568 | 0.276 | 0.548 | 44.105 | 0.0663 | 6.20 | 0.0028 | 0.27 | 93.54 |
| TNB-53 | 6.422 | 3.467 | 51.483 | 0.297 | 0.438 | 44.315 | 0.0937 | 8.54 | 0.0031 | 0.28 | 91.17 |
| TNB-54 | 6.586 | 1.996 | 53.430 | 0.089 | 0.337 | 44.148 | 0.0520 | 4.94 | 0.0009 | 0.09 | 94.98 |
| TNB-55 | 6.722 | 3.042 | 52.166 | 0.071 | 0.430 | 44.291 | 0.0811 | 7.50 | 0.0007 | 0.07 | 92.43 |
| TNB-56 | 6.812 | 2.772 | 52.234 | 0.302 | 0.544 | 44.148 | 0.0738 | 6.86 | 0.0031 | 0.29 | 92.85 |
| TNB-57 | 6.954 | 2.203 | 52.967 | 0.127 | 0.676 | 44.027 | 0.0579 | 5.46 | 0.0013 | 0.12 | 94.41 |
| TNB-58 | 7.131 | 3.511 | 51.471 | 0.201 | 0.505 | 44.312 | 0.0949 | 8.65 | 0.0021 | 0.19 | 91.16 |
| TNB-60 | 7.277 | 3.947 | 50.898 | 0.259 | 0.532 | 44.364 | 0.1079 | 9.72 | 0.0028 | 0.25 | 90.04 |
| TNB-61 | 7.417 | 3.669 | 51.314 | 0.178 | 0.486 | 44.352 | 0.0995 | 9.03 | 0.0019 | 0.17 | 90.80 |
| TNB-62 | 7.517 | 3.449 | 51.694 | 0.061 | 0.437 | 44.360 | 0.0928 | 8.49 | 0.0006 | 0.06 | 91.45 |
| basal-thallus | | | | | | | | | | | |
| TNB-9 | 0.674 | 4.173 | 50.373 | 0.216 | 1.057 | 44.180 | 0.1153 | 10.31 | 0.0023 | 0.21 | 89.48 |
| TNB-40 | 4.731 | 4.973 | 49.739 | 0.311 | 0.382 | 44.596 | 0.1391 | 12.18 | 0.0034 | 0.30 | 87.53 |
| TNB-42 | 4.962 | 5.207 | 49.149 | 0.358 | 0.878 | 44.408 | 0.1474 | 12.80 | 0.0039 | 0.34 | 86.85 |
| TNB-44 | 5.153 | 5.059 | 49.496 | 0.190 | 0.806 | 44.449 | 0.1422 | 12.43 | 0.0021 | 0.18 | 87.39 |
| TNB-64 | 7.696 | 4.524 | 50.017 | 0.219 | 0.955 | 44.285 | 0.1259 | 11.16 | 0.0024 | 0.21 | 88.63 |
| outliers | | | | | | | | | | | |
| TNB-24 | 2.652 | 0.170 | 55.435 | 0.123 | 0.530 | 43.742 | 0.0043 | 0.42 | 0.0012 | 0.12 | 99.46 |
| TNB-27 | 2.982 | 0.354 | 55.293 | 0.078 | 0.462 | 43.812 | 0.0089 | 0.88 | 0.0008 | 0.08 | 99.04 |
| TNB-59 | 7.210 | 0.242 | 55.652 | 0.045 | 0.104 | 43.957 | 0.0061 | 0.60 | 0.0004 | 0.04 | 99.36 |
| TNB-63 | 7.664 | 0.239 | 54.350 | 1.267 | 0.694 | 43.451 | 0.0061 | 0.60 | 0.0126 | 1.24 | 98.16 |

## Algal architecture

The vegetative plant tissue of the alga *Thetysphytum antarcticum* features a thallus, that is made up of a basal thallus that infills the uneven surface topography of the lithic substrate, and a main thallus above (Fig. S3). Reproductive spore bearing chambers, called conceptacles occur within the main-thallus (Fig. S3A). The basal layer is constructed by box-shaped cells, which can occur as pure organic to poorly calcified and as strongly calcified with the entire cell

lumen filled by calcite. In EMP-maps (e.g. Figs. 8 and 9), the organic parts contain high levels of sulfur, low levels of Ca, but no Mg. Instead, the blocky calcified part (Fig. S3B) contains high levels of sulfur, high-levels of magnesium and high-levels of calcium (see EMP-map 1 in Fig. 8).

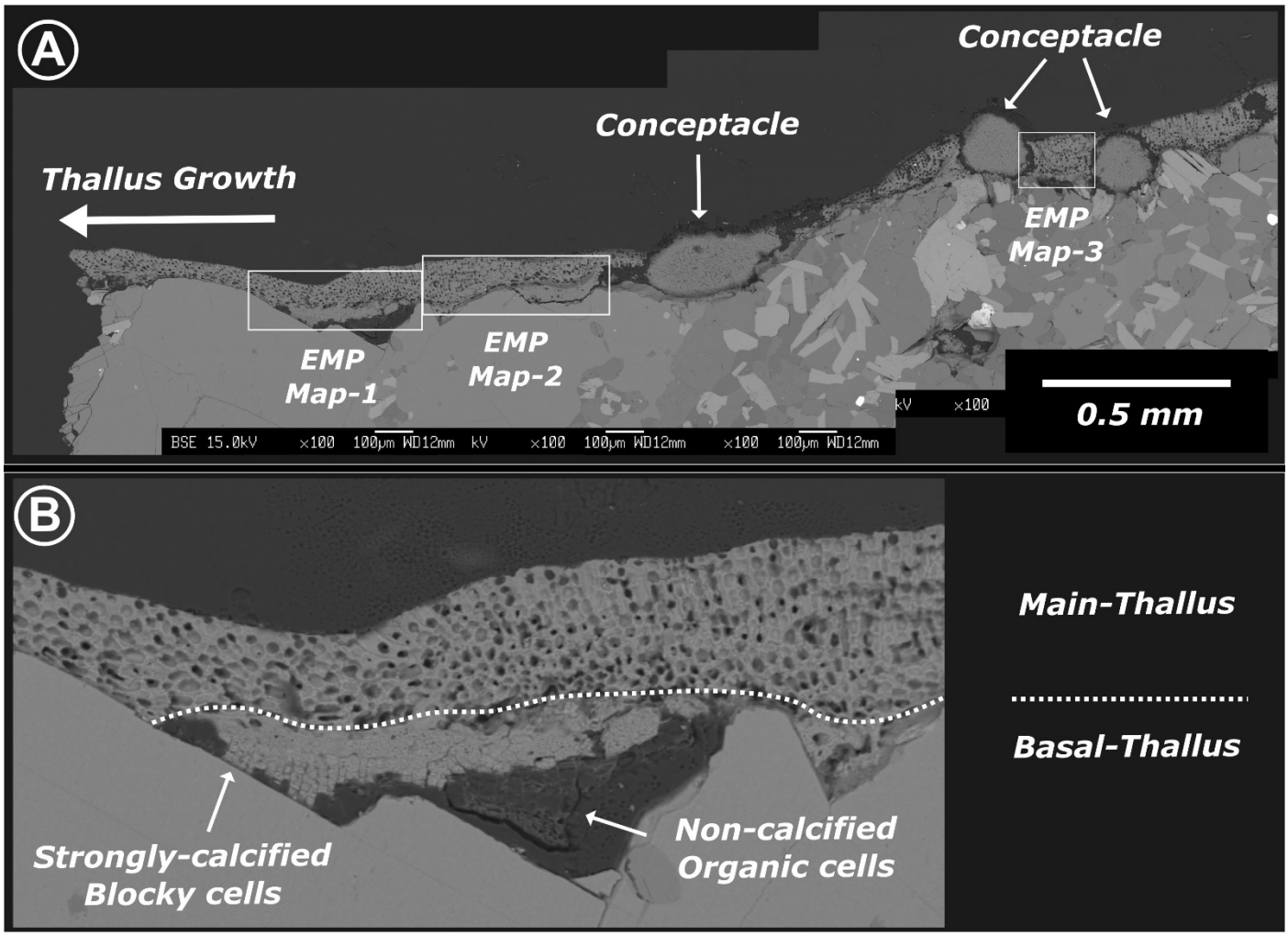


**Figure S3.** Basic architecture of the calcareous coralline alga *Thetysphytum antarcticum* with conceptacles interspersed within the thallus (A), and a clear separation of a basal thallus and the main-thallus above (B). The basal layer consists of box shaped organic cells with varying degrees of high-Mg calcite infilling.