U-Pb Zircon Geochronology Results from the Provo and Duchesne 30' x 60' Quadrangles, Utah

by

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INTRODUCTION

This Open-File Report makes available raw analytical data from laboratory procedures completed to determine the age of rock samples collected during geologic investigations funded or partially supported by the Utah Geological Survey (UGS) and the U.S. Geological Survey National Cooperative Geologic Mapping Program (STATEMAP). The references listed in table 1 generally provide additional information such as sample location, geologic setting, and significance or interpretation of the samples in the context of the area where they were collected. The data were collected in the lab by K.N. Constenius and prepared by the Arizona Laserchron Center, Department of Geosciences, University of Arizona, Tucson, Arizona, under contract to the UGS. These data are highly technical in nature and proper interpretation requires considerable training in the applicable geochronologic techniques.

The data can be accessed electronically as an attachment to the PDF file of this report and are available at https://ugspub.nr.utah.gov/publications/open_file_reports/ofr-719/ofr-719.zip.

DISCLAIMER

ACKNOWLEDGMENTS

Geologic mapping of the Provo and Duchesne 30' x 60' quadrangles was funded by the UGS and U.S. Geological Survey, National Cooperative Geologic Mapping Program (NCGMP). Provo was funded through USGS STATEMAP award numbers 99HQAG0138 (1999-2000), 01HQAG100 (2001-02), 02HQAG055 (2002-03), 03HQAG0096 (2003-04), 04HQAG0040 (2004-05), 05HQAG0084 (2005-06), and 06HQAG0037 (2006-07). Duchesne was funded through USGS STATEMAP award numbers G12AC20226 (2012-13), G13AC00169 (2013-14), G14AC00214 (2014-15), G15AC00249 (2015-16), and G16AC00191 (2016-17).

REFERENCES

Constenius, K.N., Clark, D.L., King, J.K., and Ehler, J.B., 2011, Interim geologic map of the Provo 30' x 60' quadrangle, Utah, Wasatch, and Salt Lake Counties, Utah: Utah Geological Survey Open-File Report 586DM, 42 p., 2 plates, scale 1:62,500, contains GIS data, DVD, https://doi.org/10.34191/OFR-586DM.

Constenius, K.N., Coogan, J.K., Clark, D.L., and King, J.K., in preparation, Geologic map of the Provo 30' x 60' quadrangle, Utah, Wasatch, and Salt Lake Counties, Utah: Utah Geological Survey Map, scale 1:62,500.

Sprinkel, D.A., 2018, Interim geologic map of the Duchesne 30' x 60' quadrangle, Duchesne and Wasatch Counties, Utah: Utah Geological Survey Open-File Report 689, 37 p., 2 plates, scale 1:62,500, https://doi.org/10.34191/OFR-689.

Sprinkel, D.A., in preparation, Geologic map of the Duchesne 30' x 60' quadrangle, Duchesne and Wasatch Counties, Utah: Utah Geological Survey Map, scale 1:62,500.

Table 1. *Summary of sample numbers and locations for U-Pb zircon samples from the Provo and Duchesne 30' x 60' quadrangle areas.*

Sample Number	Geologic Unit	30'x60' quadrangle	7.5' quadrangle	UTM easting NAD27-12	UTM northing NAD27-12	Latitude (°N) WGS84	Longitude (°W) WGS84	Analysis Year	Reference
KNC053107-3	Tibble Fm.	Provo	Granger Mountain	458511	4454797	40.24444	111.48853	2007	Constenius and others, 2011, 2020 in prep.
KNC060407-14	Volcanic rocks of East Traverse Mtns.	Provo	Timpanogos Cave	443888	4481994	40.48860	111.66284	2007	Constenius and others, 2011, 2020 in prep.
KNC053108-1	North Horn Fm., upper mbr.	Provo	Spanish Fork Peak	448590	4435591	40.07086	111.60363	2009	Constenius and others, 2011, 2020 in prep.
KNC071308-2	Uinta Fm., Member C	Provo	Co-op Creek	487698	4458523	40.27895	111.14543	2009	Constenius and others, 2011, 2020 in prep.
KNC070109-1	Duchesne River Fm., Starr Flat Mbr.	Provo	Wolf Creek Summit	498695	4470543	40.38733	111.01610	2010	Constenius and others, 2011, 2020 in prep.
KNC070109-2	Duchesne River Fm., Starr Flat Mbr.	Provo	Wolf Creek Summit	498666	4470528	40.38719	111.01644	2010	Constenius and others, 2011, 2020 in prep.
JC 99-37	Lower Ankareh and Upper Thaynes Fms.	Provo	Co-op Creek	482450	4466445	40.35023	111.20738	2010	Constenius and others, 2011, 2020 in prep.
KNC61093-2T	Tibble Fm.	Provo	Timpanogos Cave	445724	4481357	40.48299	111.64112	2011	Constenius and others, 2011, 2020 in prep.
KNC101711-1	younger volcaniclastic strata overlying Tvte	Provo	Timpanogos Cave	445366	4481071	40.48038	111.64532	2011	Constenius and others, 2011, 2020 in prep.
KNC101811-6	Currant Creek Fm.	Duchesne	Tabby Mountain	511134	4467295	40.35799	110.86960	2011	Sprinkel, 2018; Sprinkel, 2020 in prep.
KNC081612-1	Mesaverde Fm.	Duchesne	Raspberry Knoll	510830	4468095	40.36520	110.87316	2013	Sprinkel, 2018; Sprinkel, 2020 in prep.
KNC081612-2	Mesaverde Fm.	Duchesne	Tabby Mountain	510777	4468567	40.36945	110.87378	2013	Sprinkel, 2018; Sprinkel, 2020 in prep.
KNC081612-3	Mesaverde Fm.	Duchesne	Raspberry Knoll	510766	4468595	40.36971	110.87391	2013	Sprinkel, 2018; Sprinkel, 2020 in prep.
KNC081612-5	Mesaverde Fm.	Duchesne	Tabby Mountain	510633	4468732	40.37094	110.87547	2013	Sprinkel, 2018; Sprinkel, 2020 in prep.

Notes:
Samples in the Duchesne 30' x 60' quadrangle were collected by K.N. Constenius.

APPENDIX

Arizona LaserChron Center Procedures for 2007 and 2009 Zircon Data

Heavy mineral concentrates of the <350 micron fraction were separated magnetically. Inclusion-free zircons from the non-magnetic fraction were then handpicked under a binocular microscope. Fifty zircons were mounted in epoxy and polished to half thickness for laser ablation analyses.

Zircon crystals were analyzed in polished section with a GVI Isoprobe multi-collector ICPMS equipped with nine Faraday collectors, an axial Daly detector, and four ion-counting channels (Dickinson and Gehrels, 2003). The Isoprobe is equipped with an ArF Excimer laser, which has an emission wavelength of 193 nm. Analyses were conducted on 35 micron spots with an output energy of ~50 mJ (at 23kV) and a repetition rate of 8 Hz. Each analysis consisted of one 20-second integration on peaks with no laser firing and twenty 1-second integrations on peaks with the laser firing. Hg contribution to the ^{204}Pb mass position is accordingly removed by subtracting the on-peak background values. The depth of each ablation pit was ~15 microns. Total measurement time was ~90 s per analysis.

The collectors were configured for simultaneous measurement of ^{204}Pb in an ion-counting channel while ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{232}Th, and ^{238}U are measured with Faraday detectors. All analyses were conducted in static mode. Inter-element fractionation was monitored by analyzing fragments of a large concordant zircon crystal from Sri Lanka with a known (ID-TIMS) age of 564 ± 4 Ma (2σ) (Gehrels, unpublished data). This reference zircon was analyzed once for every three unknown samples.

The reported ages are determined from the ZIRCON AGE EXTRACTOR or TuffZirc algorithm (Ludwig, 2003) of the 206Pb/238U coherent group of at least 5 analysis (or 0.3 * #analyses, whichever larger). The age an uncertainty of the median of the coherent group is reported. The systematic error, which includes contributions from the standard calibration, age of the calibration standard, composition of common Pb, and U decay constants, is generally ~1-2% (2-sigma) and was added to the age determination as a propagated error.

DZ U-Pb analysis were conducted following Gehrels et al.(2006).

Ludwig, K.J., 2003. Isoplot 3.00 Berkeley Geochronology Center Special Publication No. 4, 70 p.

Dickinson, W.R. and Gehrels, G.E., 2003. U–Pb ages of detrital zircons from Permian and Jurassic eolian sandstones of the Colorado Plateau, USA: paleogeographic implications. Sedimentary Geology, 163: 29-66.

Gehrels, G., Valencia, V., Pullen, A., 2006, Detrital Zircon Geochronology by Laser Ablation Multicollector ICPMS at the Arizona LaserChron Center, in Olszewski, T., ed., Geochronology: Emerging Opportunities: Paleontology Society Papers, Volume 12, p. 67-76.

Stacey, J.S.K. and Kramers, J.D., 1975. Approximation of terrestrial lead isotope evolution by a two-stage model. Earth and Planetary Science Letters, 26(2): 207-221.

Arizona LaserChron Center Procedures for 2010, 2011, 2013 Zircon Data

U-Pb geochronologic analyses of detrital zircon (Nu HR ICPMS)

Zircon crystals are extracted from samples by traditional methods of crushing and grinding, followed by separation with a Wilfley table, heavy liquids, and a Frantz magnetic separator. Samples are processed such that all zircons are retained in the final heavy mineral fraction. A large split of these grains (generally thousands of grains) is incorporated into a 1” epoxy mount together with fragments of our Sri Lanka standard zircon. The mounts are sanded down to a depth of ~20 microns, polished, imaged, and cleaned prior to isotopic analysis.

U-Pb geochronology of zircons is conducted by laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) at the Arizona LaserChron Center (Gehrels et al., 2006, 2008). The analyses involve ablation of zircon with a Photon Machines Analyte G2 excimer laser (or, prior to May 2011, a New Wave UP193HE Excimer laser) using a spot diameter of 30 microns. The ablated material is carried in helium into the plasma source of a Nu HR ICPMS, which is equipped with a flight tube of sufficient width that U, Th, and Pb isotopes are measured simultaneously. All measurements are made in static mode, using Faraday detectors with $3x10_{11}$ ohm resistors for ^{238}U, ^{232}Th, ^{208}Pb-^{206}Pb, and discrete dynode ion counters for ^{204}Pb and ^{202}Hg. Ion yields are ~0.8 mv per ppm. Each analysis consists of one 15-second integration on peaks with the laser off (for backgrounds), 15 one-second integrations with the laser firing, and a 30 second delay to purge the previous sample and prepare for the next analysis. The ablation pit is ~15 microns in depth.

For each analysis, the errors in determining $^{206}Pb/^{238}U$ and $^{206}Pb/^{204}Pb$ result in a measurement error of ~1-2% (at 2-sigma level) in the $^{206}Pb/^{238}U$ age. The errors in measurement of $^{206}Pb/^{207}Pb$ and $^{206}Pb/^{204}Pb$ also result in ~1-2% (at 2-sigma level) uncertainty in age for grains that are >1.0 Ga, but are substantially larger for younger grains due to low intensity of the 207Pb signal. For most analyses, the cross-over in precision of $^{206}Pb/^{238}U$ and $^{206}Pb/^{207}Pb$ ages occurs at ~1.0 Ga.

^{204}Hg interference with ^{204}Pb is accounted for measurement of ^{202}Hg during laser ablation and subtraction of ^{204}Hg according to the natural $^{202}Hg/^{204}Hg$ of 4.35. This Hg is correction is not significant for most analyses because our Hg backgrounds are low (generally ~150 cps at mass 204).

Common Pb correction is accomplished by using the Hg-corrected ^{204}Pb and assuming an initial Pb composition from Stacey and Kramers (1975). Uncertainties of 1.5 for $^{206}Pb/^{204}Pb$ and 0.3 for $^{207}Pb/^{204}Pb$ are applied to these compositional values based on the variation in Pb isotopic composition in modern crystal rocks.

Inter-element fractionation of Pb/U is generally ~5%, whereas apparent fractionation of Pb isotopes is generally <0.2%. In-run analysis of fragments of a large zircon crystal (generally every fifth measurement) with known age of 563.5 ± 3.2 Ma (2-sigma error) is used to correct for this fractionation. The uncertainty resulting from the calibration correction is generally 1-2% (2-sigma) for both $^{206}Pb/^{207}Pb$ and $^{206}Pb/^{238}U$ ages.

Concentrations of U and Th are calibrated relative to our Sri Lanka zircon, which contains ~518 ppm of U and 68 ppm Th.

The analytical data are reported in the tables. Uncertainties shown in these tables are at the 1-sigma level, and include only measurement errors. Analyses that are >20% discordant (by comparison of $^{206}Pb/^{238}U$ and $^{206}Pb/^{207}Pb$ ages) or >5% reverse discordant (in italics in tables) are not considered further.

The resulting interpreted ages are shown on Pb*/U concordia diagrams and relative age-probability diagrams using the routines in Isoplot (Ludwig, 2008). The age-probability diagrams show each age and its uncertainty (for measurement error only) as a normal distribution, and sum all ages from a sample into a single curve. Composite age probability plots are made from an in-house Excel program (see Analysis Tools for link) that normalizes each curve according to the number of constituent analyses, such that each curve contains the same area, and then stacks the probability curves.

References:

Gehrels, G.E., Valencia, V., Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation–multicollector–inductively coupled plasma–mass spectrometry: Geochemistry, Geophysics, Geosystems, v. 9, Q03017, doi:10.1029/2007GC001805.

Gehrels, G.E., Valencia, V., Pullen, A., 2006, Detrital zircon geochronology by Laser-Ablation Multicollector ICPMS at the Arizona LaserChron Center, *in* Loszewski, T., and Huff, W., eds., Geochronology: Emerging Opportunities, Paleontology Society Short Course: Paleontology Society Papers, v. 11, 10 p.

Ludwig, K.R., 2008, Isoplot 3.60. Berkeley Geochronology Center, Special Publication No. 4, 77 p.

Stacey, J.S., and Kramers, J.D., 1975, Approximation of terrestrial lead isotope evolution by a two stage model: Earth and Planetary Science Letters, v. 26, p. 207 221.

Notes inserted below data table:

1. Analyses with >10% uncertainty (1-sigma) in 206Pb/238U age are not included.
2. Analyses with >10% uncertainty (1-sigma) in 206Pb/207Pb age are not included, unless 206Pb/238U age is <500 Ma.
3. Best age is determined from 206Pb/238U age for analyses with 206Pb/238U age <1000 Ma and from 206Pb/207Pb age for analyses with 206Pb/238Uage > 1000 Ma.
4. Concordance is based on 206Pb/238U age / 206Pb/207Pb age. Value is not reported for 206Pb/238U ages <500 Ma because of large uncertainty in 206Pb/207Pb age.
5. Analyses with 206Pb/238U age > 500 Ma and with >20% discordance (<80% concordance) are not included.
6. Analyses with 206Pb/238U age > 500 Ma and with >5% reverse discordance (<105% concordance) are not included.
7. All uncertainties are reported at the 1-sigma level, and include only measurement errors.
8. Systematic errors are as follows (at 2-sigma level): [sample 1: 2.5% (206Pb/238U) & 1.4% (206Pb/207Pb)] These values are reported on cells U1 and W1 of NUagecalc.
9. Analyses conducted by LA-MC-ICPMS, as described by Gehrels et al. (2008).
10. U concentration and U/Th are calibrated relative to Sri Lanka zircon standard and are accurate to ~20%.
11. Common Pb correction is from measured 204Pb with common Pb composition interpreted from Stacey and Kramers (1975).

12. Common Pb composition assigned uncertainties of 1.5 for 206Pb/204Pb, 0.3 for 207Pb/204Pb, and 2.0 for 208Pb/204Pb.
13. U/Pb and 206Pb/207Pb fractionation is calibrated relative to fragments of a large Sri Lanka zircon of 563.5 ± 3.2 Ma (2-sigma).
14. U decay constants and composition as follows: 235U = 9.8485 x 10-10, 238U = 1.55125 x 10-10, 238U/235U = 137.88.
15. Weighted mean and concordia plots determined with Isoplot (Ludwig, 2008).

References:

Gehrels, G.E., Valencia, V., Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation-multicollector-inductively coupled plasma-mass spectrometry: Geochemistry, Geophysics, Geosystems, v. 9, Q03017, doi:10.1029/2007GC001805.

Ludwig, K., 2008, Isoplot 3.6: Berkeley Geochrono9logy Center Special Publication 4, 77 p.

Stacey, J.S., and Kramers, J.D., 1975, Approximation of terrestrial lead isotope evolution by a two stage model: Earth and Planetary Science Letters, v. 26, p. 207-221.

U-Pb geochronologic analyses of igneous zircon (Nu HR ICPMS)

Zircon crystals are extracted from samples by traditional methods of crushing and grinding, followed by separation with a Wilfley table, heavy liquids, and a Frantz magnetic separator. Samples are processed such that all zircons are retained in the final heavy mineral fraction. A split of these grains (generally 50-100 grains) are selected from the grains available and incorporated into a 1” epoxy mount together with fragments of our Sri Lanka standard zircon. The mounts are sanded down to a depth of ~20 microns, polished, imaged, and cleaned prior to isotopic analysis.

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For each analysis, the errors in determining $^{206}Pb/^{238}U$ and $^{206}Pb/^{204}Pb$ result in a measurement error of ~1-2% (at 2-sigma level) in the $^{206}Pb/^{238}U$ age. The errors in measurement of $^{206}Pb/^{207}Pb$ and $^{206}Pb/^{204}Pb$ also result in ~1-2% (at 2-sigma level) uncertainty in age for grains that are >1.0 Ga, but are substantially larger for younger grains due to low intensity of the ^{207}Pb signal. For most analyses, the cross-over in precision of $^{206}Pb/^{238}U$ and $^{206}Pb/^{207}Pb$ ages occurs at ~1.0 Ga.

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The resulting interpreted ages are shown on Pb*/U concordia diagrams and weighted mean diagrams using the routines in Isoplot (Ludwig, 2008). The weighted mean diagrams show the weighted mean (weighting according to the square of the internal uncertainties), the uncertainty of the weighted mean, the external (systematic) uncertainty that corresponds to the ages used, the final uncertainty of the age (determined by quadratic addition of the weighted mean and external uncertainties), and the MSWD of the data set.

References:

Gehrels, G.E., Valencia, V., Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation–multicollector–inductively coupled plasma–mass spectrometry: Geochemistry, Geophysics, Geosystems, v. 9, Q03017, doi:10.1029/2007GC001805.

Ludwig, K.R., 2008, Isoplot 3.60. Berkeley Geochronology Center, Special Publication No. 4, 77 p.

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6. Analyses with 206Pb/238U age > 500 Ma and with >5% reverse discordance (<105% concordance) are not included.
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8. Systematic errors are as follows (at 2-sigma level): [sample 1: 2.5% (206Pb/238U) & 1.4% (206Pb/207Pb)] These values are reported on cells U1 and W1 of NUagecalc.
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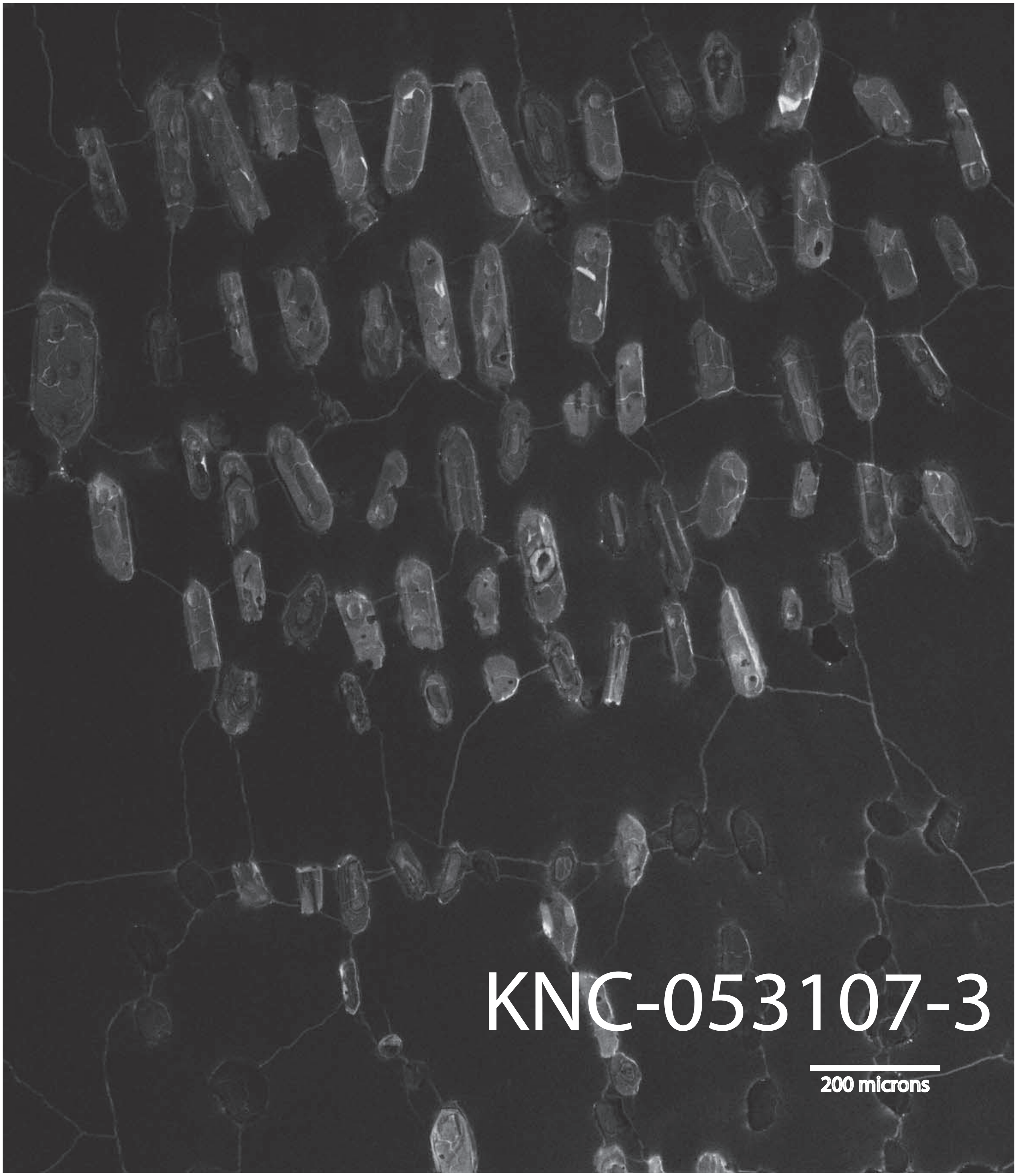
References:

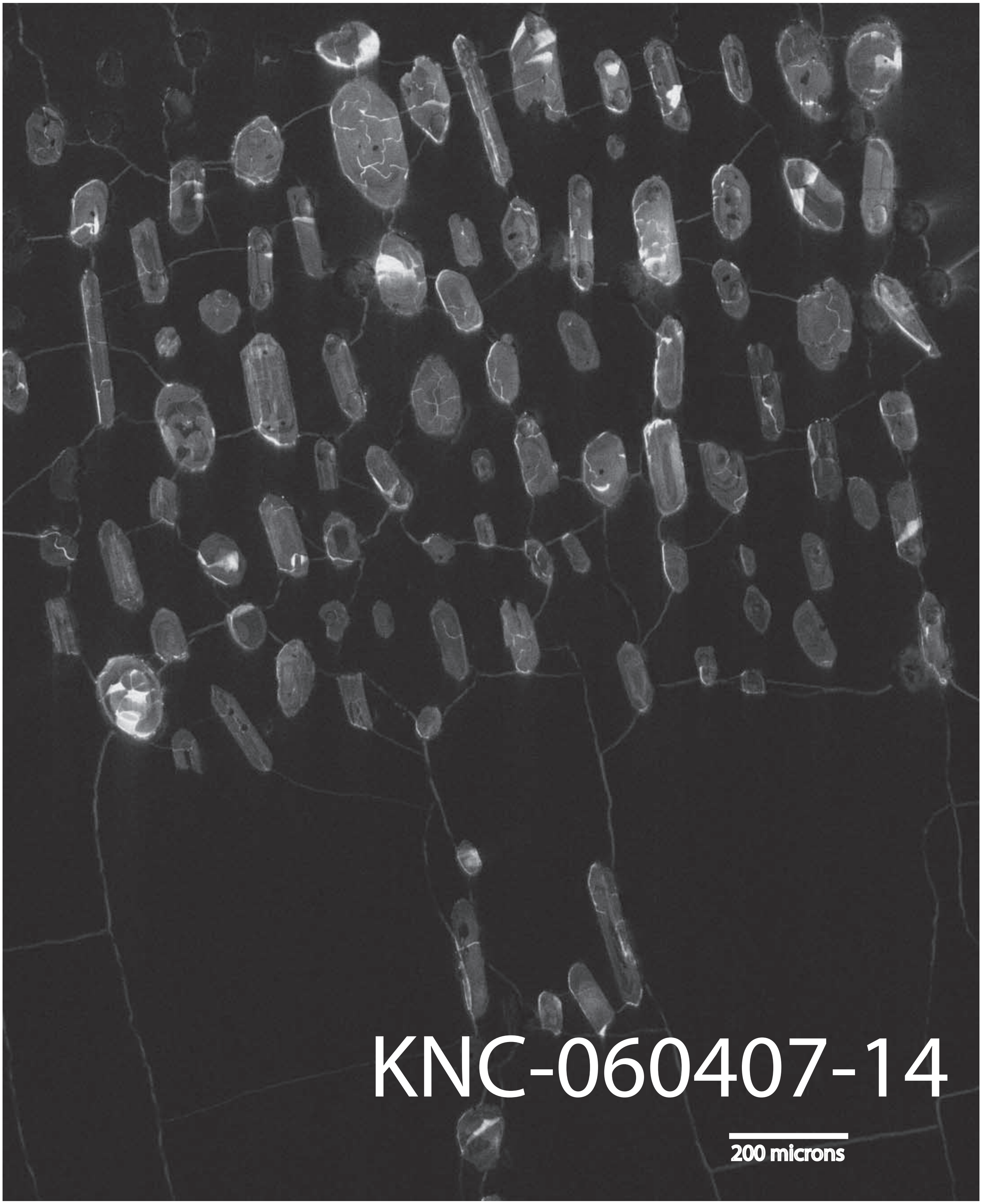
Gehrels, G.E., Valencia, V., Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation-multicollector-inductively coupled plasma-mass spectrometry: Geochemistry, Geophysics, Geosystems, v. 9, Q03017, doi:10.1029/2007GC001805.

Ludwig, K., 2008, Isoplot 3.6: Berkeley Geochrono9logy Center Special Publication 4, 77 p.

Stacey, J.S., and Kramers, J.D., 1975, Approximation of terrestrial lead isotope evolution by a two stage model: Earth and Planetary Science Letters, v. 26, p. 207-221.

Zircon Images (Cathodoluminescence and Scanning Electron Microscope)

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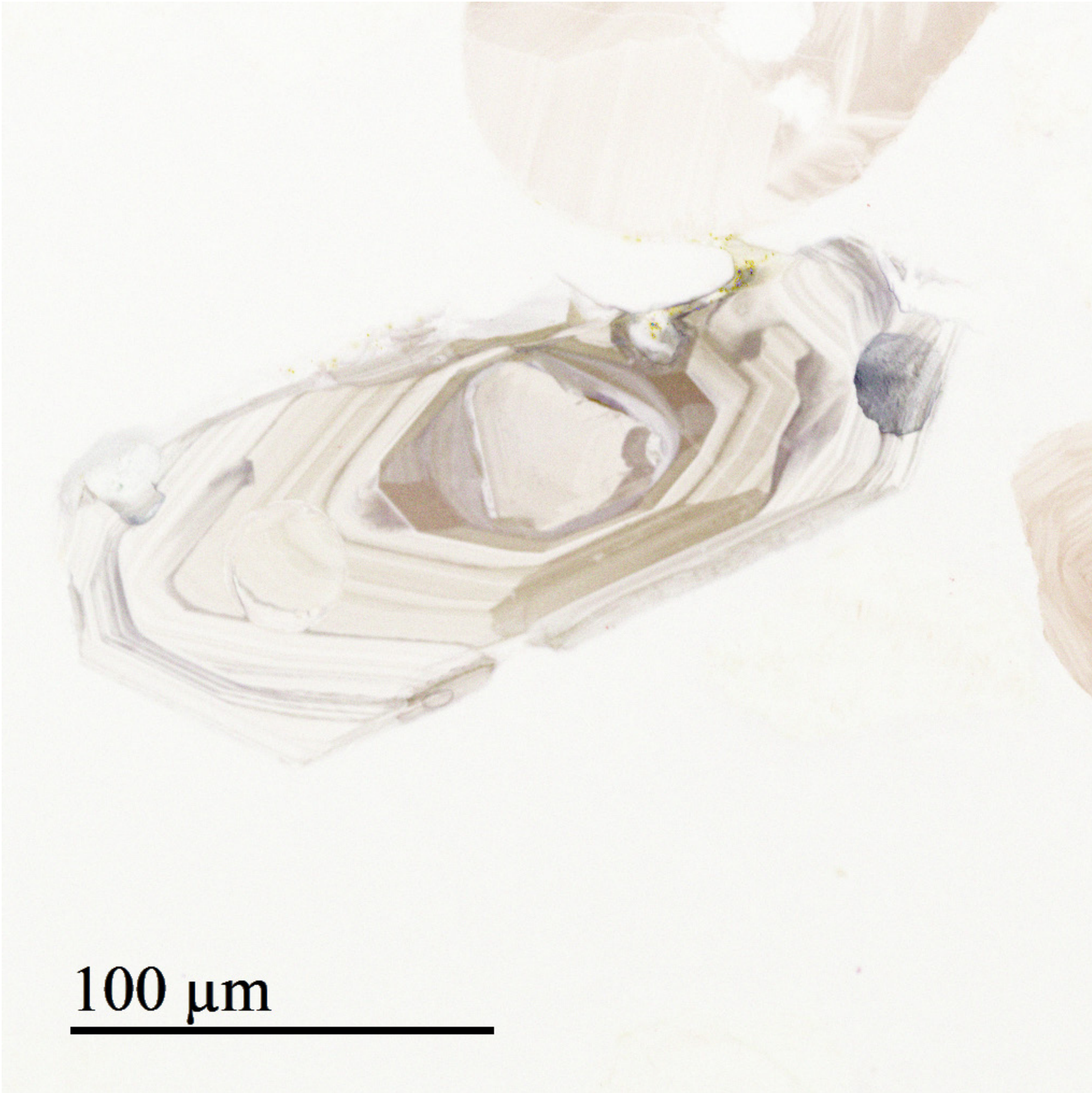

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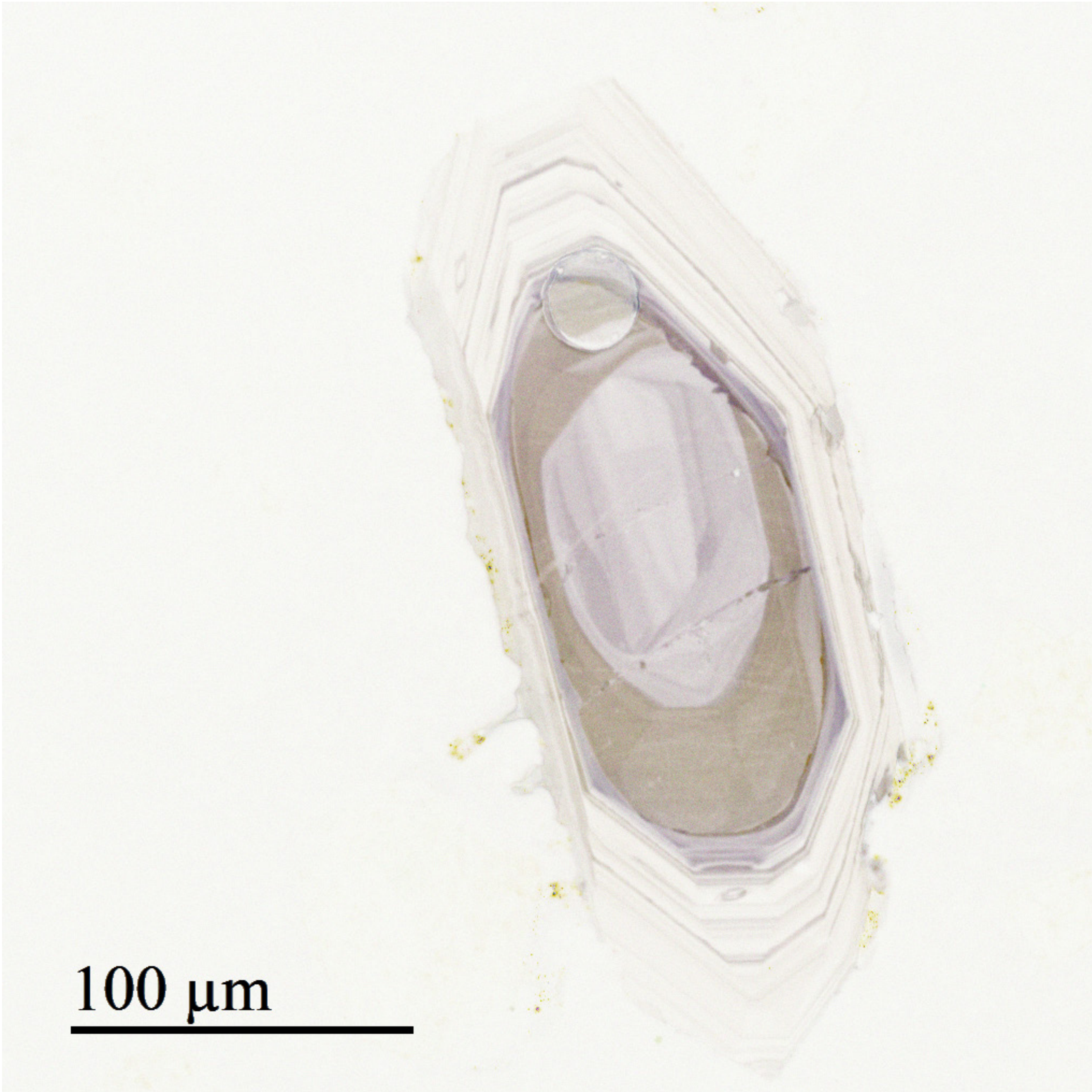

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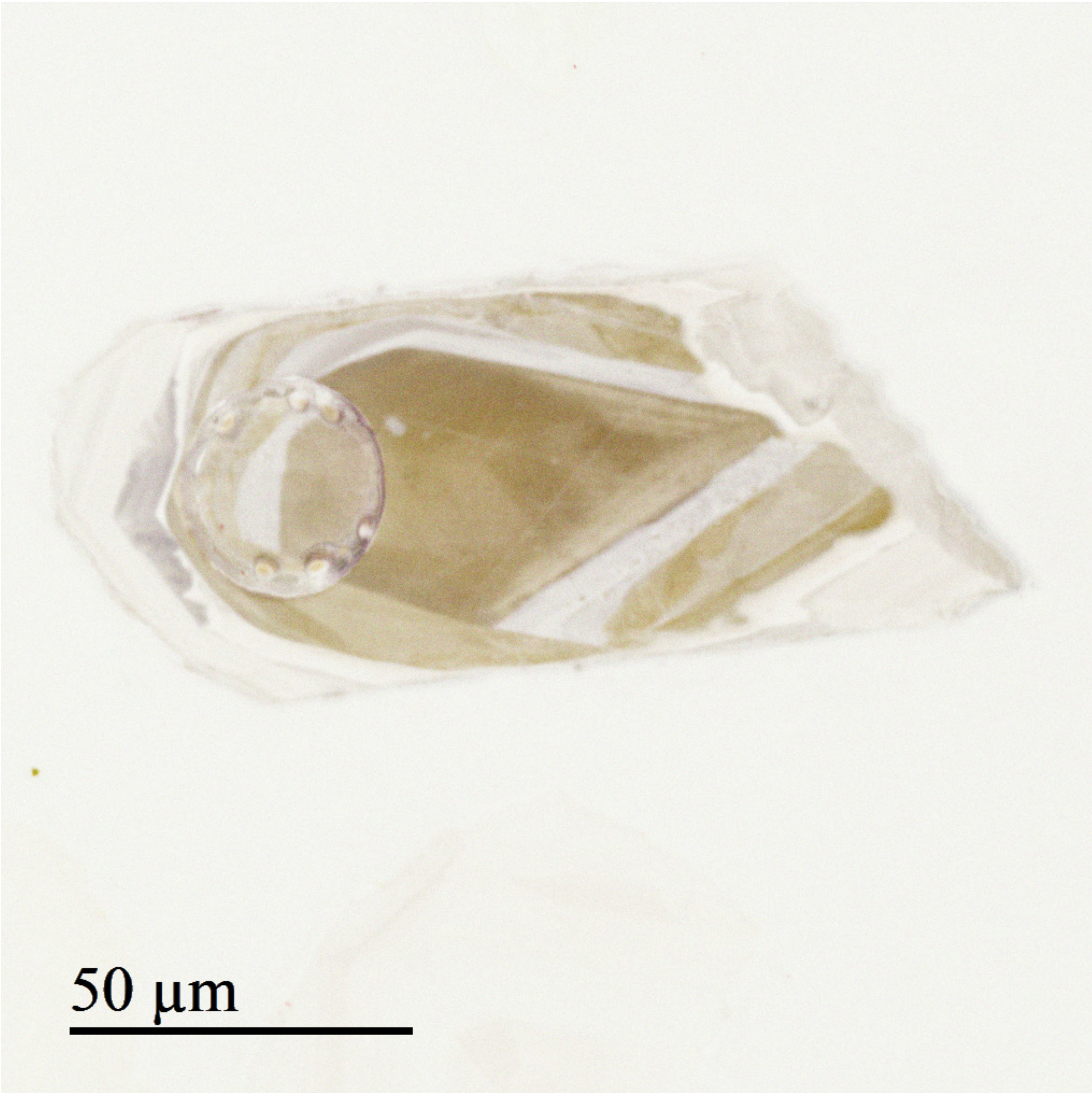

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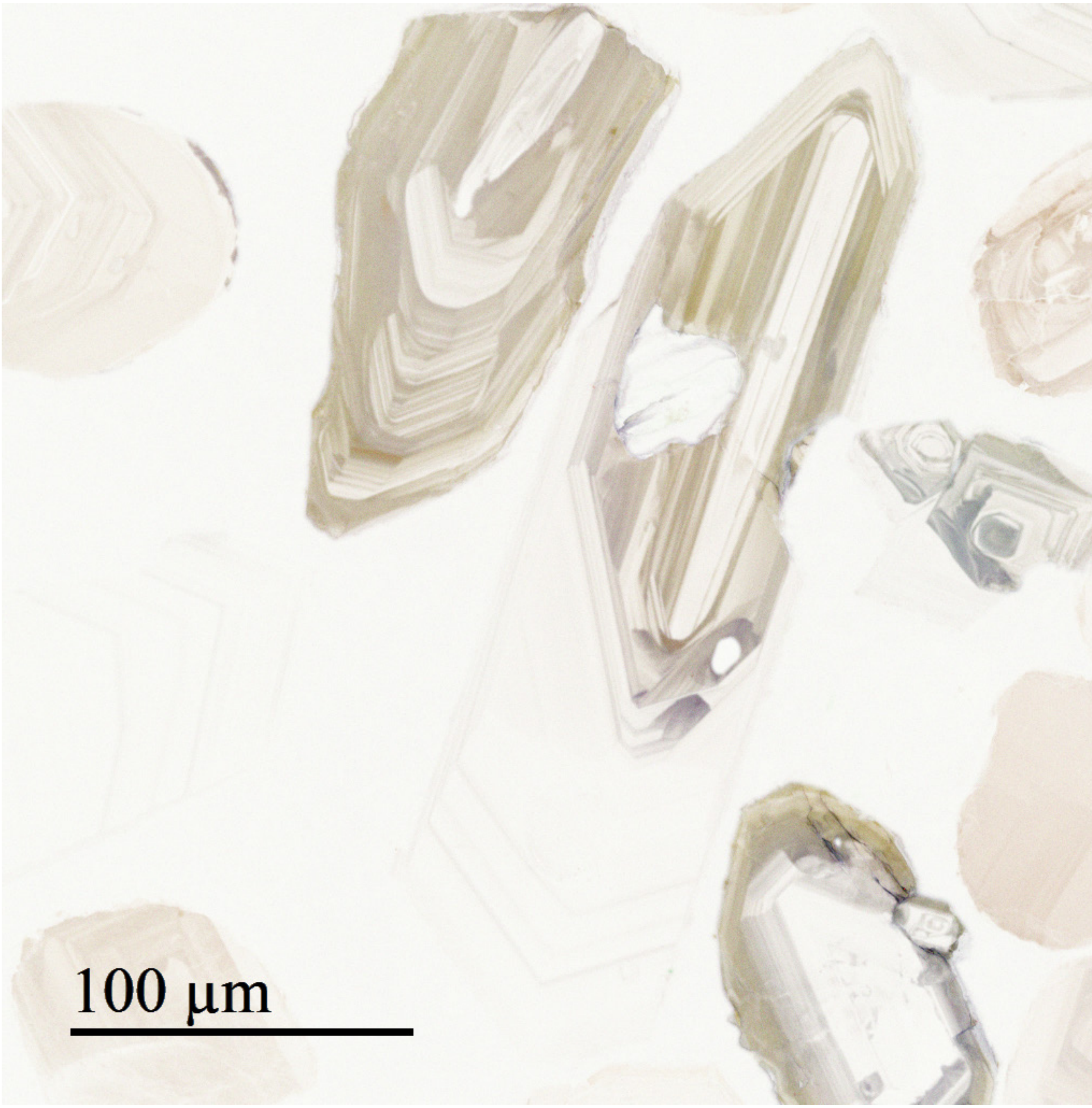

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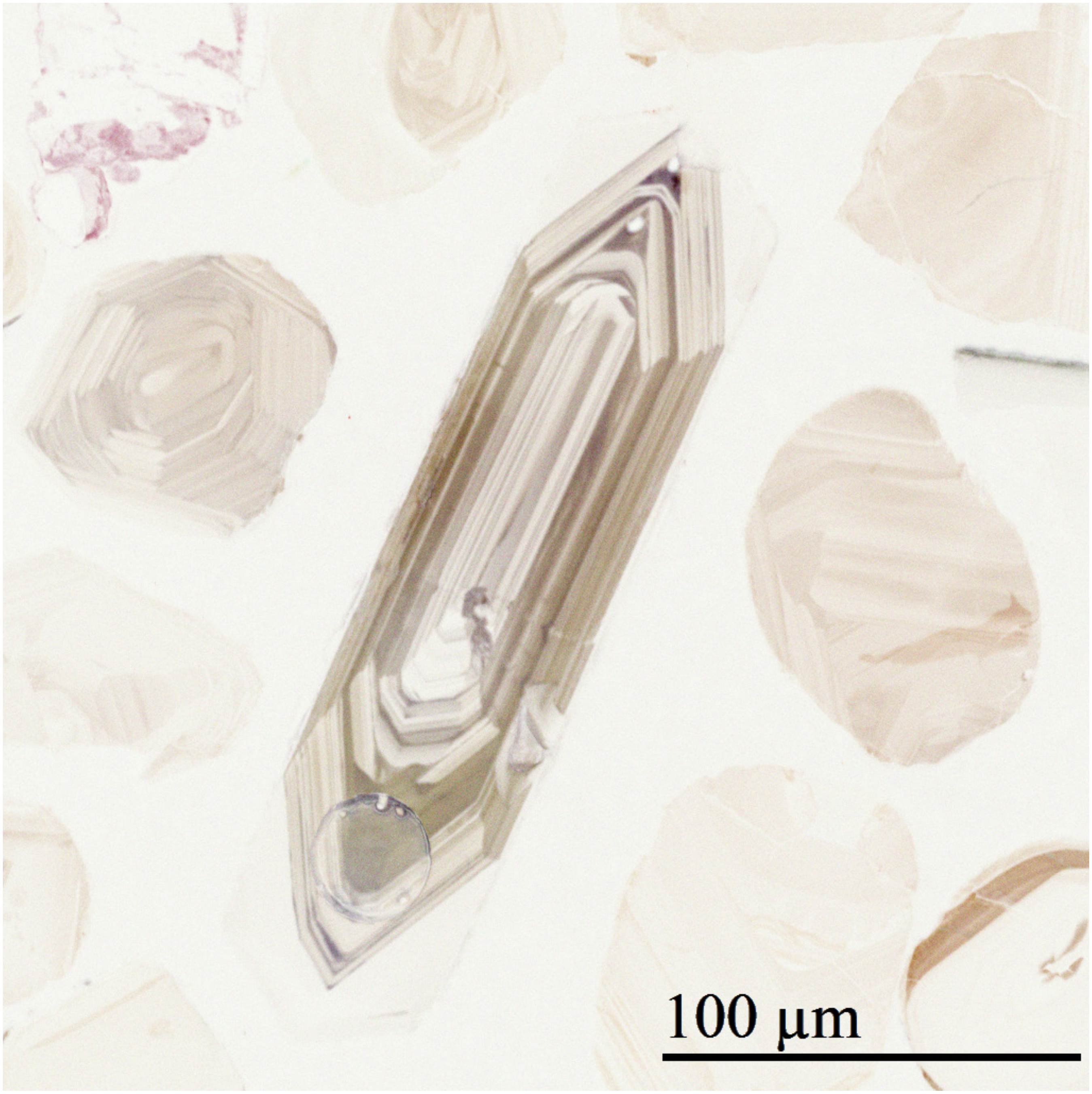

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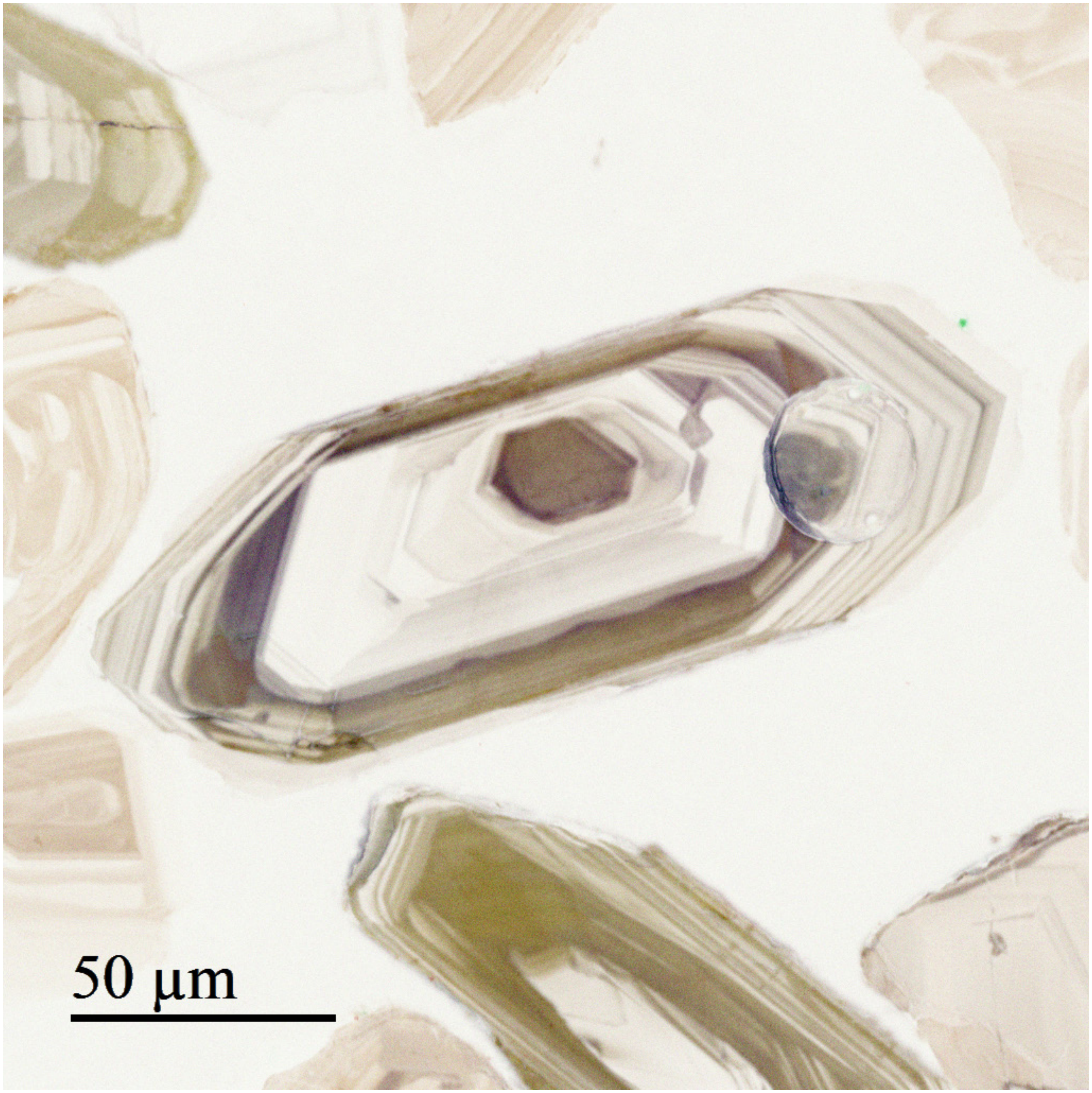

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Sample JC99-7 no images of zircon grains

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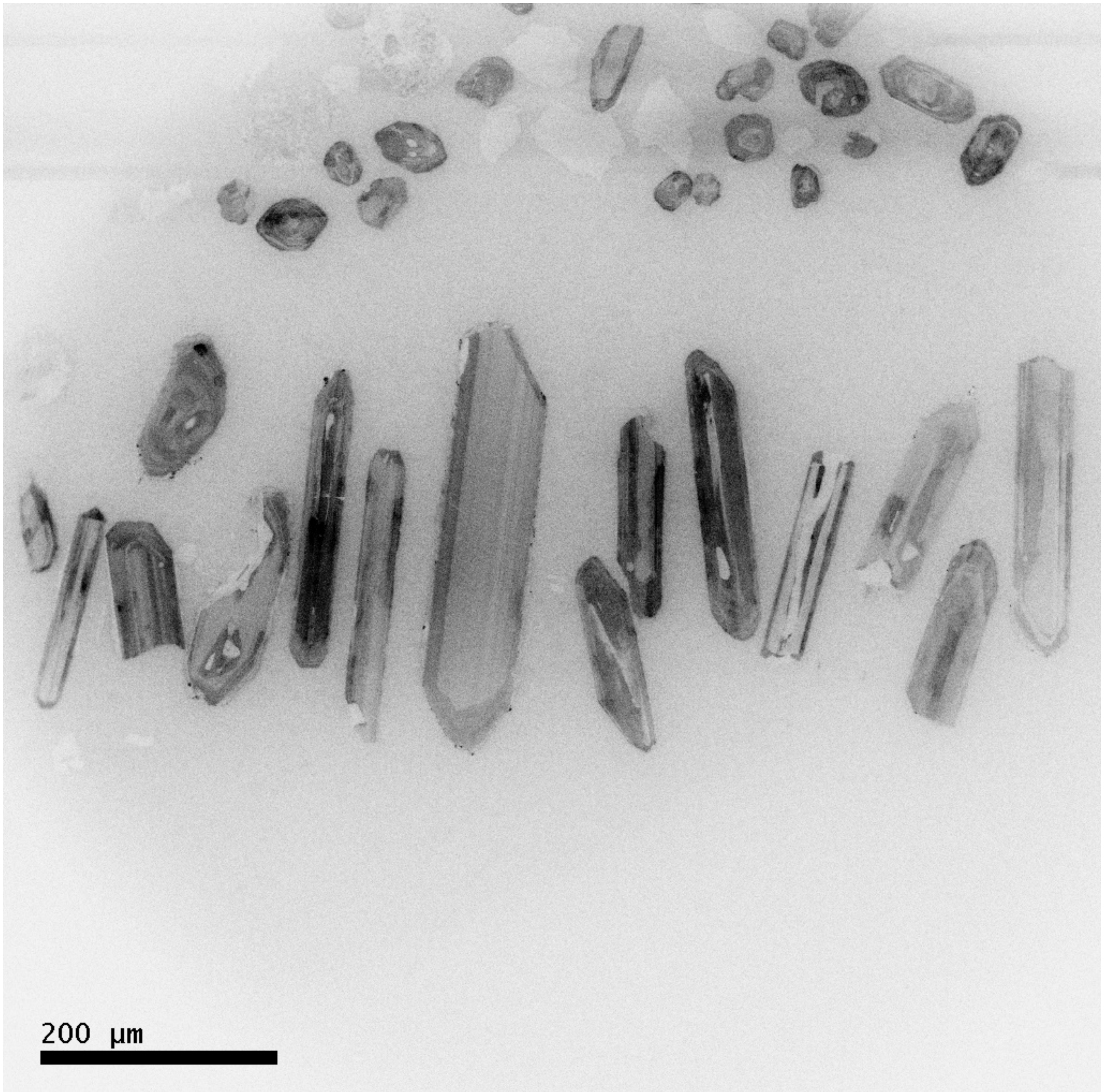

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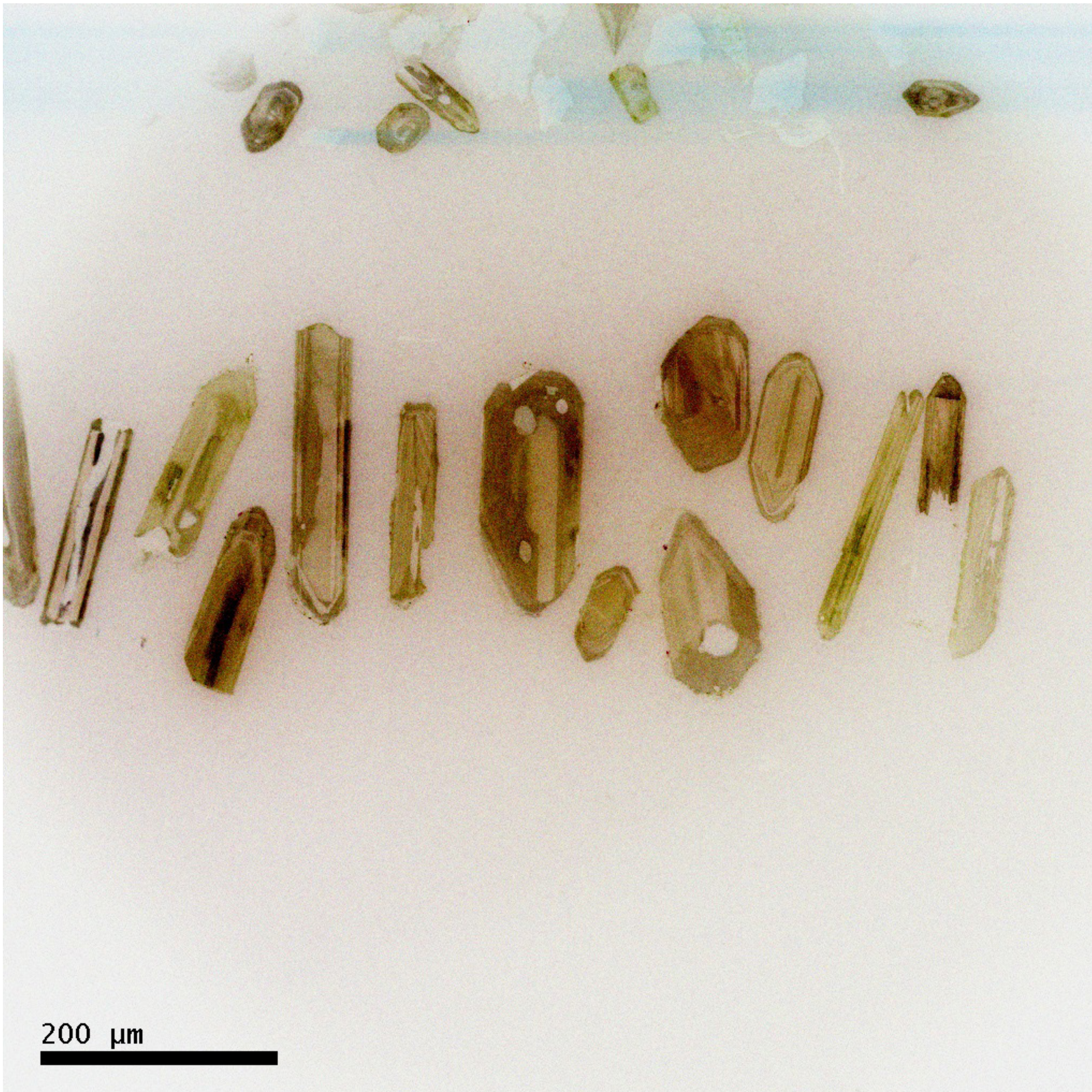

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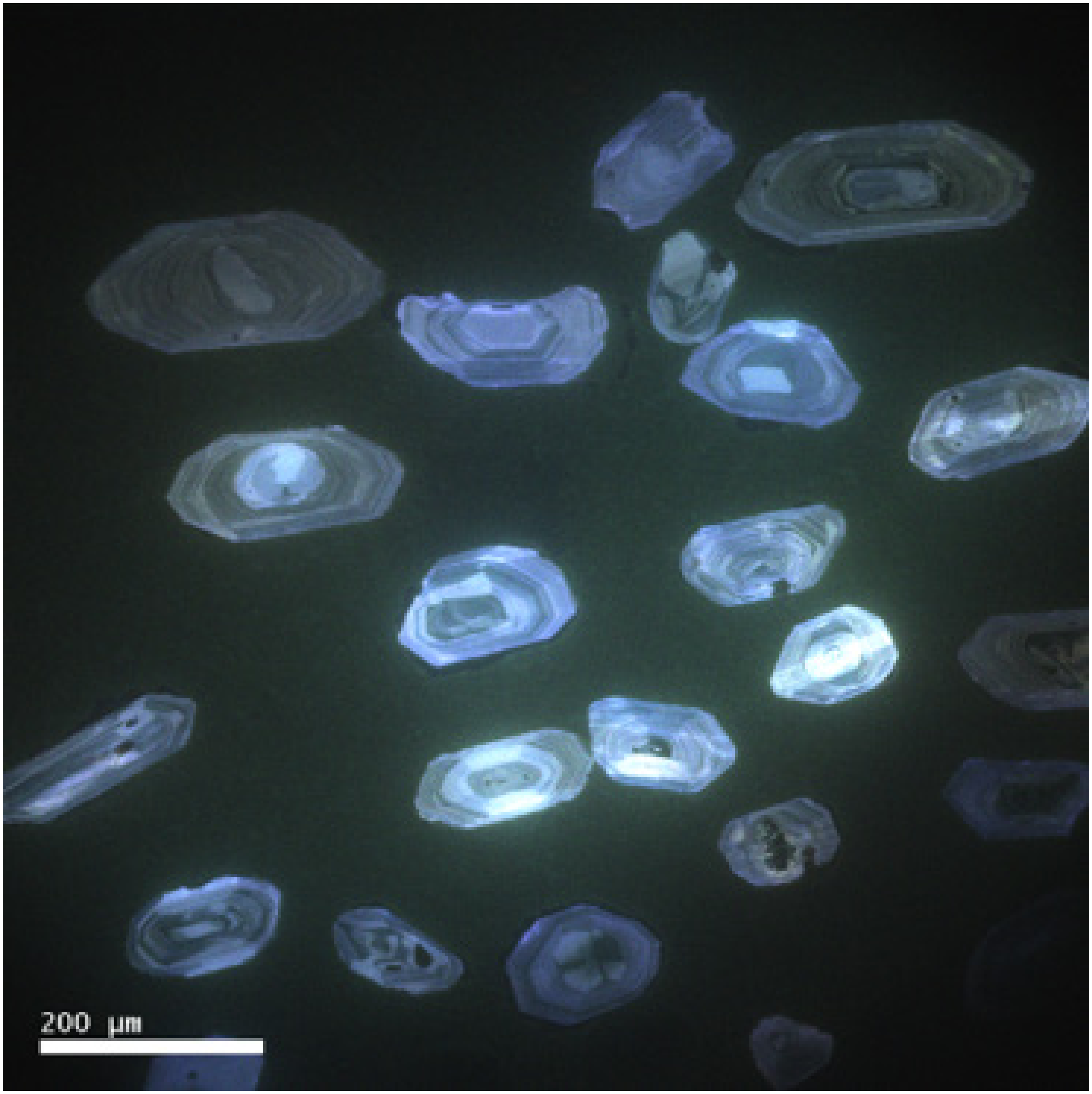
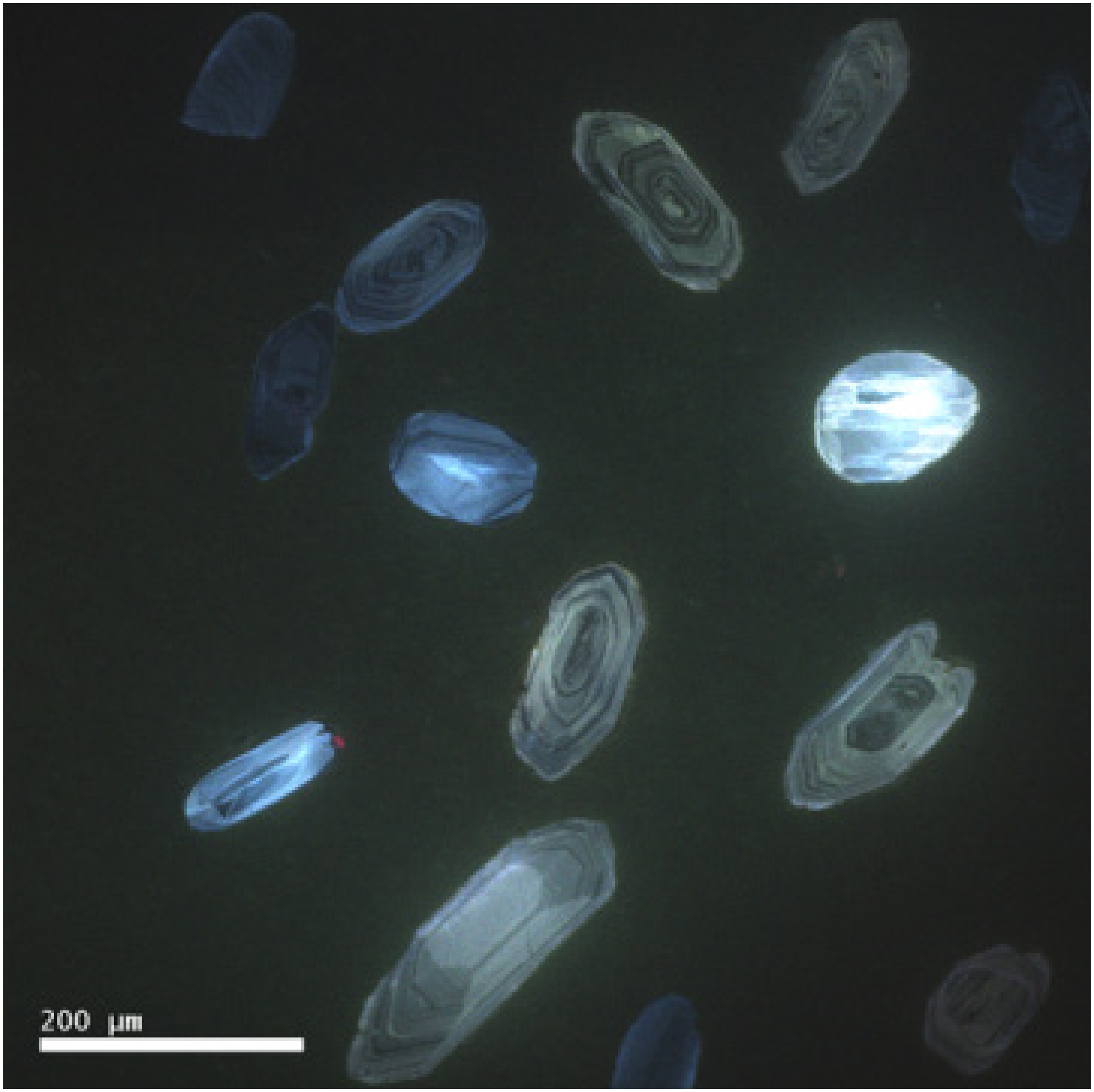


KNC-101711-1



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