

Supplemental text, tables, and figures for Levy et al.

Buoyant doming generates metamorphic core complexes in the North American Cordillera

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DR1 – Geological map of the northern Ruby Mountains-southern East

Humboldt Range

DR2 – Electron backscatter diffraction methods

DR3 – Kinematic vorticity analysis methods

DR4 – Secondary ion microprobe methods

DR5 – Diapir ascent velocity analytical model details

DR1 – Geological maps of the study area

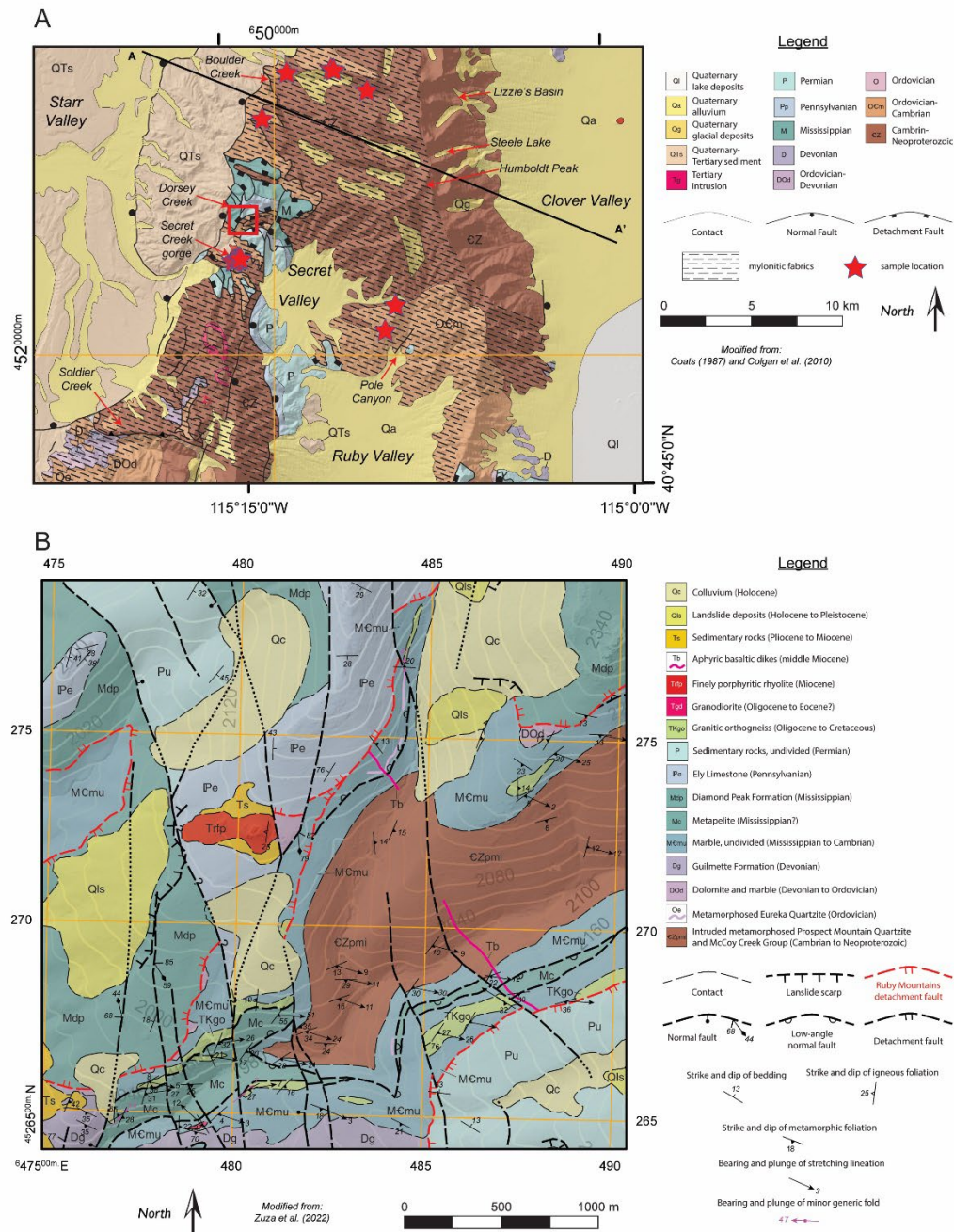


Figure DR1. A) Geological map of the northern Ruby Mountains-East Humboldt Range study area. B) Detailed geological map of the Dorsey Creek area. Middle Miocene basalt dikes (Tb) that crosscut the mylonitic fabric are truncated by the Ruby Mountains detachment fault.

DR2 – EBSD data collection details and grain size analysis

Electron backscatter diffraction (EBSD) analysis was conducted with 15 samples at the University of Nevada, Reno using the JEOL JSM-7100FT field-emission scanning electron microscope with an Oxford NordlysMax2 EBSD detector (Table 1, Fig. DR2). Thin sections for each sample were polished using a vibratory polisher with 0.05 μm colloidal silica for 6–8 hours. EBSD data was collected at a working distance of 25 mm and 70° tilt using a beam energy of 25–30 kV and probe current of 18. EBSD maps were collected at a step size of 0.2–6 μm depending on the estimated size of recrystallized grains. For select samples, maps were collected at a larger and smaller step size to capture a large area of the fabric and to resolve small grains, respectively. EBSD data was processed using Oxford Instruments Channel 5 software to correct for wild spikes and a 7 nearest neighbor zero solutions correction. For select samples wild spikes and zero solutions corrections were conducted using the MTEX toolbox (5.7.0; <https://mtex-toolbox.github.io/>) (Bachmann et al., 2010) for MATLAB. Quartz crystallographic axes are plotted as one-point-per-grain lower-hemisphere pole figures (Fig. DR3). In Fig. DR6, all quartz crystallographic axes are plotted in lower-hemisphere pole figures for kinematic vorticity analysis. Fabric parameters M and PGR provide a measure of fabric strength (M) and the shape of the CPO (P – point; G – girdle; R – random) (Table 2). The M-index is calculated in MTEX using the function calcMIndex.m following the code of Mainprice et al. (2015) and the method of Skemer et al. (2005). Higher M-index values corresponding to a stronger CPO than lower M-index values. PGR values were calculated using the code of Mainprice et al. (2015) following the method Vollmer (1990). Values close to 1, e.g., P = 0.9, indicates the CPO is dominated by a point geometry. Due to a low proportion of quartz in sample AZ 8-19-19 (2), it has been omitted from our grain size and kinematic vorticity analysis.

Recrystallized grain size analysis was conducted following the protocol of Cross et al. (2017) using the *RexRelict.m* script (<https://doi.org/10.1002/2017GL073836>) (Table 2, Fig. DR3). We do not apply the GOS-threshold to distinguish recrystallized versus relict grains, as we assume the quartz in our samples is all recrystallized. Our analysis follows the same data input and initial grain calculation scheme, as well as grain size estimation scheme. Grain size is determined by the area-equivalent diameter. No stereological correction is used. The mean grain size is given by the root mean square of the recrystallized grain population. Differential stress estimates from mean recrystallized grain size estimates were calculated using the paleopiezometric calibration of Cross et al. (2017) (Table 2).

The quartz c-axis fabric opening angle thermometer (e.g., Law, 2014; Faleiros et al., 2016) was applied to sample AZ 8-4-18 (3), which displayed a nice c-axis girdle with an opening angle of 65° (Fig. DR3). Applying the opening angle thermometer calibration of Faleiros et al. (2016), we estimate a deformation temperature of 496 °C.

To evaluate strain rate, we apply the wet quartzite flow law of Tople et al. (2019). The form of the flow law is:

$$\dot{\epsilon} = A\sigma^n f_{H_2O}^r e^{-\frac{Q}{RT}} \quad (1)$$

where $A = 1.75 \times 10^{-12}$ ($\text{MPa}^{-n}\text{s}^{-1}$), $n = 4$, $r = 1$, $Q = 1.25 \times 10^5$ Jmol^{-1} , R = gas constant, T = temperature, and $f_{H_2O} = 50$ MPa. Water fugacity was calculated using T. Withers' fugacity calculator (<https://publish.uwo.ca/~awither5/fugacity/index.htm>).

Table 1: Sample locations

Sample	Structural Position	Location		
		Latitude	Longitude	Unit
AZ 10-8-19 (1a)	1	40.83177	-115.14803	Mdp
"		"	"	"
AZ 7-1-20 (1)	2	40.93692	-115.23821	Oe
200718-6	3	40.86394	-115.24889	Ocm
AZ8-19-19-(2)	4	40.95774	-115.19940	Tmg
AZ8-19-19-(4)	5	40.95701	-115.17796	CZpm
AZ8-19-19-(5)	6	40.95703	-115.17836	CZpm
AZ 6-30-20 (2)	7	40.94923	-115.21765	CZpm
AZ 8-4-18 (3)	8	40.84163	-115.13982	CZpm
"		"	"	"
AZ 8-4-18 (1)	9	40.84158	-115.13997	CZpm
"		"	"	"
020619-2	10	40.86344	-115.24653	CZpm
200718-4	11	40.86350	-115.24592	CZpm
200718-3a	12	40.86369	-115.24514	CZpm
020619_5	13	40.86400	-115.24389	CZpm
020619-4	14	40.86456	-115.24300	CZpm
020619-3	15	40.86433	-115.24258	CZpm
AZ 7-2-20 (4)	16	40.94657	-115.15773	Zmu

Table 2: Microstructural data

Sample	Structural Position	EBSD	Fabric parameters				Paleopiezometry			
		Step size (μm)	M	P	G	R	Mean recrystallized grain size (μm)	1SD (μm)	Differential stress (MPa)	uncertainty (+ / -)
AZ 10-8-19 (1a)	1	0.5	0.03	0.12	0.25	0.63	-	-	-	-
"		0.2	0.03	0.13	0.16	0.71	3.8	1.8	193.5	98.7/42.3
AZ 7-1-20 (1)	2	1	0.90	0.26	0.29	0.44	13.1	8.7	89.2	88.1/24.5
200718-6	3	3	0.05	0.16	0.28	0.56	14.1	6.0	85.4	35.8/17.1
AZ8-19-19-(4)	5	5	0.40	0.68	0.25	0.07	44.6	31.1	41.4	46.6/11.7
AZ8-19-19-(5)	6	5	0.50	0.80	0.16	0.04	55.7	43.1	36.0	55.7/10.9
AZ 6-30-20 (2)	7	3	0.34	0.61	0.38	0.02	44.8	32.1	41.2	49.7/11.9
AZ 8-4-18 (3)	8	5	0.36	0.66	0.26	0.08	-	-	-	-
"		2	0.42	0.72	0.24	0.03	44.0	36.7	41.7	87.4/13.2
AZ 8-4-18 (1)	9	5	0.38	0.61	0.30	0.09	-	-	-	-
"		2	0.32	0.53	0.37	0.09	32.7	24.5	50.3	69.7/14.9
020619-2	10	3	0.38	0.68	0.17	0.15	35.8	17.8	47.5	25.7/10.7
200718-4	11	5	0.30	0.56	0.32	0.12	34.9	20.3	48.3	35.3/12.1
200718-3a	12	2	0.35	0.63	0.31	0.62	55.3	29.3	36.1	21.9/8.5
020619_5	13	5	0.28	0.51	0.39	0.09	38.5	25.2	45.4	43.4/12.3
020619-4	14	2	0.20	0.42	0.37	0.21	37.3	25.2	46.3	48.0/12.9
020619-3	15	2	0.25	0.43	0.49	0.09	45.4	33.4	40.9	53.2/12.0
AZ 7-2-20 (4)	16	6	0.57	0.80	0.14	0.07	115.1	96.5	22.8	49.0/7.3

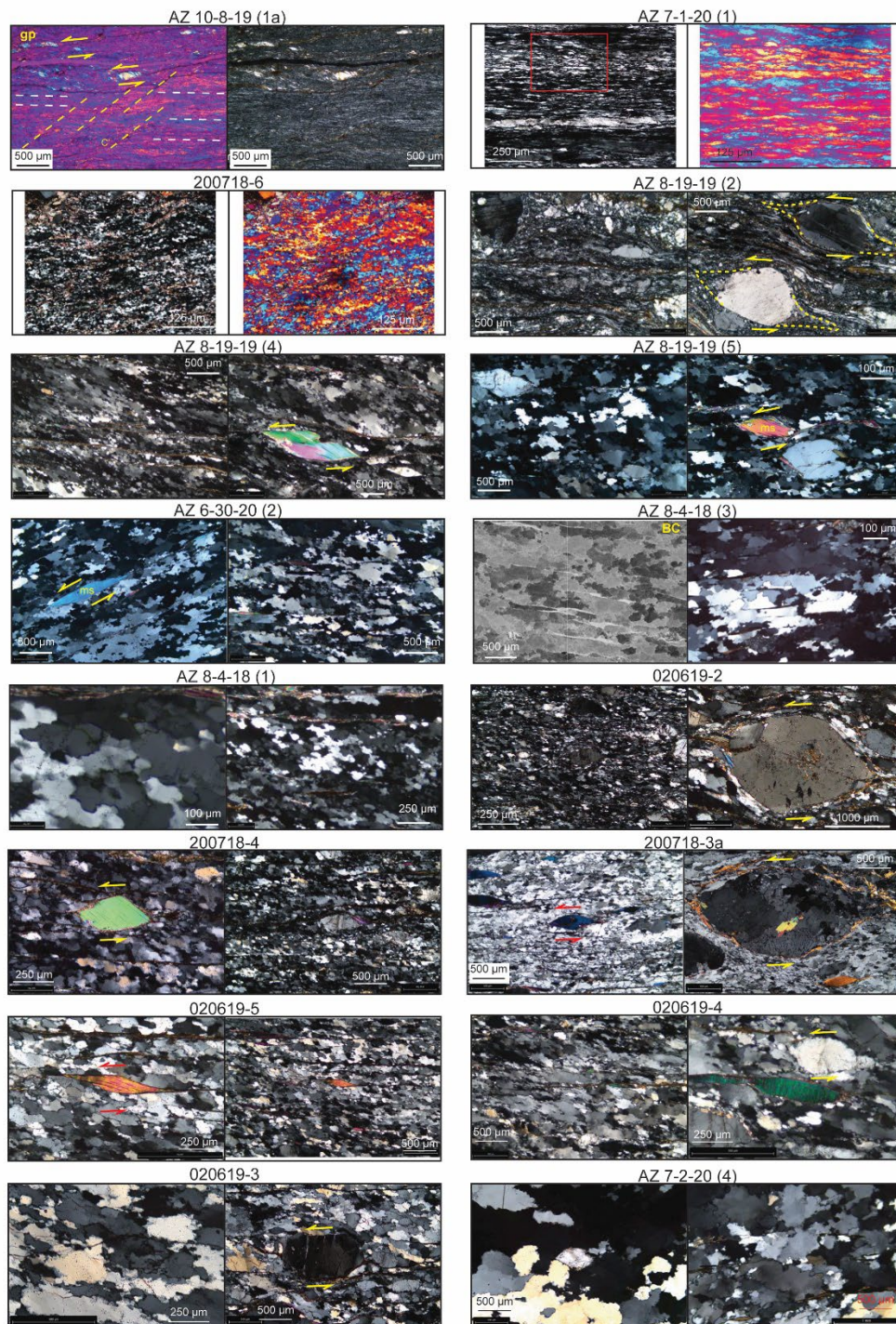
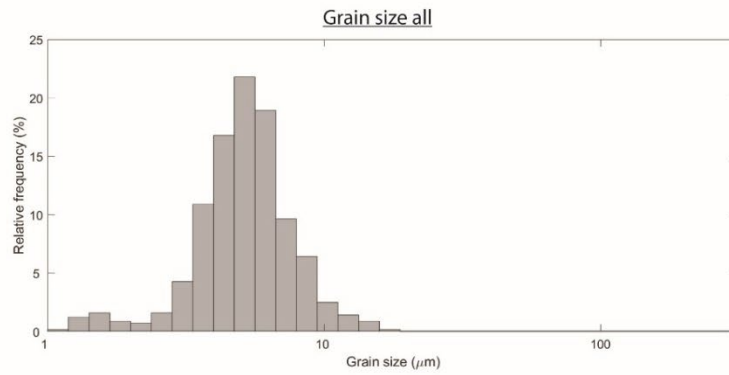
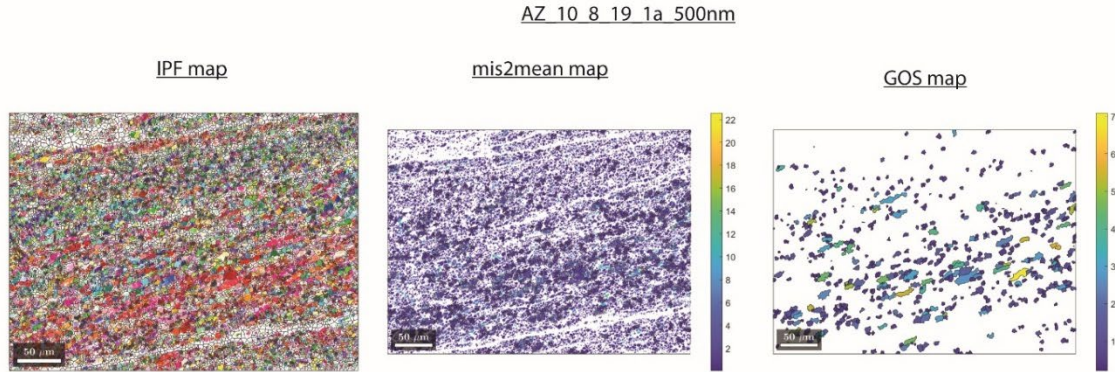


Figure DR2. Photomicrographs of each sample analyzed in this study showing characteristic microstructures. Photos are oriented left to west.



Lower-hemisphere pole figures (one point per grain)

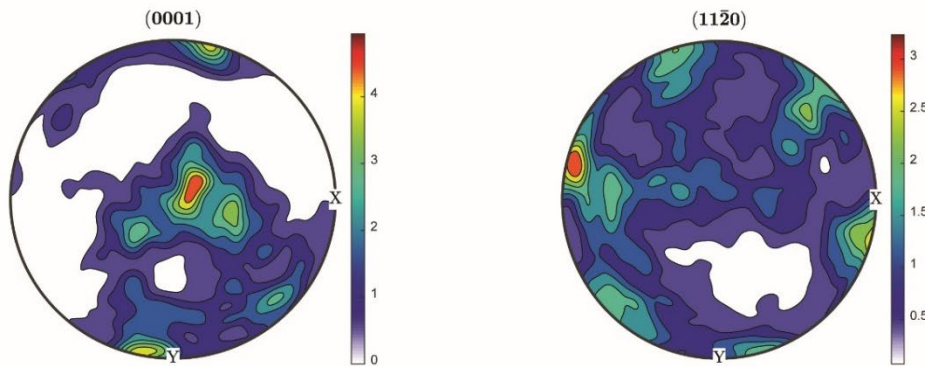
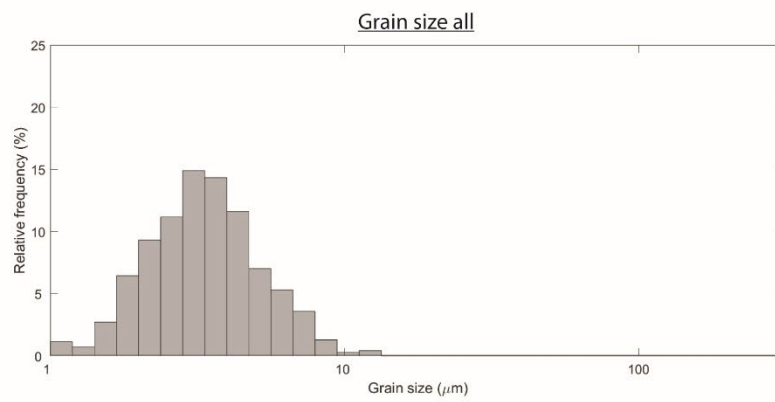
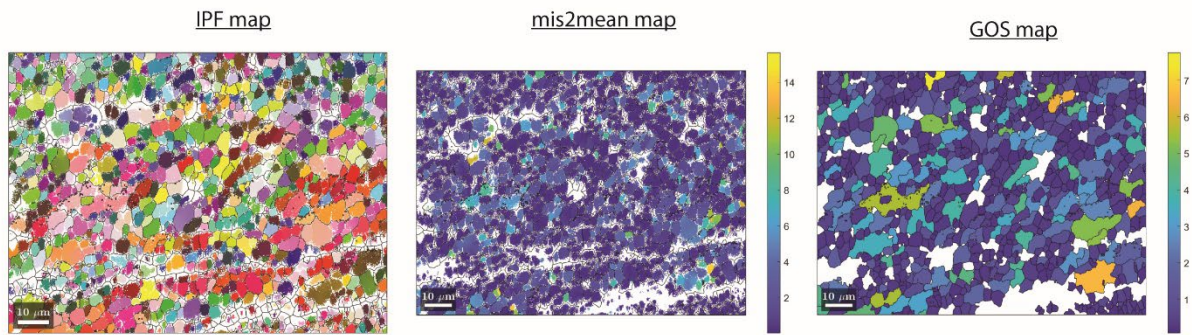


Figure DR3. EBSD maps showing inverse pole figure (IPF) map, misorientation to the mean (mis2mean) map, and the grain orientation spread (GOS) map. The mis2mean and GOS map scales are in units of degrees. The histogram shows the distribution of grain sizes. The lower-hemisphere pole figures display the quartz crystallographic preferred orientation. The pole figure scales are multiples of uniform density (M.U.D.).

AZ 10 8 19 1a 200nm



Lower-hemisphere pole figures (one point per grain)

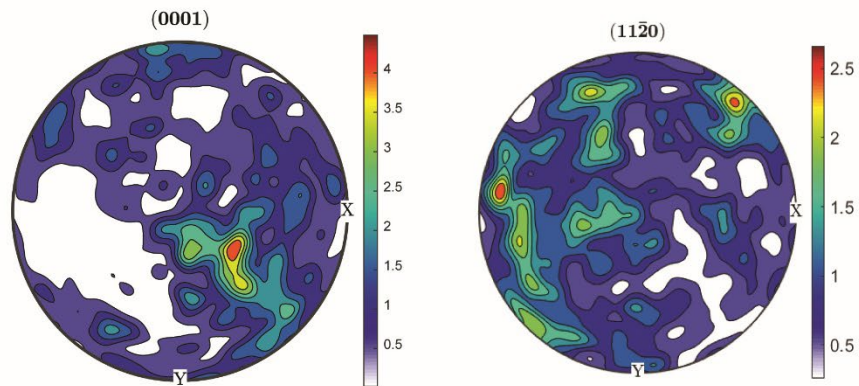


Figure DR3. (*continued*)

AZ 7 1 20 1 1 μ m

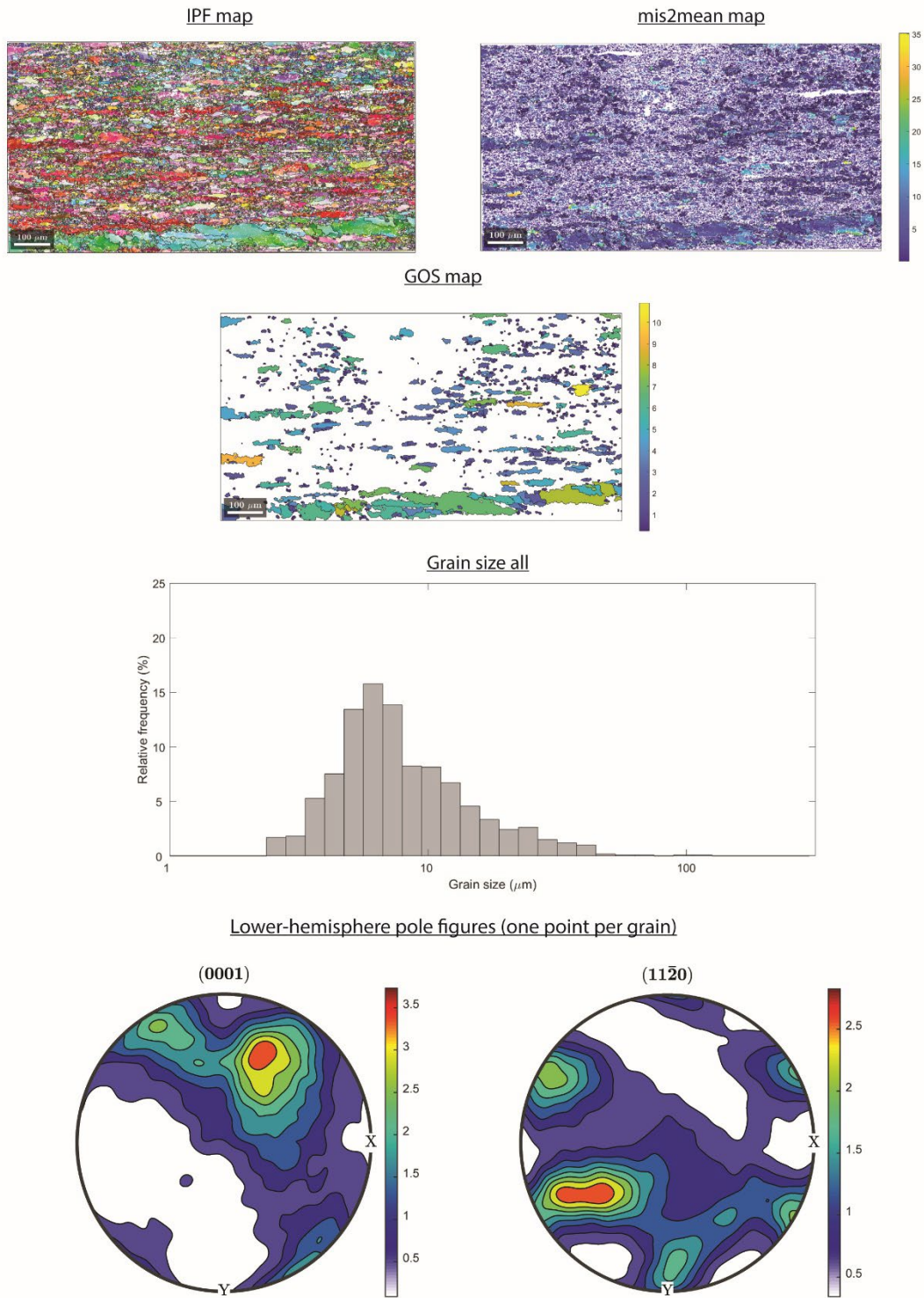
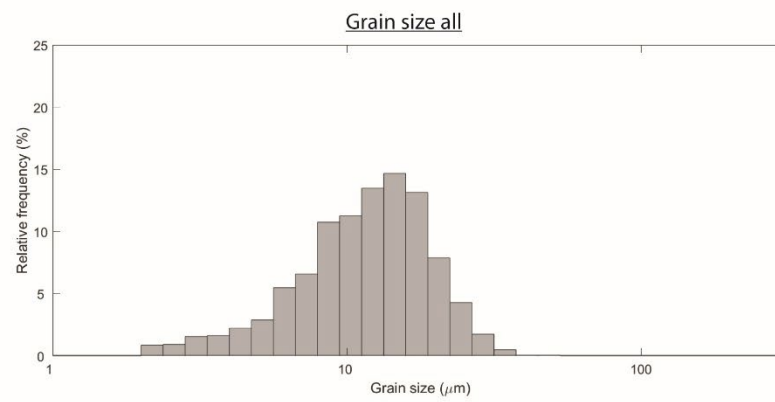
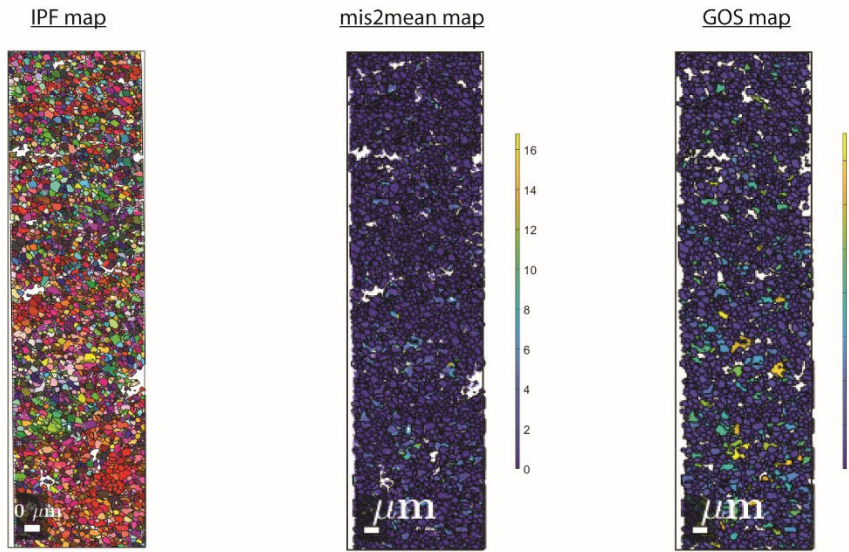


Figure DR3. (*continued*)

200718-6_3um



Lower-hemisphere pole figures (one point per grain)

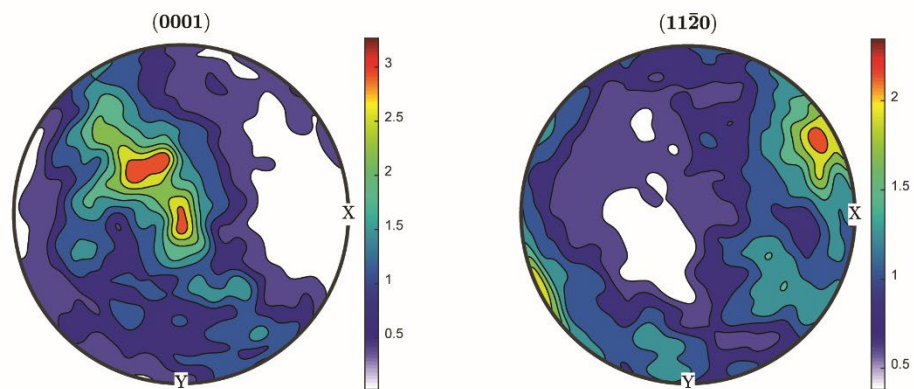
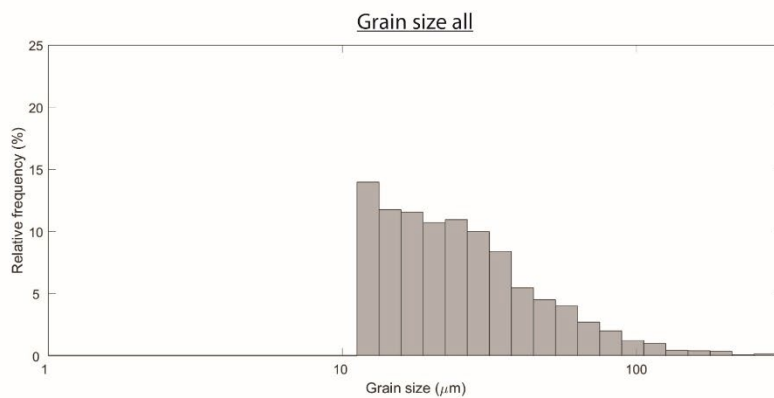
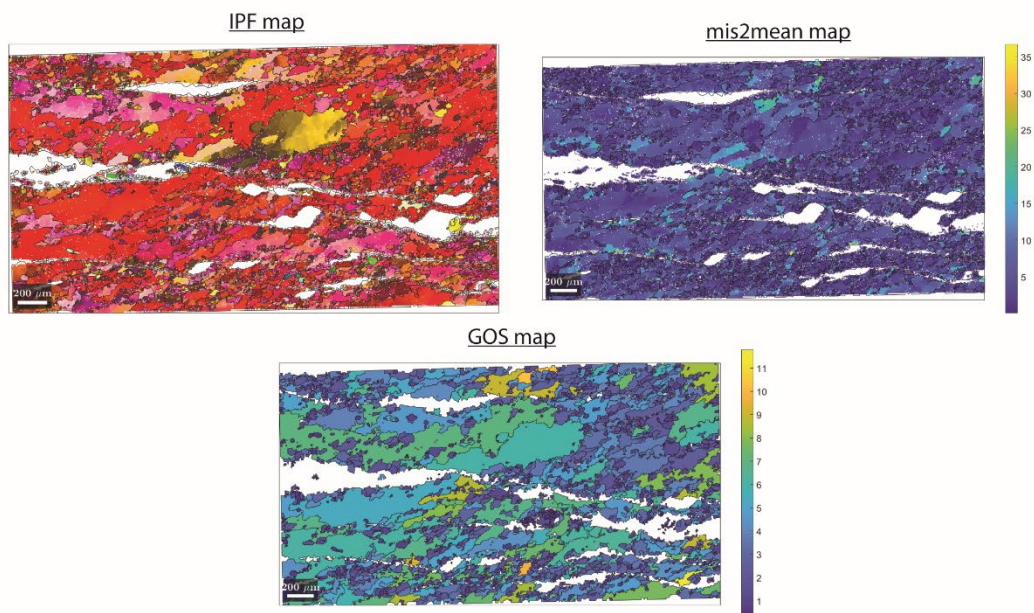


Figure DR3. (*continued*)

AZ 8 19 19 4 5um



Lower-hemisphere pole figures (one point per grain)

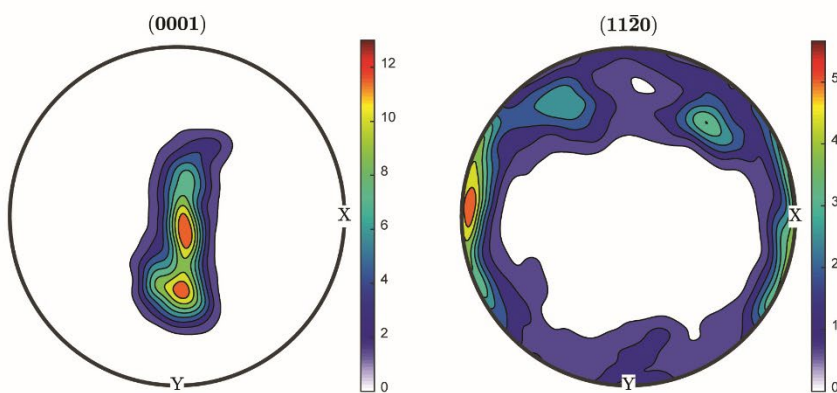
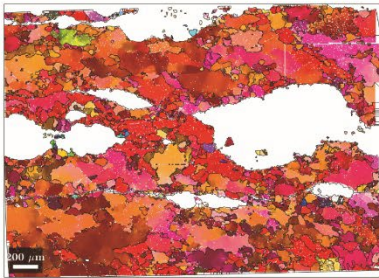


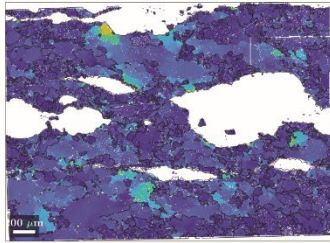
Figure DR3. (*continued*)

AZ 8 19 19 5 5um

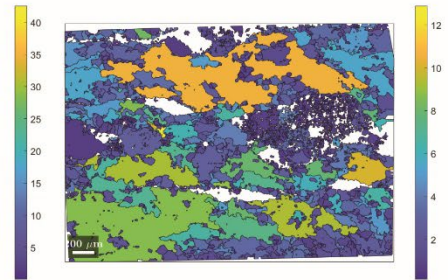
IPF map



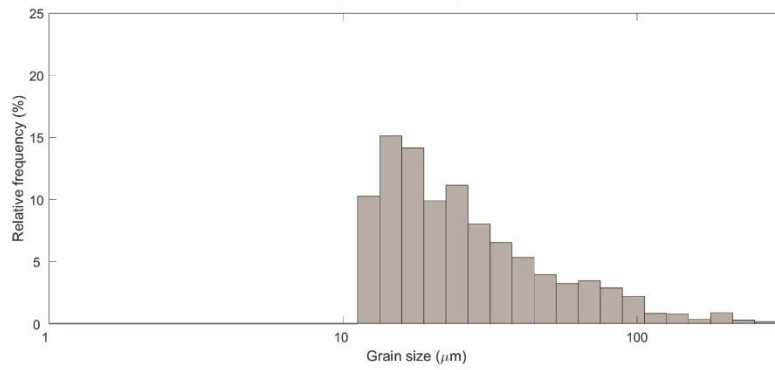
mis2mean map



GOS map



Grain size all



Lower-hemisphere pole figures (one point per grain)

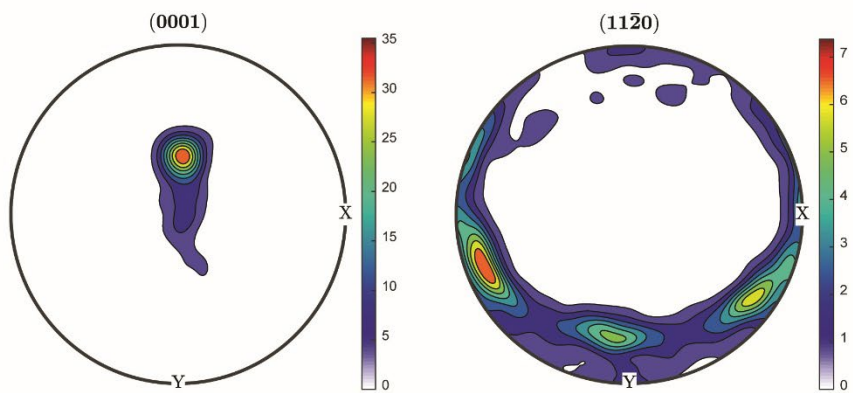
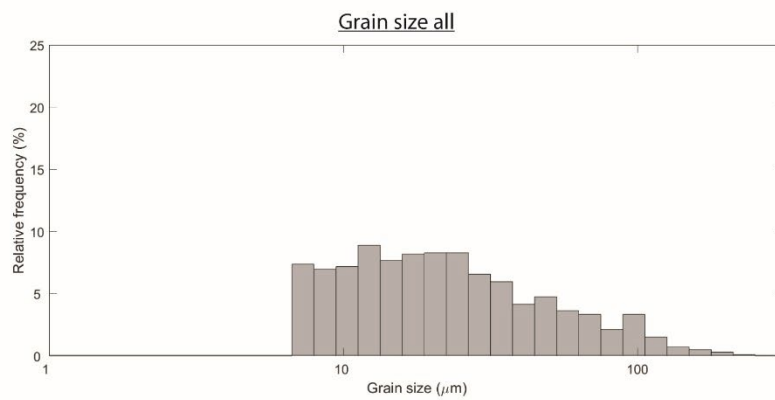
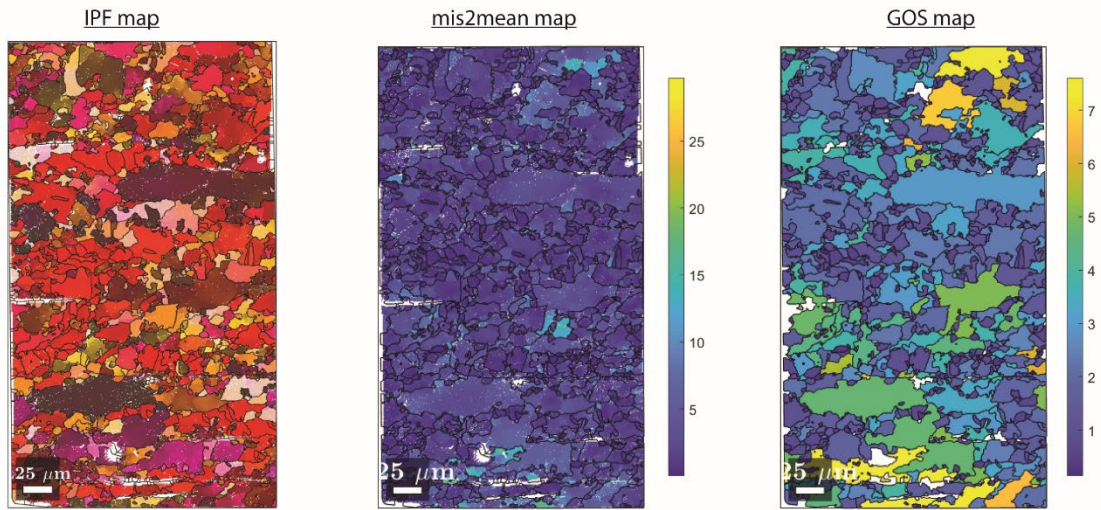


Figure DR3. (*continued*)

AZ 6 30 20 2 3um



Lower-hemisphere pole figures (one point per grain)

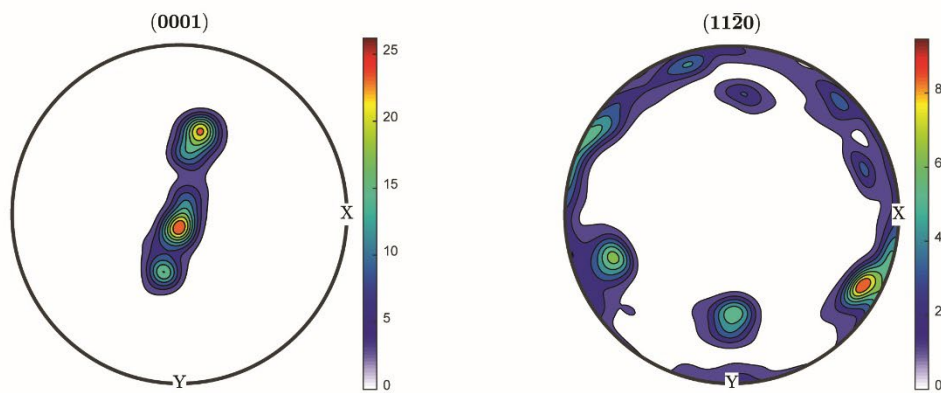
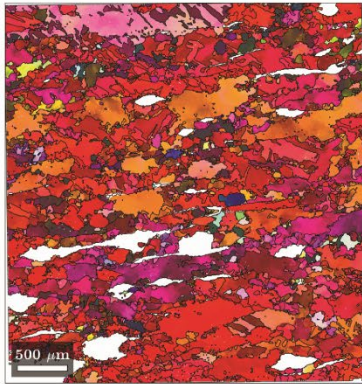


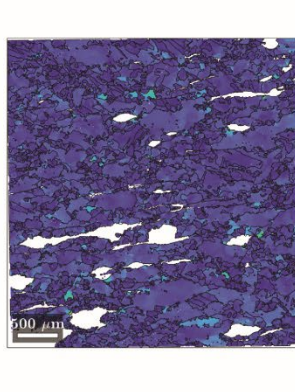
Figure DR3. (*continued*)

AZ 8 4 18 3 5um

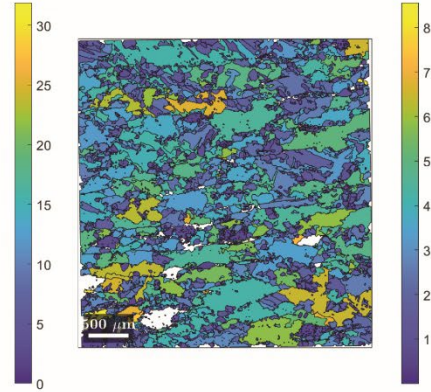
IPF map



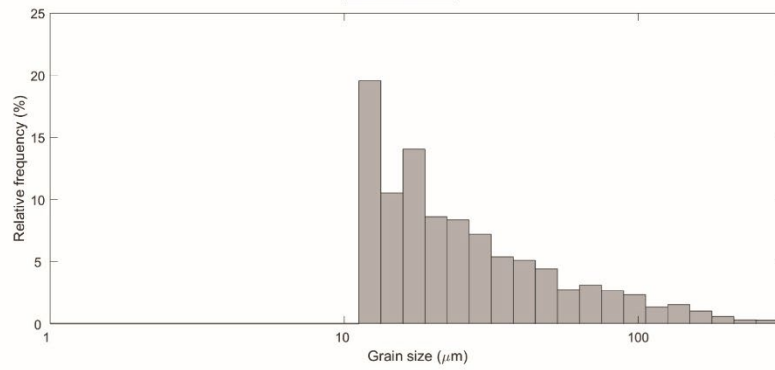
mis2mean map



GOS map



Grain size all



Lower-hemisphere pole figures (one point per grain)

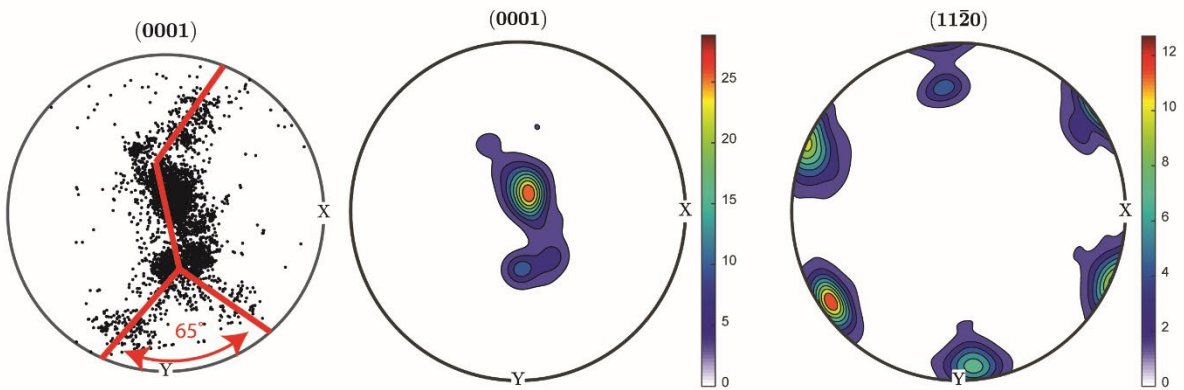
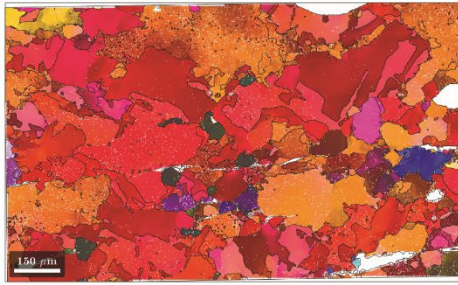


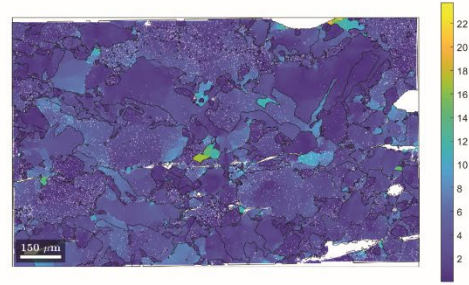
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AZ 8 4 18 3 2um

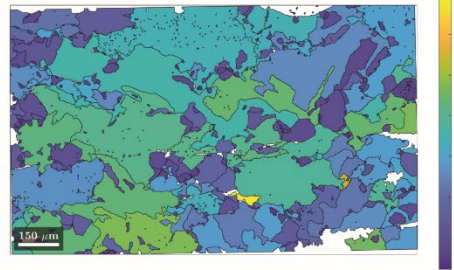
IPF map



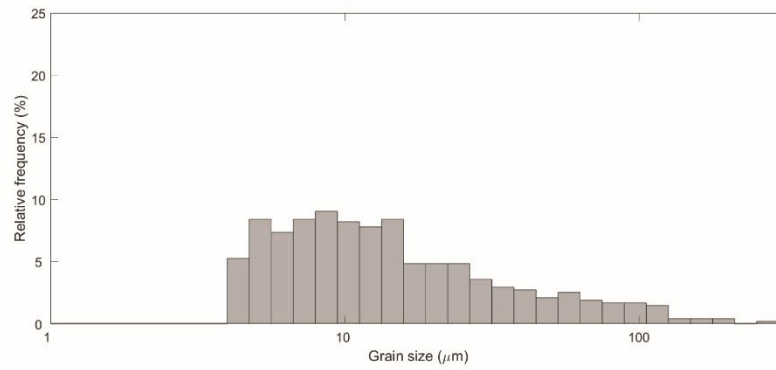
mis2mean map



GOS map



Grain size all



Lower-hemisphere pole figures (one point per grain)

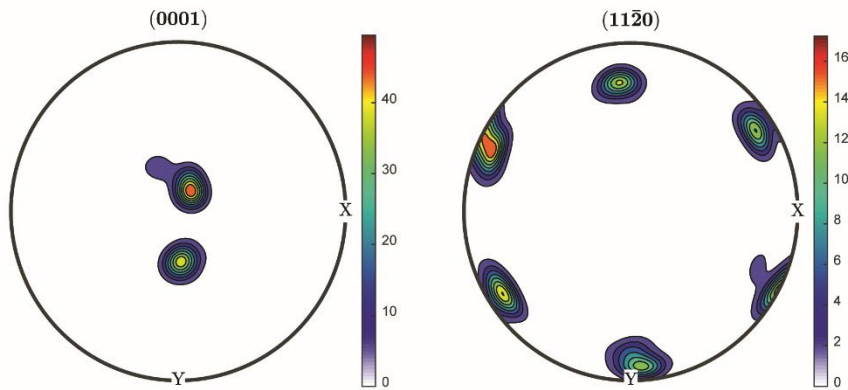
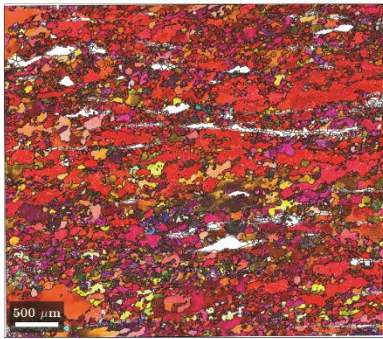


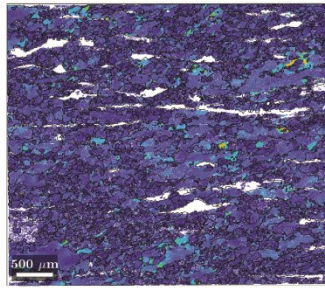
Figure DR3. (*continued*)

AZ 8 4 18 1 5um

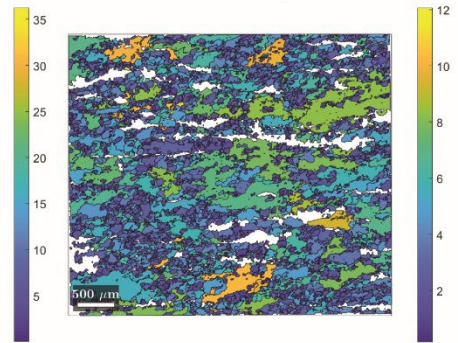
IPF map



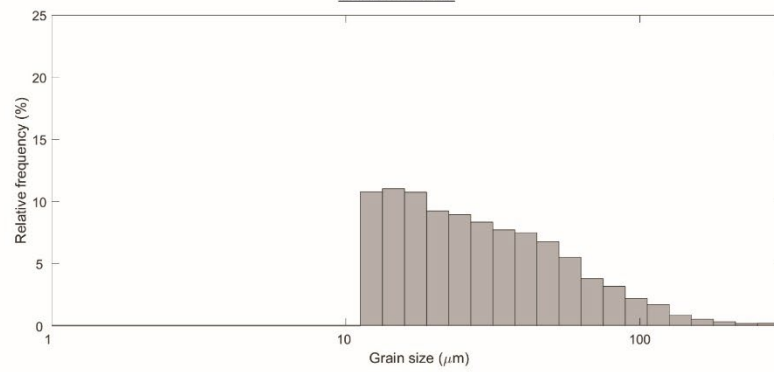
mis2mean map



GOS map



Grain size all



Lower-hemisphere pole figures (one point per grain)

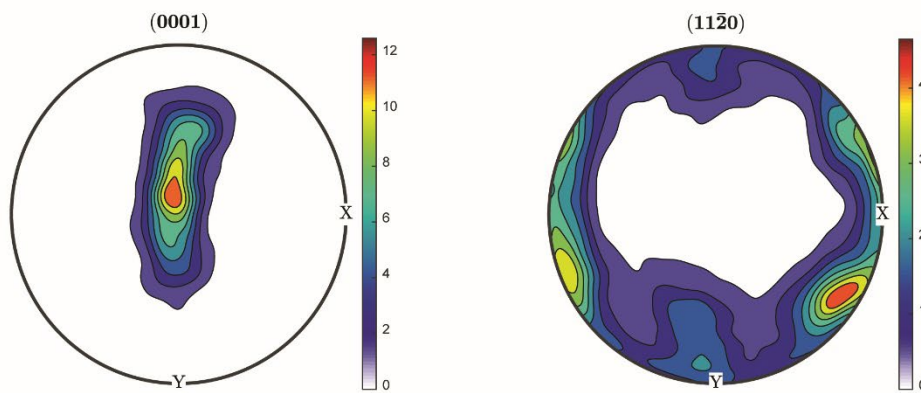
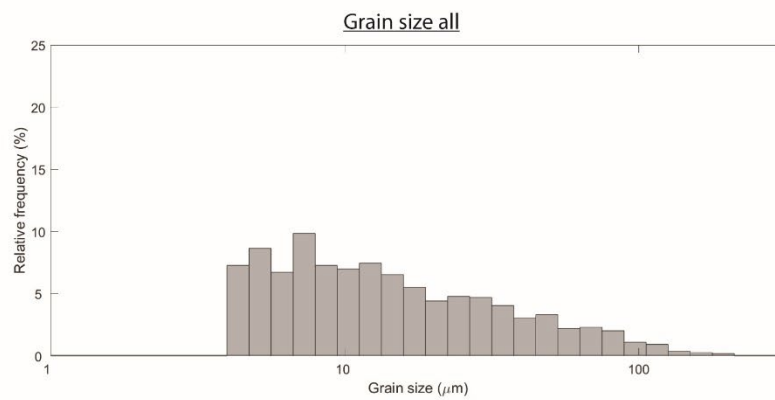
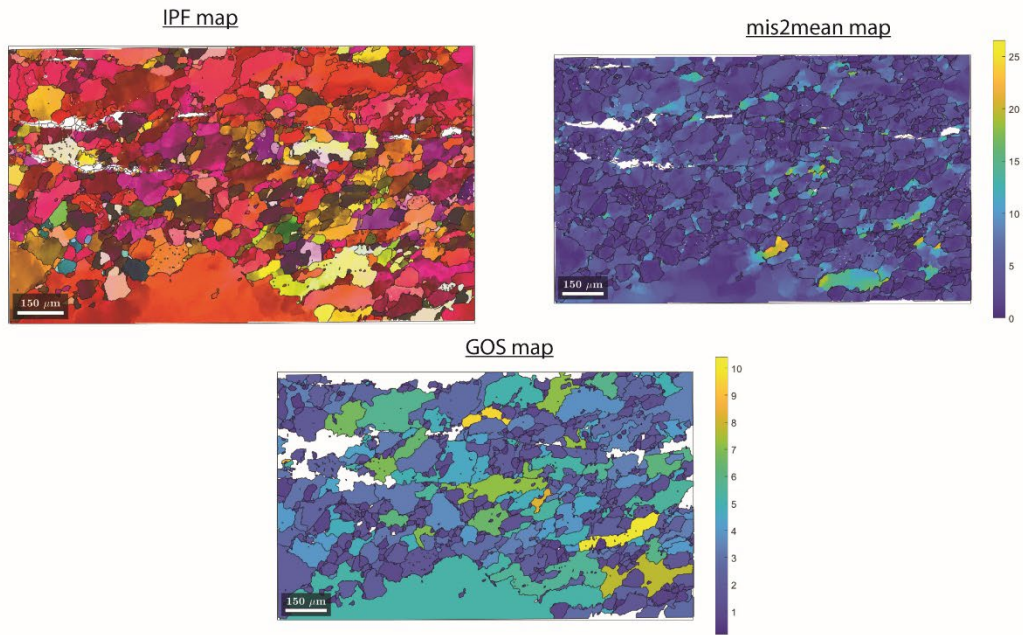


Figure DR3. (*continued*)

AZ 8 4 18 1 2 μ m



Lower-hemisphere pole figures (one point per grain)

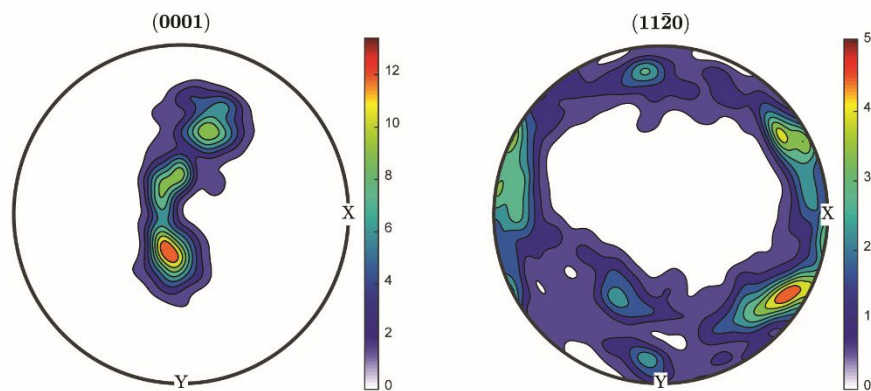
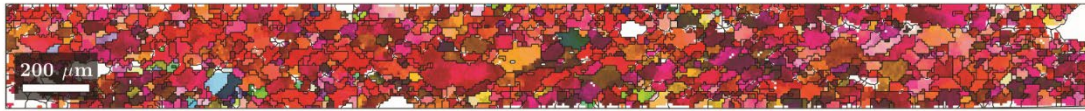


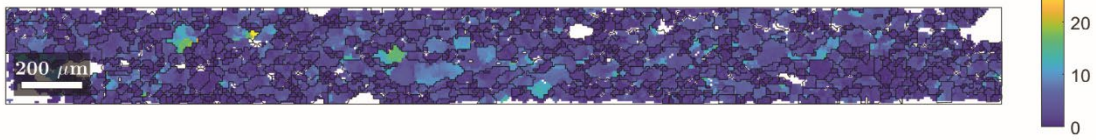
Figure DR3. (*continued*)

020619-2_3um

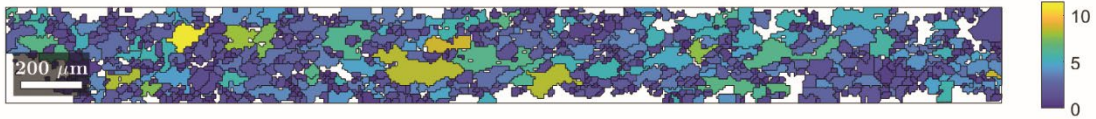
IPF map



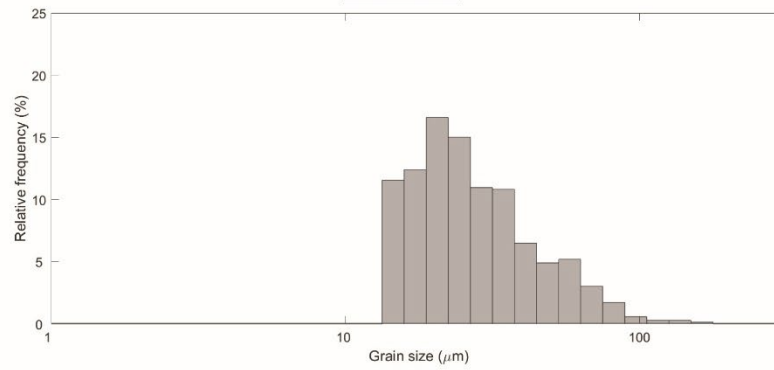
mis2mean map



GOS map



Grain size all



Lower-hemisphere pole figures (one point per grain)

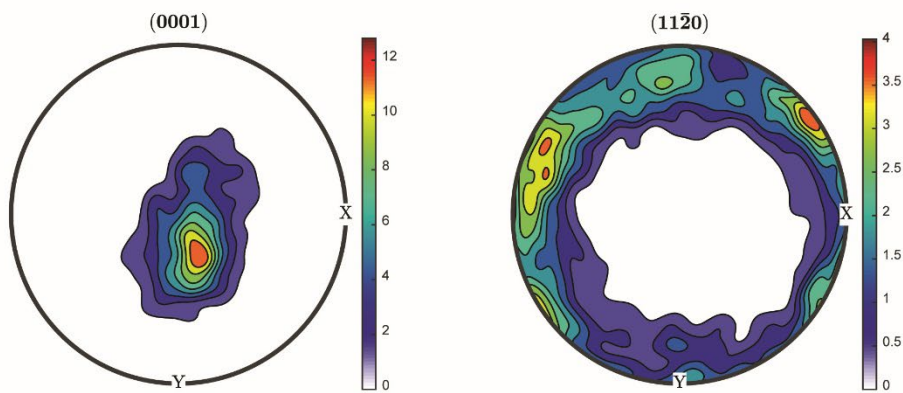
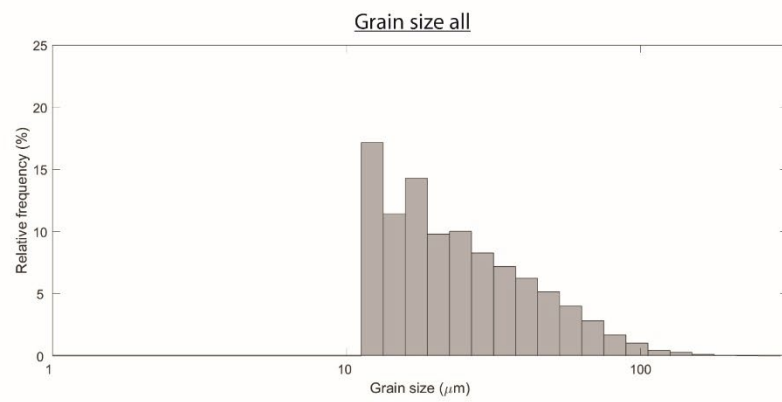
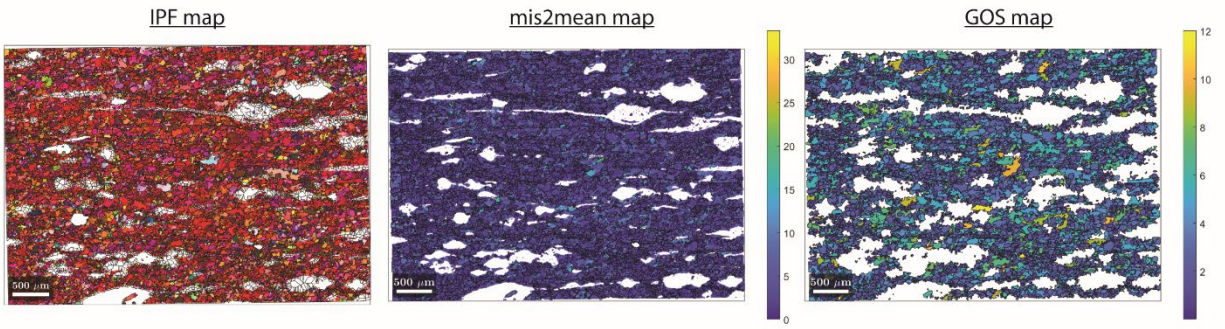


Figure DR3. (*continued*)

200718-4 5um



Lower-hemisphere pole figures (one point per grain)

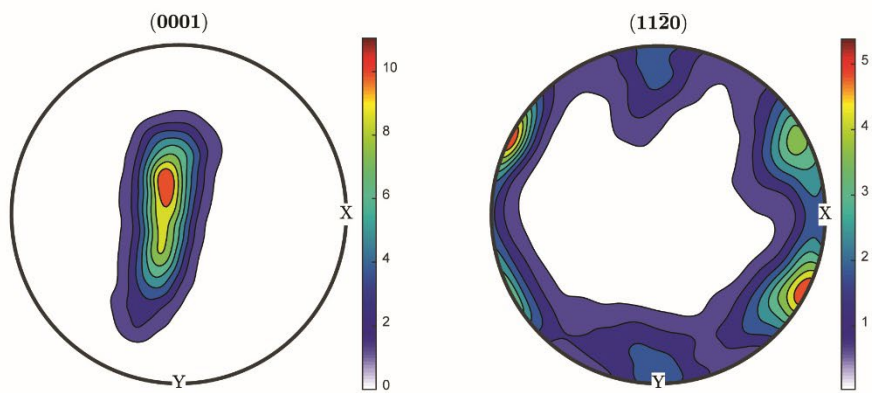
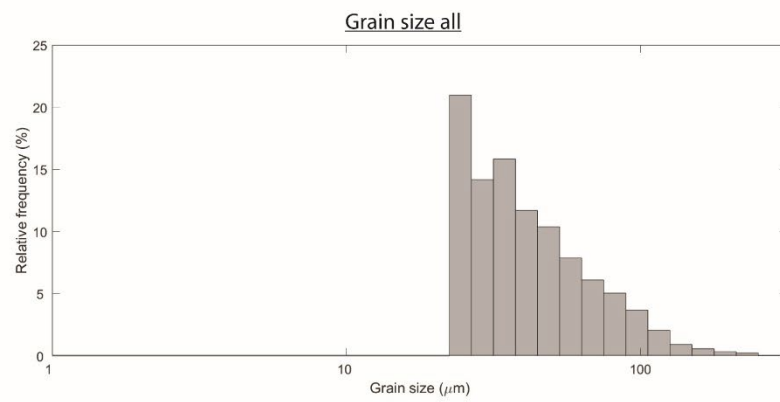
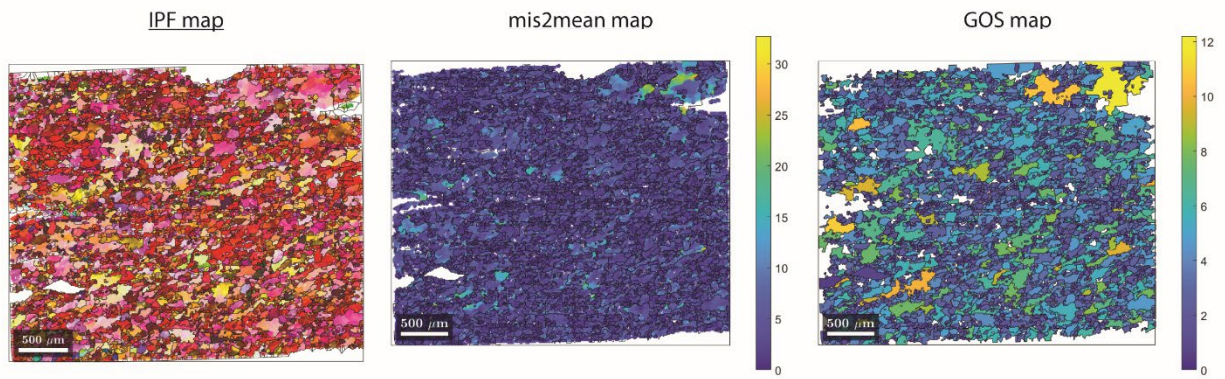


Figure DR3. (*continued*)

200718-3 2um



Lower-hemisphere pole figures (one point per grain)

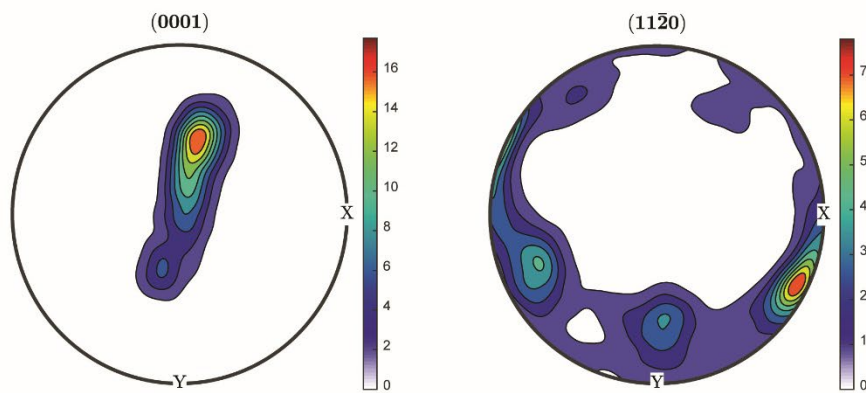


Figure DR3. (*continued*)

020619-5 5um

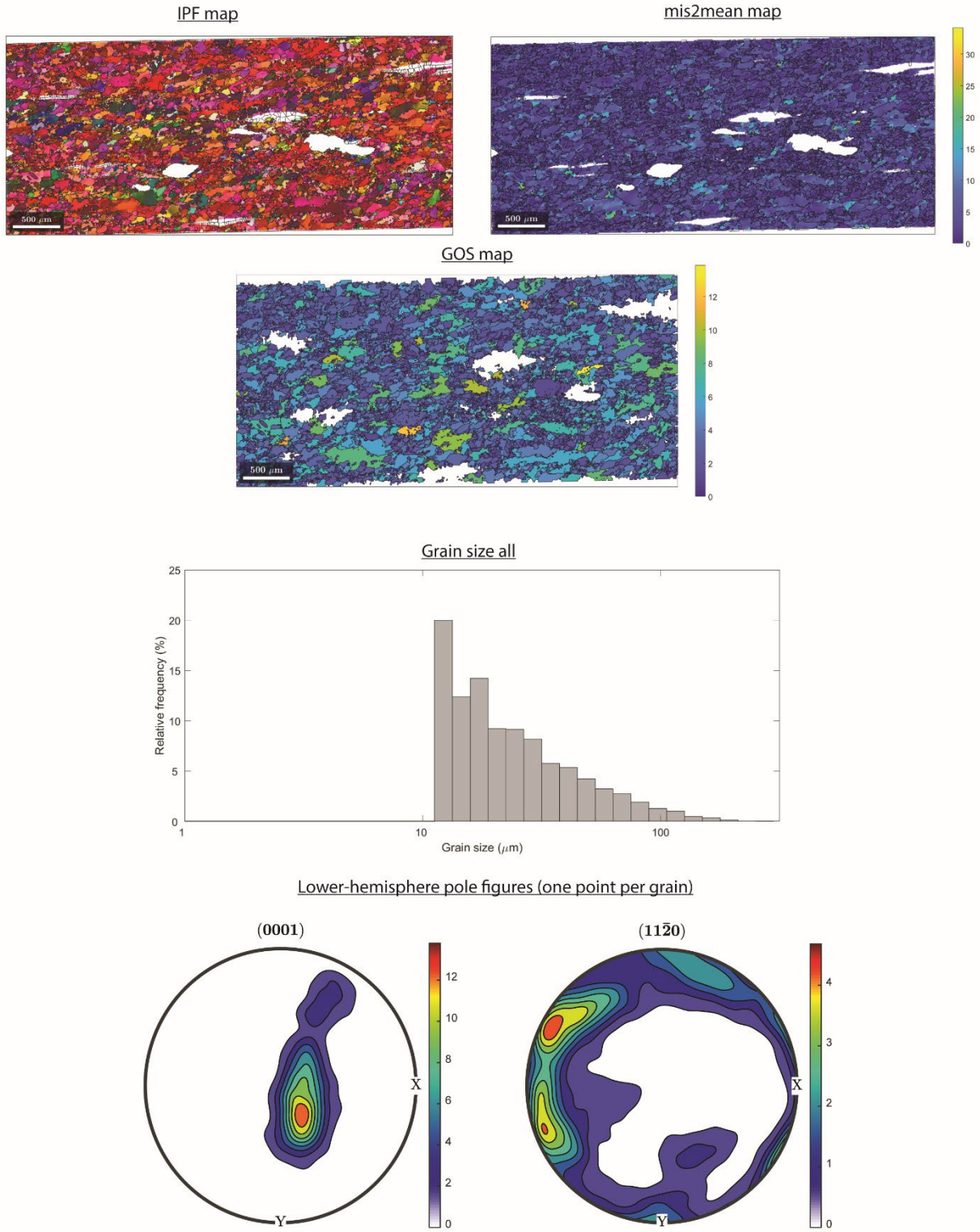
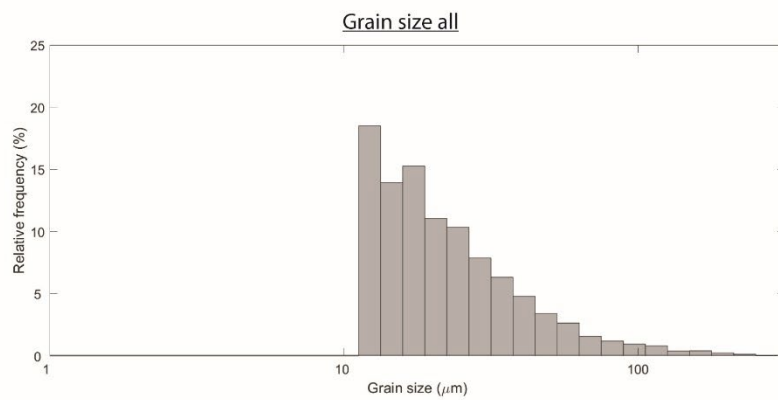
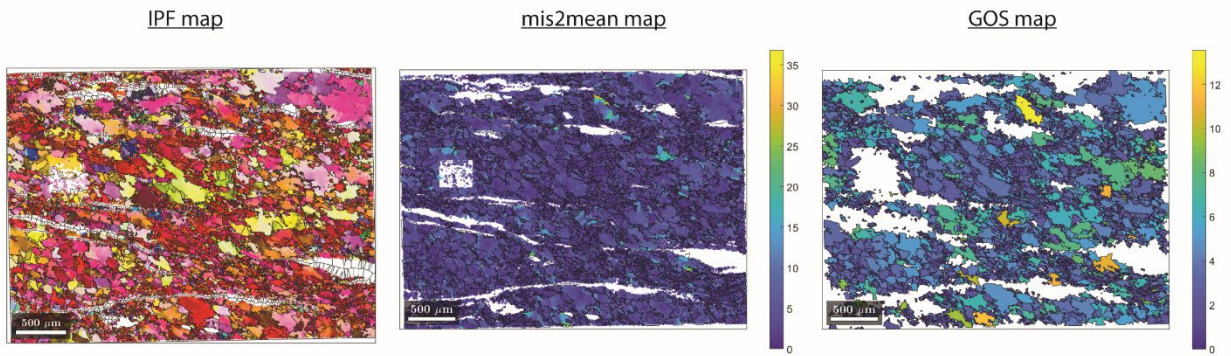


Figure DR3. (*continued*)

020619-4 2um



Lower-hemisphere pole figures (one point per grain)

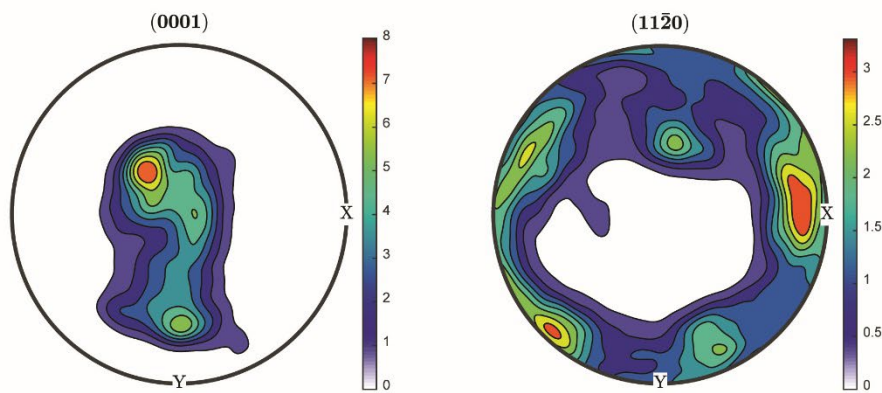
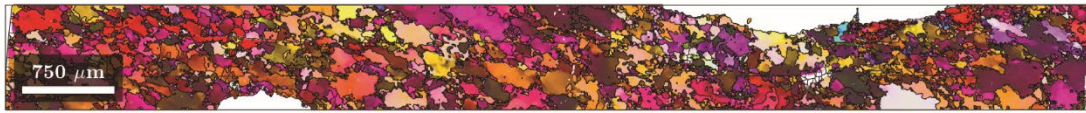


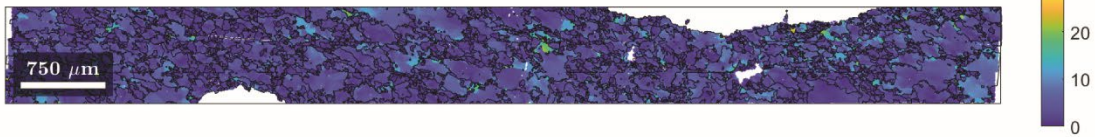
Figure DR3. (*continued*)

020619-3 2um

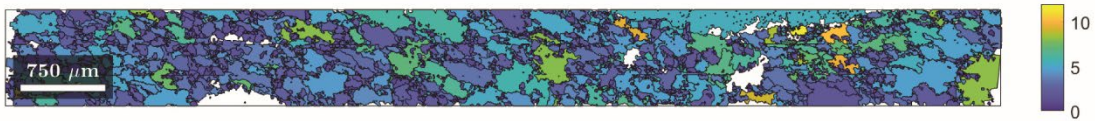
IPF map



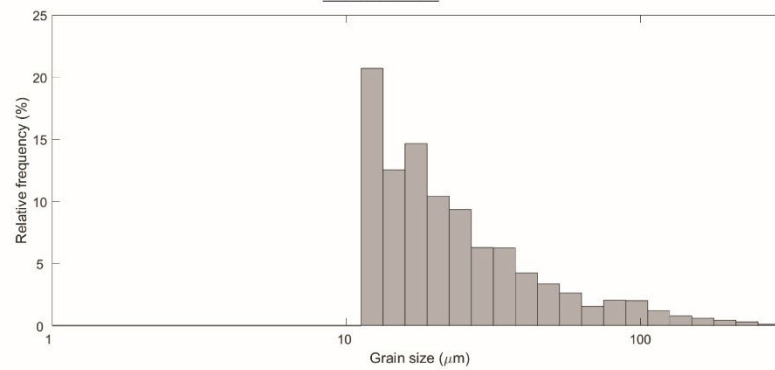
mis2mean map



GOS map



Grain size all



Lower-hemisphere pole figures (one point per grain)

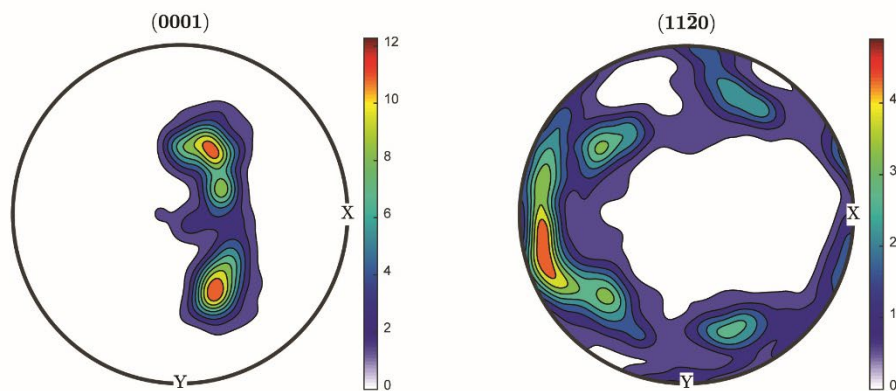
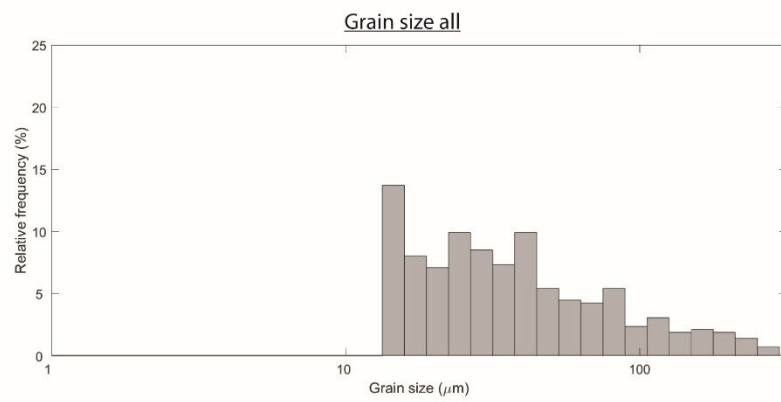
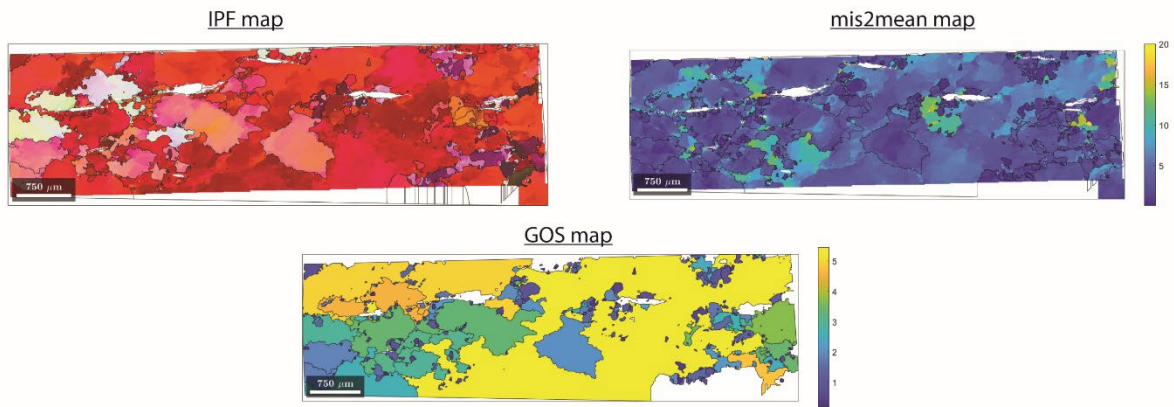


Figure DR3. (*continued*)

AZ 7 2 20 4 6 μ m



Lower-hemisphere pole figures (one point per grain)

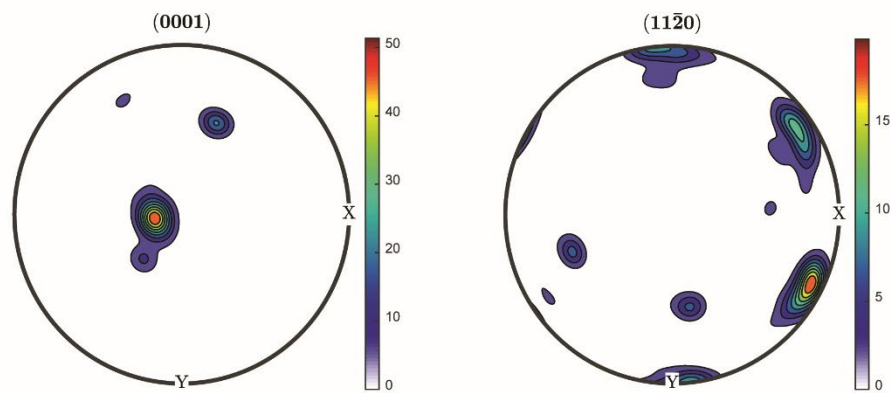


Figure DR3. (*continued*)

DR3 – Kinematic Vorticity Calculations

To estimate kinematic vorticity of our quartz mylonite samples, we apply the oblique grain shape fabric method (Fig. DR4; e.g., Wallis, 1995; see Xypolias (2010) for a review of the method). This approach requires an estimate of the angle between the instantaneous stretching axis (ISA) and shear plane from the primary foliation, δ and β respectively (Fig. DR4). EBSD grain-boundary maps were fit by ellipses, and the mean ellipse long axis was assumed to represent ISA (Fig. DR7). Shear plane orientations were determined directly from c-axis pole figure plots by calculating the angle between a best fit line through the quartz CPO and the vertical axis of the pole figure (Fig. DR7).

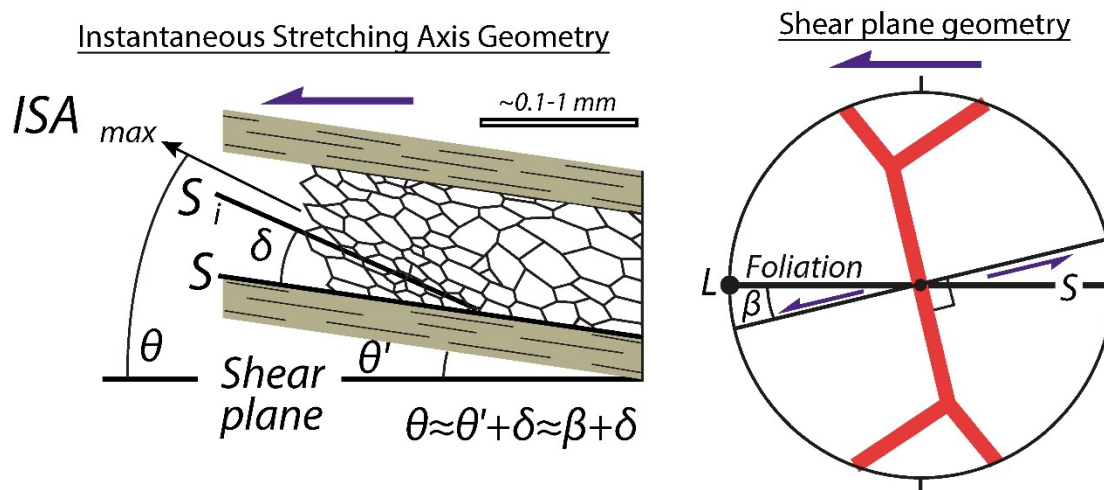


Figure DR4. Illustration of rock fabric and pole figure showing the geometric relationships between the instantaneous stretching axis (ISA), the foliation (S) and the shear plane.

Vorticity analysis was conducted using the MTEX toolbox (5.7.0; <https://mtex-toolbox.github.io/>) (Bachmann et al., 2010). We fit ellipses to all grains to estimate ISA. All grain boundaries were smoothed using the *smooth.m* function. The *fitEllipse.m* function was used for ellipse fitting. Grains with an aspect ratio less than 1.4 were removed from the subset. The mean ISA was determined using a kernel density estimate of ellipse axes with the maxima defining the mean vector. The best fit vector of quartz c-axes was computed using the all c-axis orientation. The best fit vector was estimated as the mean plane orthogonal to c-axis vectors. The angle between the best fit vector and the horizontal is the parameter β .

Ellipse and c-axis fits were inspected visually to validate the results. Where the c-axis best fit was visually misaligned with the bulk shape of the CPO or inclined towards the ISA, a best fit line was determined manually, or the a-axis fit was used. Quartz a-axes were fit manually to provide a second measure of β (e.g., Little et al., 2016). Quartz a-axes commonly form a conjugate pattern across the X plane (Fig. DR5). The strength of either conjugate pair may vary depending on the components of coaxial and non-coaxial strain (e.g., Law, 1990). In the samples we have analyzed, we note fitting the dominant a-axis maxima generates estimates of β much greater than the value acquired from fitting the c-axis maxima. If instead the center of the a-axis conjugate pair is fit, the β value will match the c-axis maxima derived value well. The quality of a-axis fits was checked against the m-pole maxima, which should be orthogonal to the c-axis maxima. The

MTEX c-axis best fit method does a poor job fitting samples with symmetric quartz c-axis girdles. The c-axis best fit was determined manually as a line through the center of the girdle. Both manual and MTEX β values are listed in Table 3. The kinematic vorticity number is given by:

$$W_k = \sin (2 * (\beta + \delta)) \quad (2)$$

The best W_k values are calculated as the mean of W_k calculated from MTEX and manually determined β values. If either the c- or a-axis best fit lines were uncertain, the fit with higher confidence was used. An uncertainty of $\pm 5^\circ$ was assigned to each W_k estimate. Figure DR7 shows the results of the vorticity analysis for each sample.

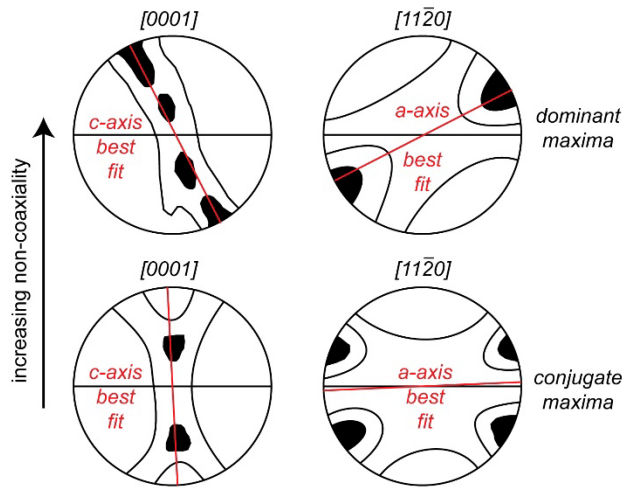


Figure DR5. Cartoon quartz pole figures displaying the relationships between c- and a-axes (modified from Law, 1990). The top pole figures show a case where a dominant a-axis maxima has developed perpendicular to the asymmetric c-axis single girdle. The bottom pole figures show a case where conjugate a-axis maxima are developed across the X plane and perpendicular to the c-axis girdle.

Table 3: Kinematic vorticity data

Sample	Structural Position	Kinematic vorticity						uncertainty ^d	Depth ^f
		δ MTEX	β MTEX	β manual ^b	Wk MTEX	Wk manual	Wk best		
AZ 10-8-19 (1a)	1	-	-	-	-	-	-	-	188
AZ 7-1-20 (1)	2	0.0	5.5 ^a	3.0	0.19	0.10	0.15 ^c	0.17	229
200718-6	3	-	-	-	-	-	-	-	358
AZ8-19-19-(4)	4	20.8	8.40	9.6 ^e	0.85	-	0.85	0.17	460
AZ8-19-19-(5)	5	7.7	2 ^e	8.6	0.33	0.54	0.54	0.17	460
020619-2	6	1.7	14.8 ^e	4	0.55	0.20	0.2 ^c	0.17	498
200718-4	7	12.3	9.4	0	0.69	0.41	0.41	0.17	498
200718-3a	8	18.5	14.2	1.8	0.91	0.65	0.78 ^c	0.17	498
020619_5	9	15.3	14.0	8.6	0.85	0.74	0.80 ^c	0.17	498
020619-4	10	19.0	3.60	5.6	0.71	0.76	0.73 ^c	0.17	498
020619-3	11	17.3	8.4	7.0	0.78	0.75	0.76 ^c	0.17	498
AZ 6-30-20 (2)	12	4.7	14.5	1.0	0.62	0.20	0.41 ^c	0.17	498
AZ 8-4-18 (3)	13	2.8	3.20	4.4	0.21	0.25	0.23 ^c	0.17	608
AZ 8-4-18 (1)	14	15.0	1.60	0	0.55	0.50	0.52 ^c	0.17	608
AZ 7-2-20 (4)	15	-	-	-	-	-	-	-	852

^a - β from girdle axis

^b - β from <a> axes

^c - average of Wk estimates

^d - 5° uncertainty

^e - fit uncertain

^f - meters

S

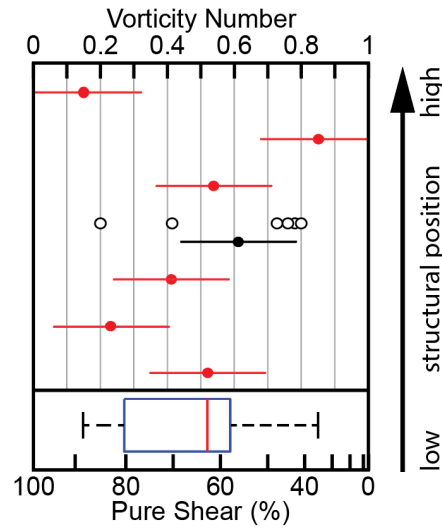


Figure DR6. Kinematic vorticity analysis results sorted by structural depth. The box and whisker plot show 50% of the vorticity number estimates fall between 0.28 and 0.59 (blue box), with a median value of 0.52 (red bar). Relationship between vorticity number and pure shear from Law et al. (2004).

AZ_7_1_20_1_1um

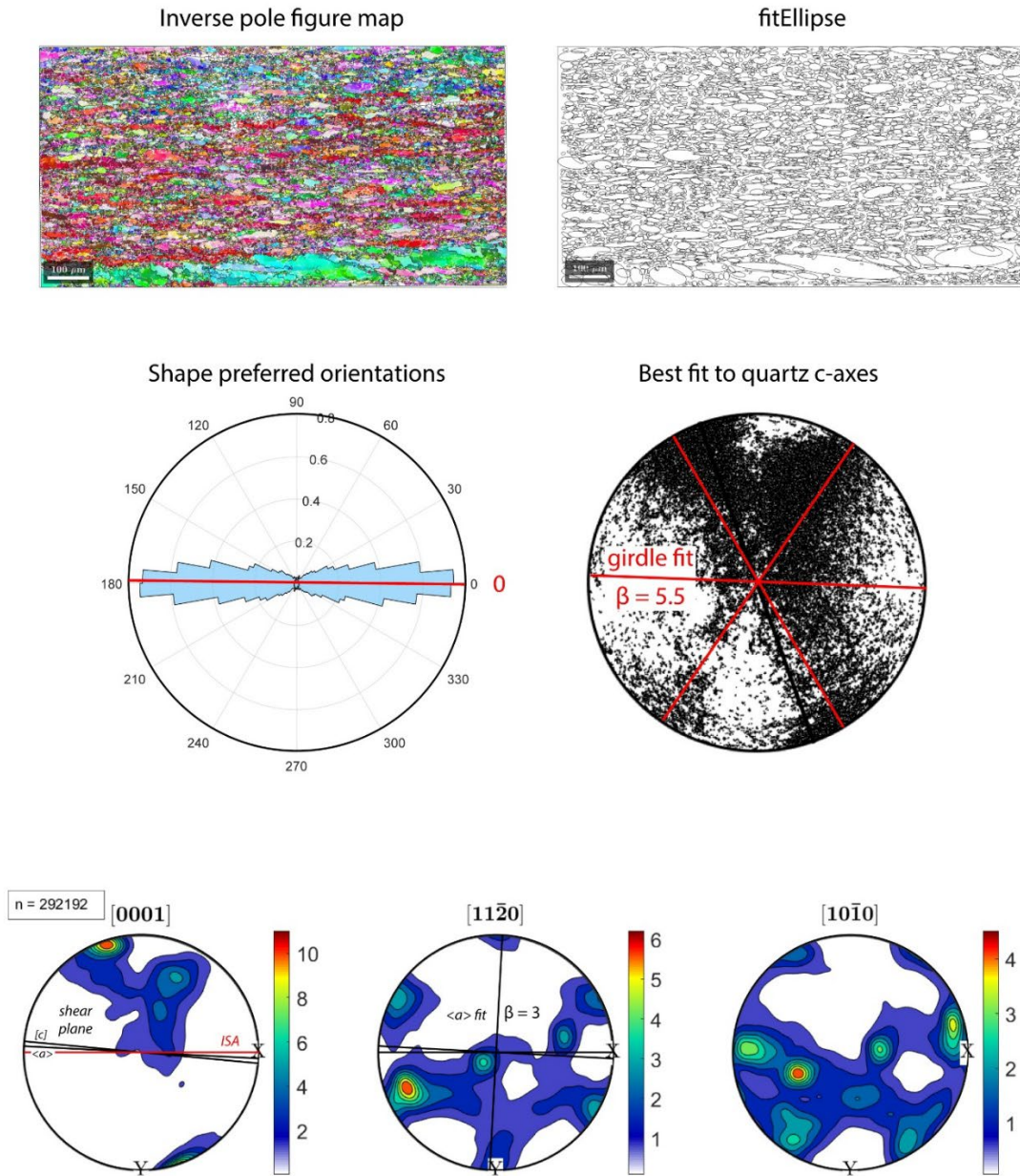
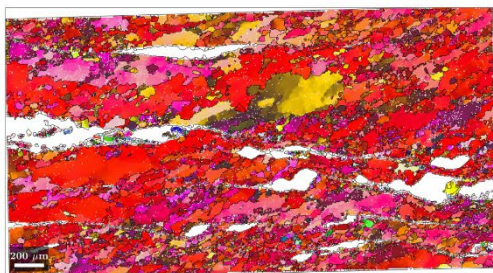


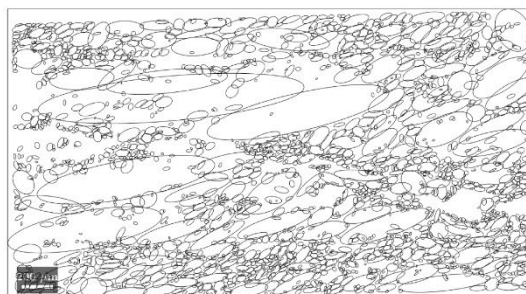
Figure DR7. Results of grain ellipse fitting and quartz c-axis fitting to calculate kinematic vorticity number. Inverse pole figure maps (IPF) and fitEllipse maps show the orientation of ellipses relative to the rock fabric. The shape preferred orientation plot shows the distribution of ellipse axes as a polar histogram. The best fit to quartz c-axes is shown as a black line plotted over all c-axis orientations. Pole figures plot all orientations and show the orientation of the ISA and shear plane derived from c- and a-axis fits. The pole figure scales are multiples of uniform density (M.U.D.).

AZ-8_19_19_4_5um

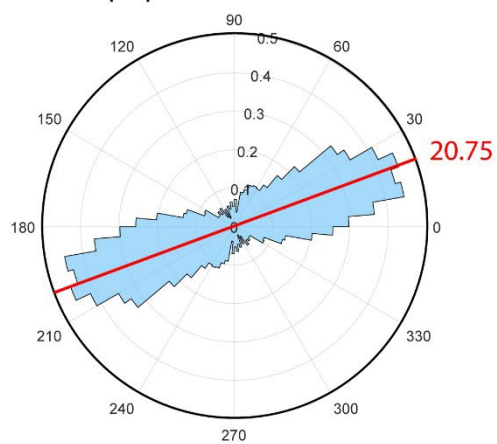
Inverse pole figure map



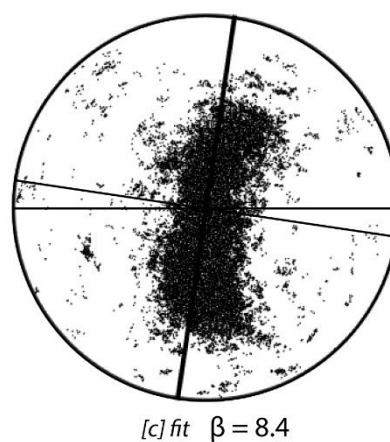
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



n = 176812

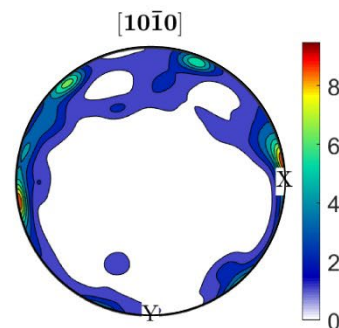
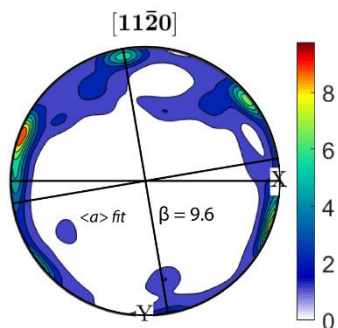
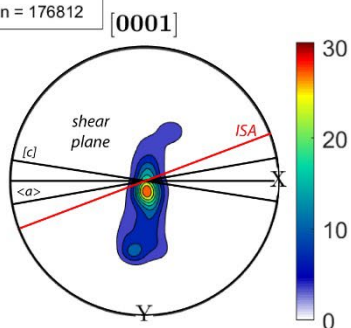
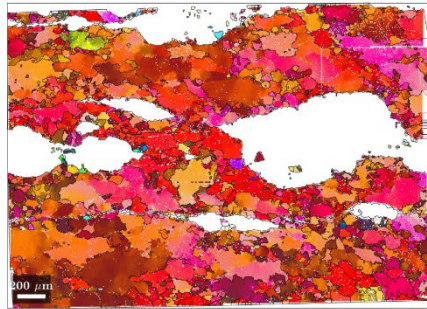


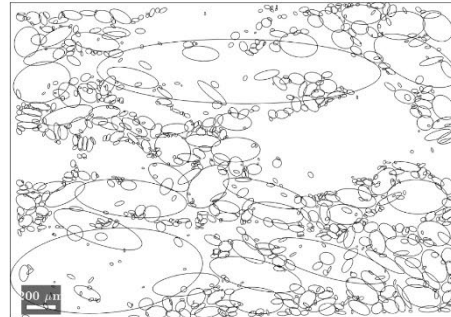
Figure DR7. (continued)

AZ-8_19_19_5_5um

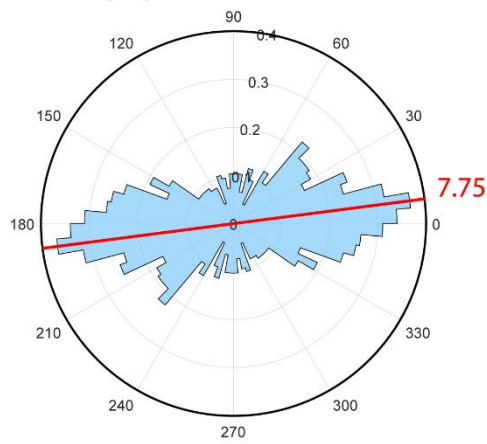
Inverse pole figure map



fitEllipse



Shape preferred orientations



Best fit to quartz c-axes

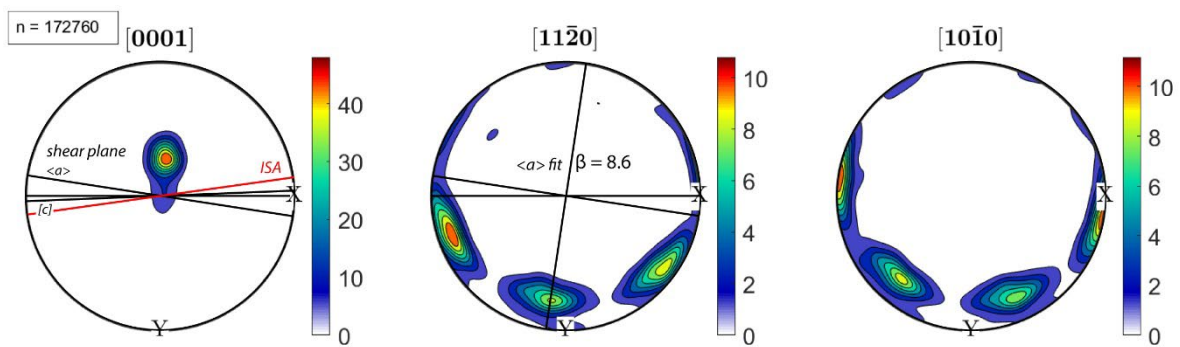
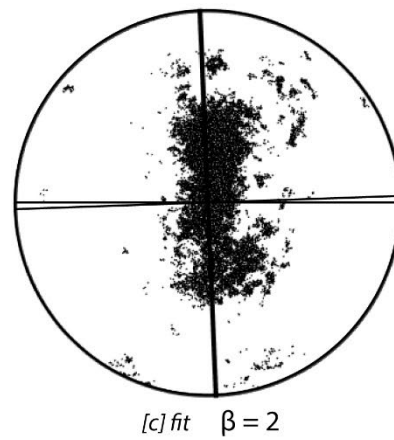
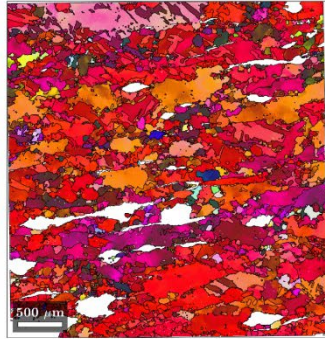


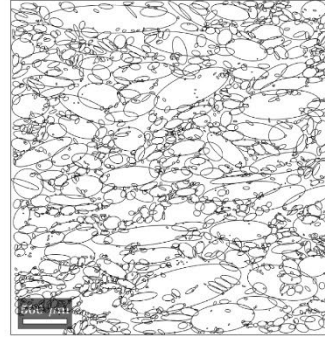
Figure DR7. (continued)

AZ-8_4_18_3_5um

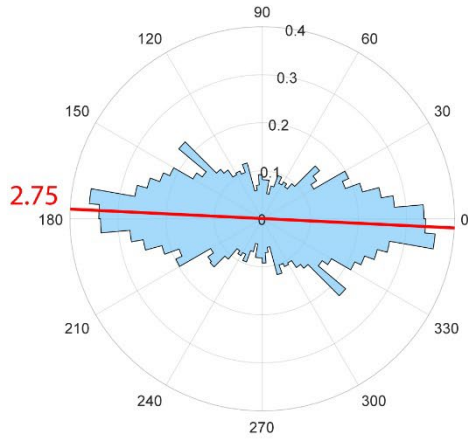
Inverse pole figure map



fitEllipse



Shape preferred orientations



Best fit to quartz c-axes

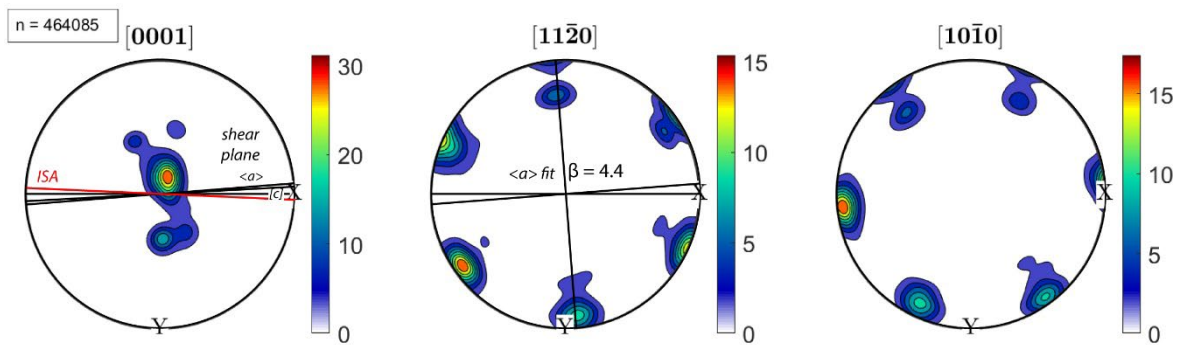
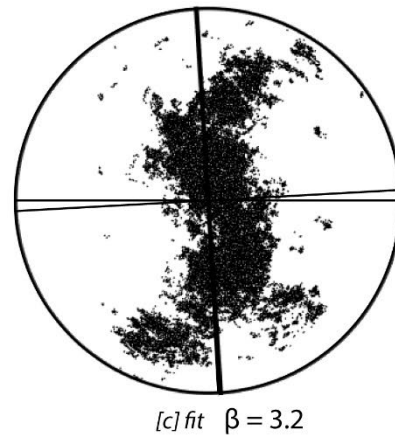
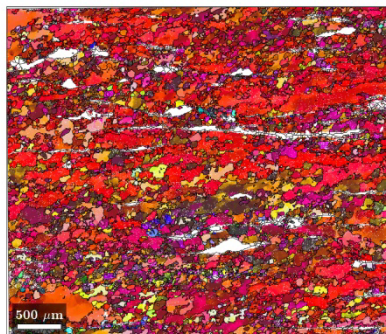


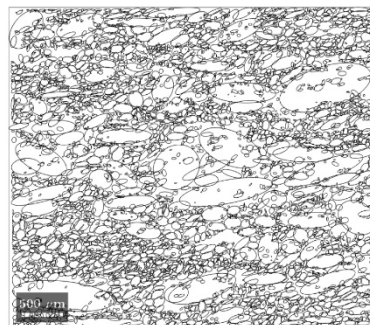
Figure DR7. (continued)

AZ-8_4_18_1_5um

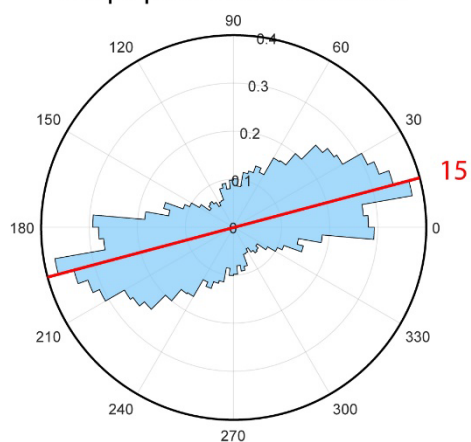
Inverse pole figure map



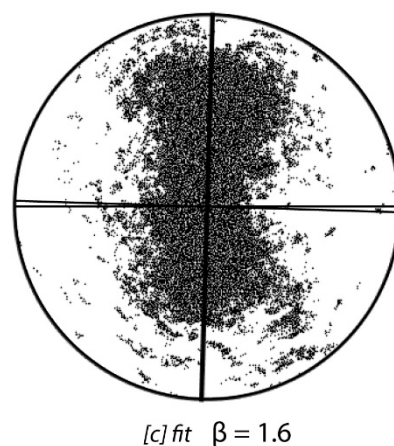
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



n = 524164

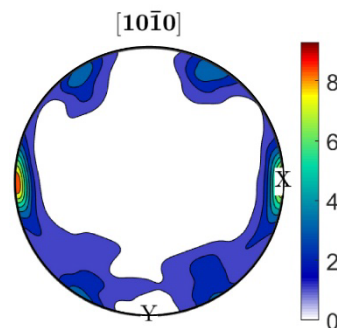
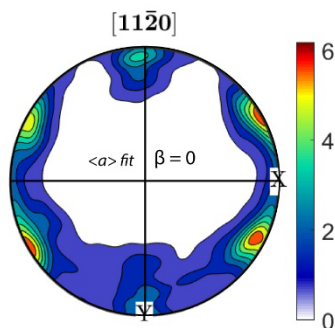
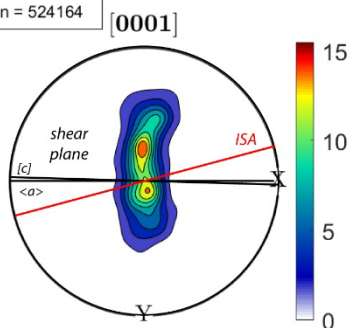


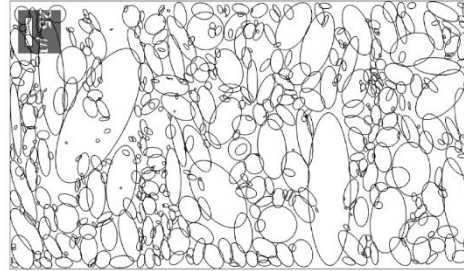
Figure DR7. (continued)

AZ_6_30_20_2_3um

Inverse pole figure map

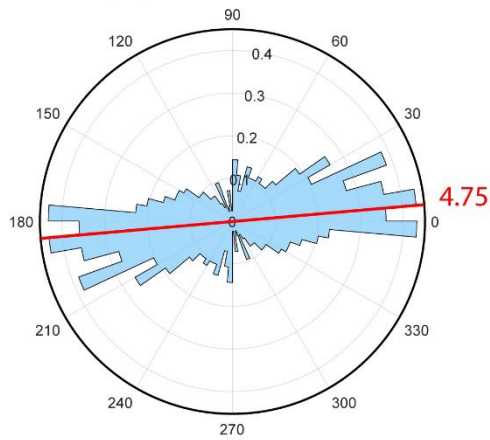


fitEllipse

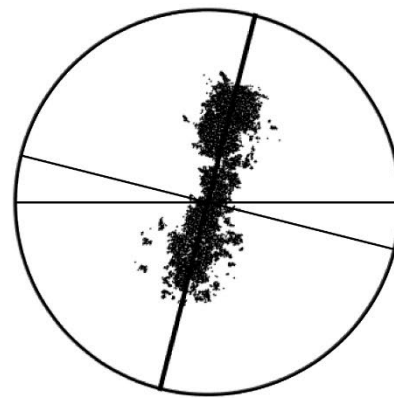


**flipped 90° to the right for space*

Shape preferred orientations



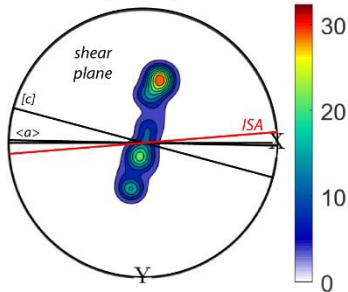
Best fit to quartz c-axes



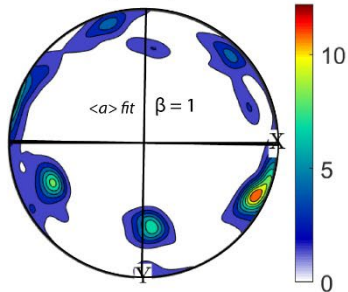
$[c]$ fit $\beta = 14.5$

n = 200767

$[0001]$



$[11\bar{2}0]$



$[10\bar{1}0]$

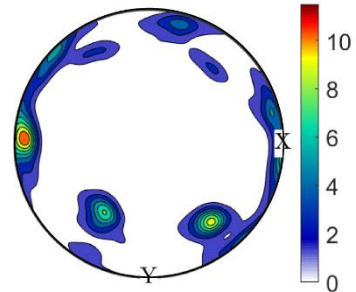


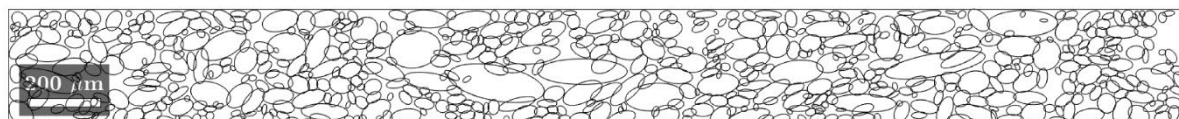
Figure DR7. (continued)

020619_2_3um

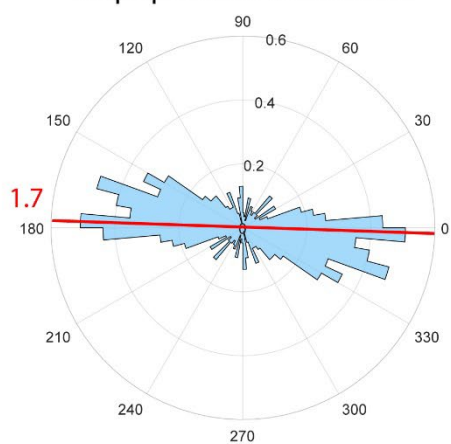
Inverse pole figure map



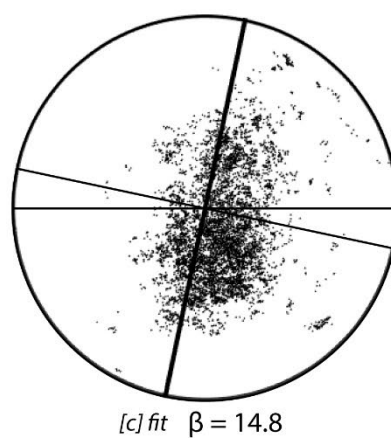
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



n = 15737

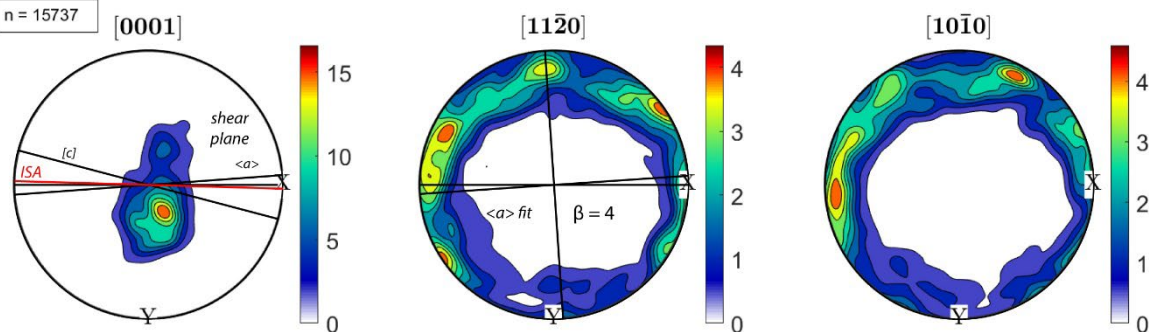
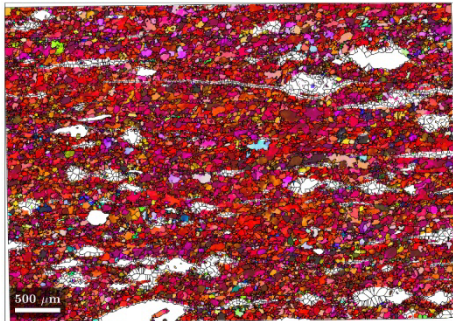


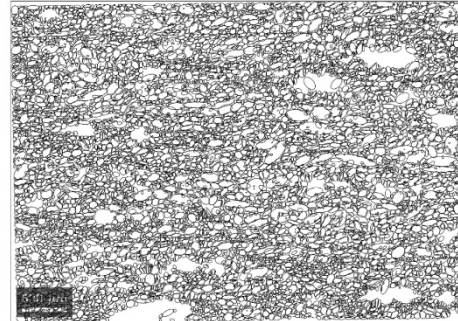
Figure DR7. (continued)

200718_4_5um

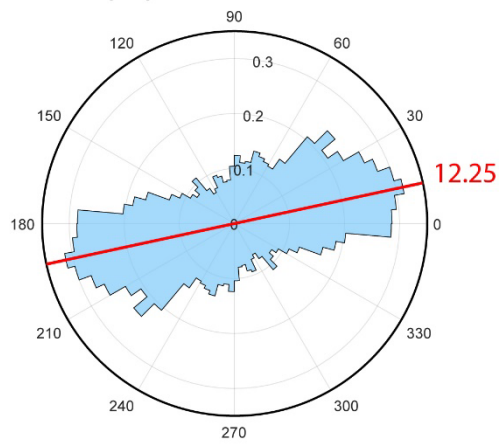
Inverse pole figure map



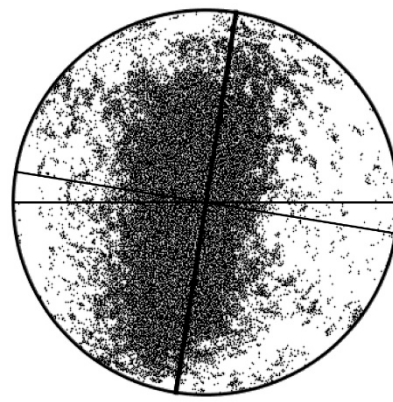
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



$[c] \text{ fit } \beta = 9.4$

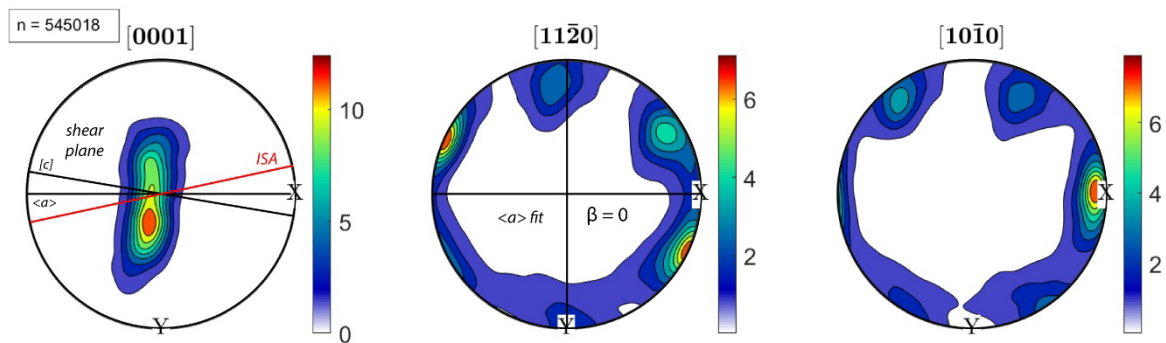
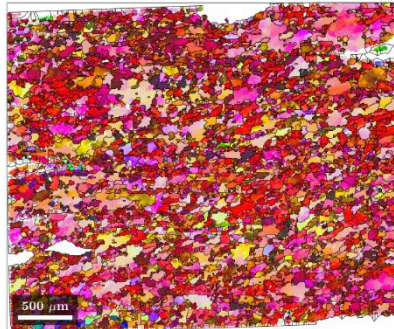


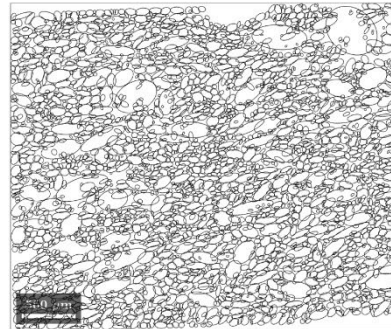
Figure DR7. (continued)

200718_3a_2um

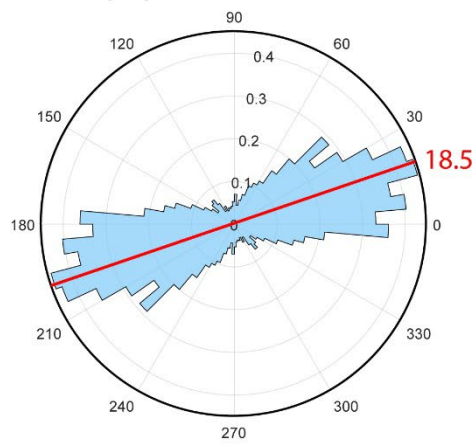
Inverse pole figure map



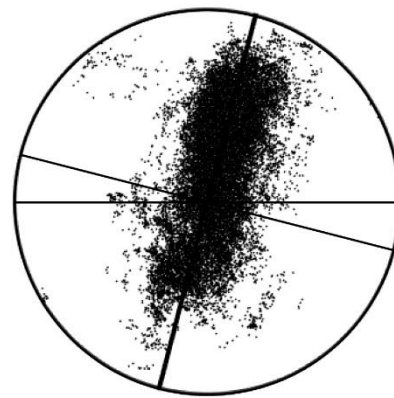
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



$[c] \text{ fit } \beta = 14.2$

n = 89884

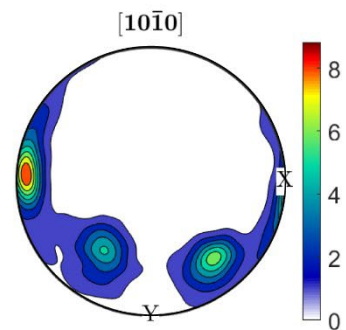
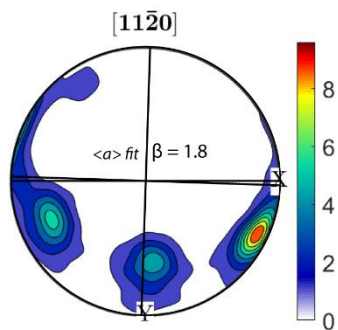
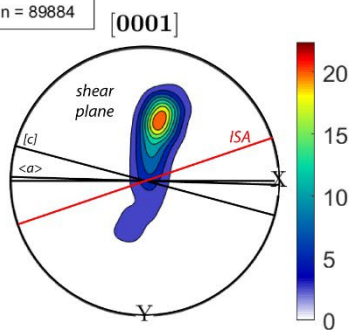
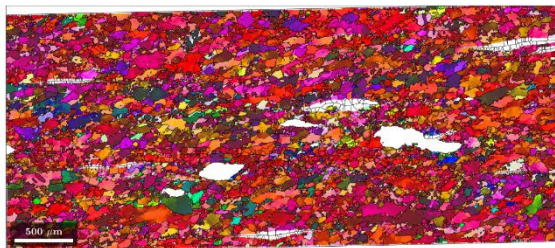


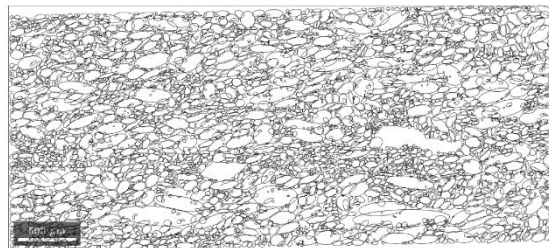
Figure DR7. (continued)

020619_5_2um

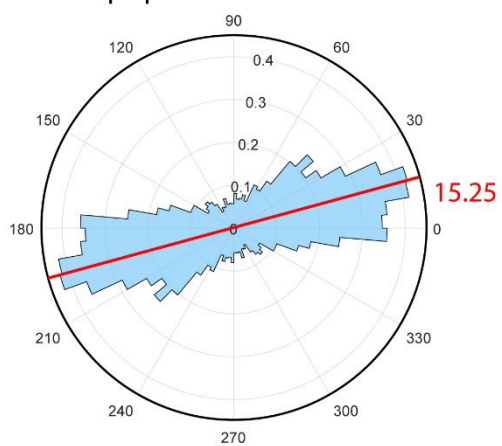
Inverse pole figure map



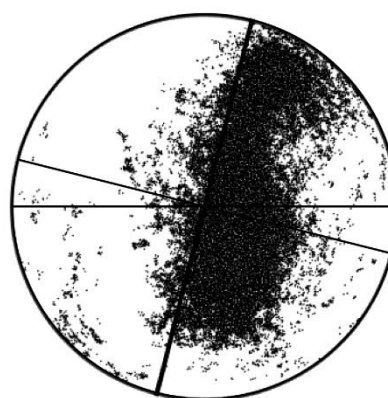
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



$[c] \text{ fit } \beta = 14$

n = 331460

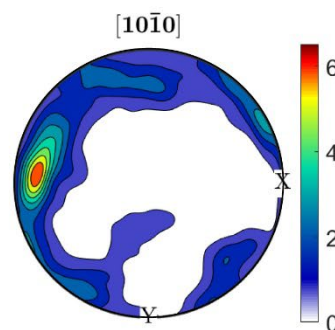
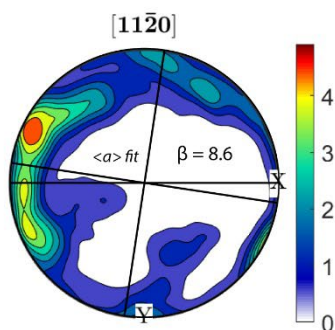
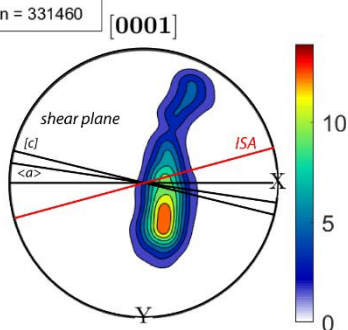
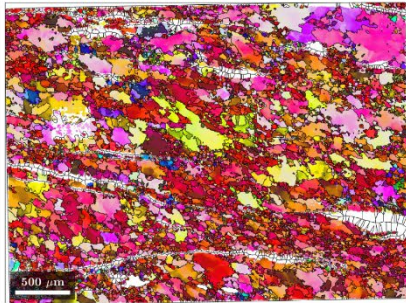


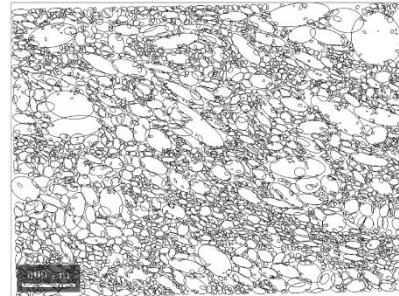
Figure DR7. (continued)

020619_4_2um

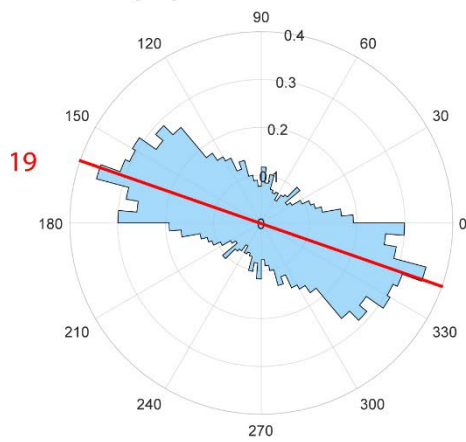
Inverse pole figure map



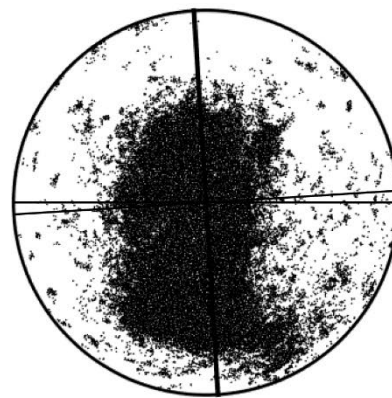
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



$[c]$ fit $\beta = 3.6$

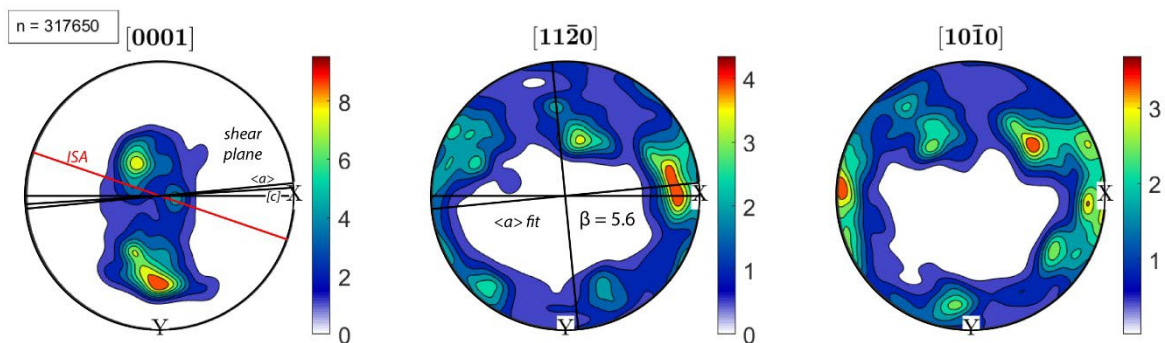
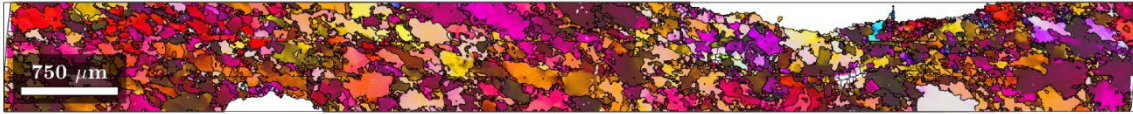


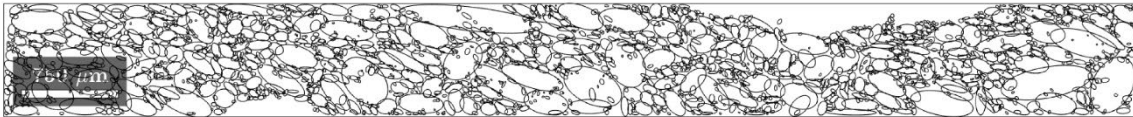
Figure DR7. (continued)

020619_3_2um

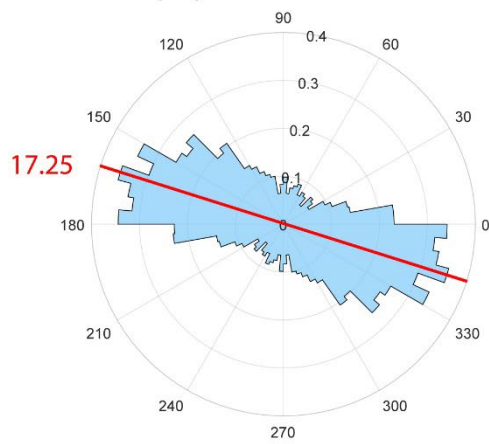
Inverse pole figure map



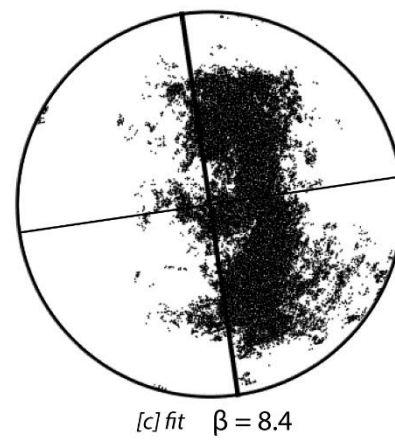
fitEllipse



Shape preferred orientations



Best fit to quartz c-axes



n = 259014

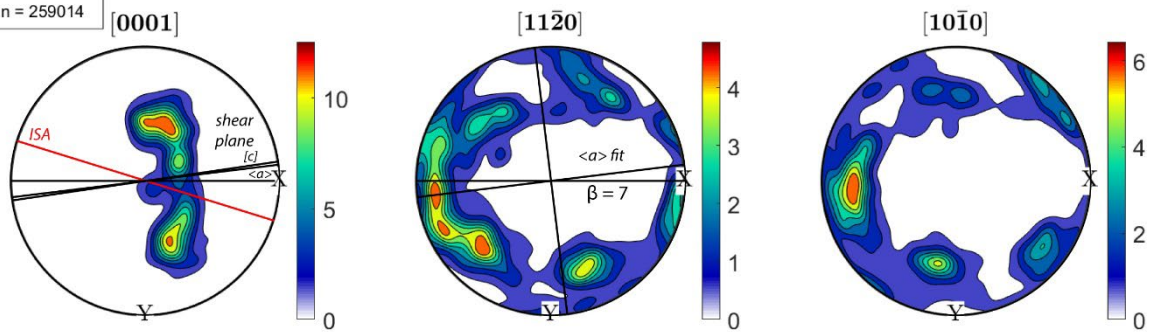


Figure DR7. (continued)

DR4 – Secondary Ion Microprobe analytical details

Seven samples representative of different structural levels of the mylonite zone were selected for Ti-in-quartz thermometry (Table 4). Zones displaying representative microstructures within the thin section of each sample were cut into ~5x5 mm squares using a slow speed saw. EBSD and cathodoluminescence maps were collected for each sample to guide spot placement on recrystallized grains.

Ti concentrations were measured on a Cameca IMS 1280 ion probe at the Northeast National Ion Microprobe Facility (Woods Hole Oceanographic Institution). A 250 pA 16O⁻ primary beam was accelerated at 12kV and focused to a diameter of 5 μ m. Secondary ions of 30Si⁺, 40Ca⁺, 48Ti⁺, and 49Ti⁺ were extracted at a 10kV voltage potential. Entrance and exit slit widths were set to achieve a mass resolving power >6500, sufficient to separate 48Ti⁺ from 48Ca⁺ and 49Ti⁺ from 48TiH⁺ and 48CaH⁺. After 300 seconds of pre-sputtering, each mass was measured on an ETP electron multiplier (EM) for count times ranging from 3-10 seconds within each measurement cycle, over a total of 5 cycles, and ratios were derived using 30Si as the reference mass. Electron multiplier background was determined by measurement at 29.7 within each cycle and was ~0.01 CPS. An maximum estimate of 48Ca⁺ contribution to the 48Ti⁺ measurement (assuming complete peak overlap) was calculated by multiplying the measured 40Ca/30Si by the naturally occurring 48Ca/40Ca ratio (1.93E-3). However, good agreement between concentrations derived by measuring uncorrected 48Ti/30Si and 49Ti/30Si demonstrate that a correction for potential 48Ca⁺ interference was not required. Two linear calibrations for Ti concentration, plotting Ti (μ g/g) vs. 48Ti/30Si and 49Ti/30Si were obtained by analyzing four synthetic quartz crystals with Ti concentrations ranging from 21 to 813 μ g/g (Thomas et al. 2010, Ashley et al., 2013, Nachlas et al., 2014). Data processing for each measurement utilized in-house matlab codes, and included EM deadtime correction, time interpolation within each cycle, and two sigma filtering of cycle ratios. ⁴⁸Ti and ⁴⁹Ti normalized to ³⁰Si were measured over 10 cycles for each analysis, of which the mean and standard deviation were calculated. These data were corrected for drift in the standards measurements. The mean and standard deviation of the corrected values were used to calculate the ³⁰Si normalized concentrations of ⁴⁸Ti and ⁴⁹Ti. The concentrations of ⁴⁸Ti are used for thermometry.

Ti concentrations were measured from at least 12 spots in each sample (Table 4, Fig. DR8). The mean and standard deviation was calculated for each sample. In some cases, outlier values were omitted from the mean and standard deviation calculations. Our mean concentrations were then used to calculate temperature estimates using the calibration of Thomas et al. (2010). We calculated temperature estimates of the mean Ti concentration, as well as the upper and lower standard deviation values ([Ti] + 2 SD, [Ti] – 2 SD). The Thomas et al. (2010) calibration depends on a_{TiO2} and pressure. The a_{TiO2} is not independently constrained in this study, however a value of 0.25 is assumed. We consider this a reasonable assumed value for a_{TiO2} based on the absence of Ti-bearing phases (i.e., rutile, titanite, ilmenite), and the estimation of a_{TiO2} in chemically comparable quartz mylonites in previous studies (e.g., Lusk and Platt, 2020). We assume pressures between 3 and 4 kbar for our calculations. These values are based on thermobarometry of rocks within the Ruby-East Humboldt mylonite zone (e.g., Hurlow et al., 1991).

Additionally, there is uncertainty associated with the calibration of the Ti-in-quartz thermobarometer of Thomas et al. (2010). The uncertainties in the calibration constants are incorporated into our results through calculation of total quantified uncertainty, which combines uncertainty in individual measurements and the calibration. We do so by calculating temperature

as a function of $[Ti] + 2SD$ using calibration constants + error to get T_{hi} . The opposite is done to calculate T_{lo} ($[Ti] - 2SD$ using calibration constants – error). The final total quantified uncertainty is calculated as $+Total\ Error = T_{hi} - T$ and $-Total\ Error = T - T_{lo}$.

Table 4: SIMS Ti-in-Quartz data

Sample	Structural Position	n	[Ti] (ppm)	2 SD	aTiO ₂	P (kbar)	Temperature (°C)	-2SD (°C)	+2SD (°C)	-TotErr (°C)	+TotErr (°C)
AZ 10-8-19 (1)	1	16	1.91	1.6	0.25	3	405	93	37	122	73
AZ 7-1-20 (1)	2	23	5.42	3.4	0.25	3	471	63	35	97	74
200718-6	3	14	0.31	0.1	0.1	3	373	23	17	69	32
AZ 6-30-20 (2)	7	16	11.83	3.3	0.25	4	551	26	21	65	62
AZ 8-14-18 (1)	9	9	5.21	3.8	0.25	4	488	83	41	116	80
200718-3	12	12	13.31	6.0	0.25	4	558	46	37	125	121
AZ 7-2-20 (4)	16	20	17.86	6.1	0.25	4	587	36	27	77	71

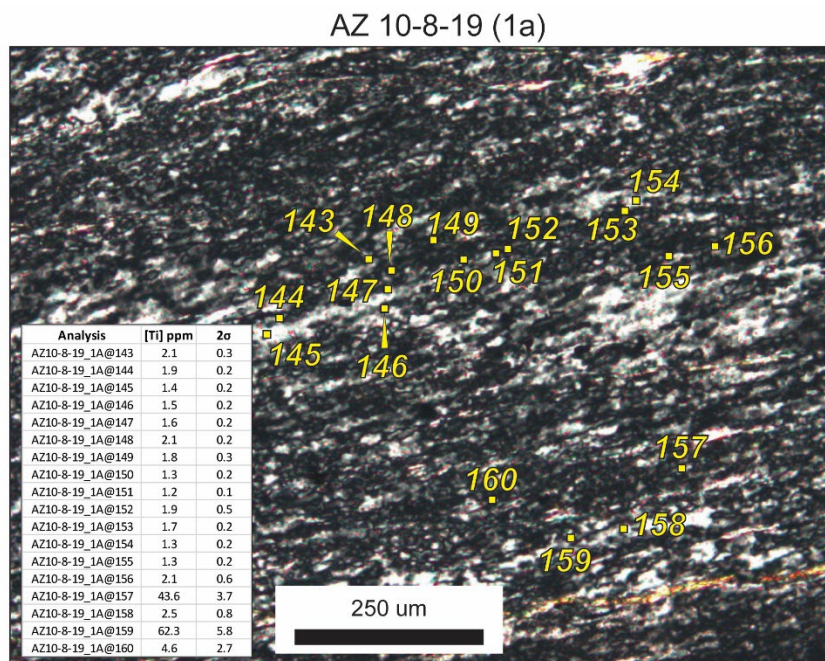


Figure DR8. Photomicrographs showing the locations and concentrations of SIMS Ti-in-quartz analyses.

AZ 7-1-20 (1)

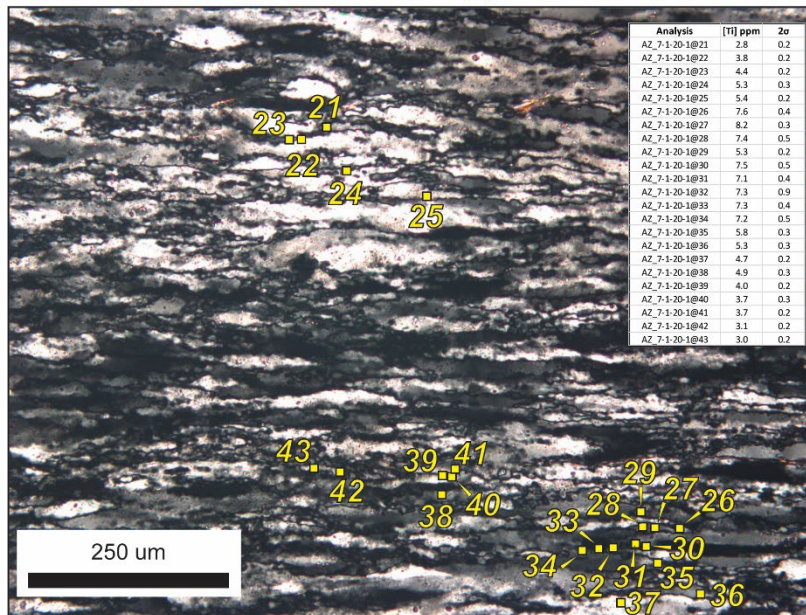


Figure DR8. (continued)

200718-6

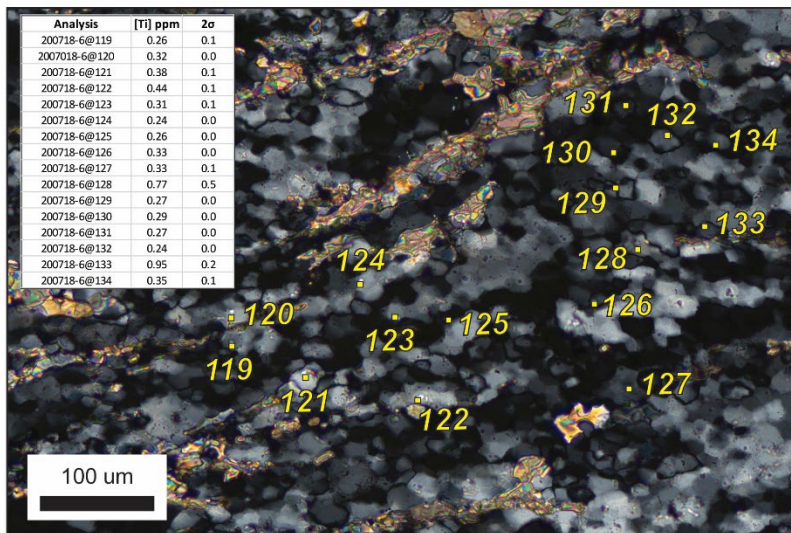


Figure DR8. (continued)

AZ 8-4-18 (1)

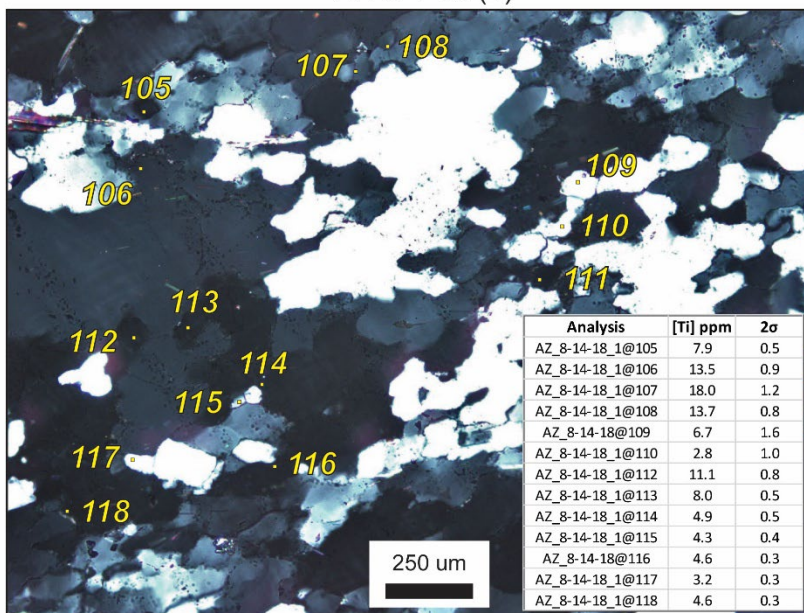


Figure DR8. (continued)

AZ 6-30-20 (2)

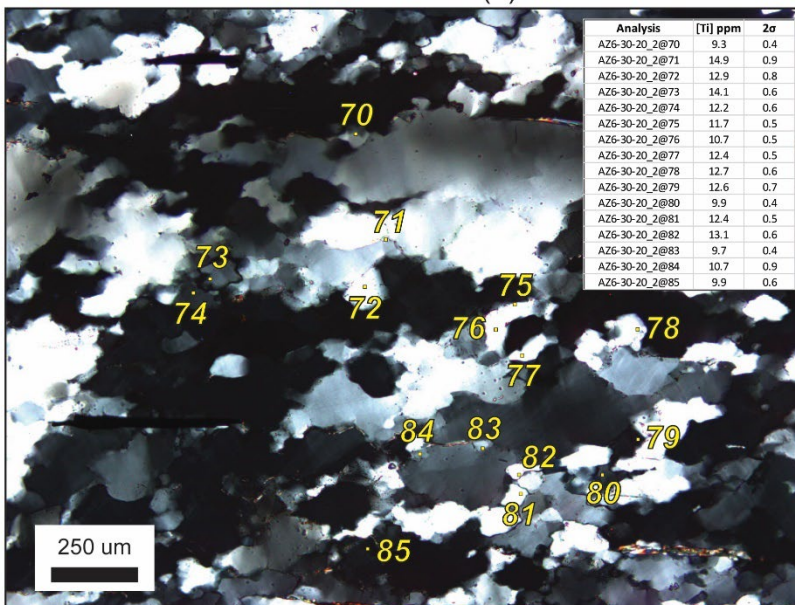


Figure DR8. (continued)

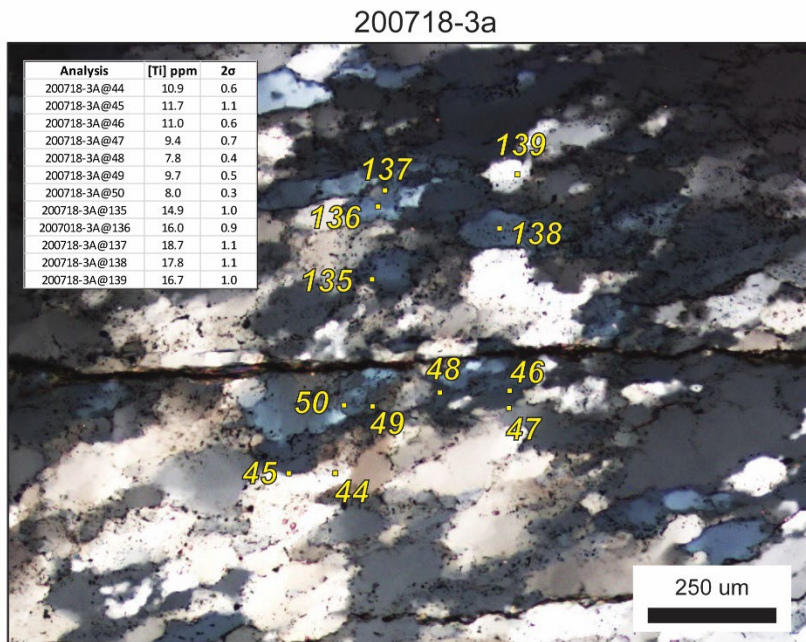


Figure DR8. (*continued*)

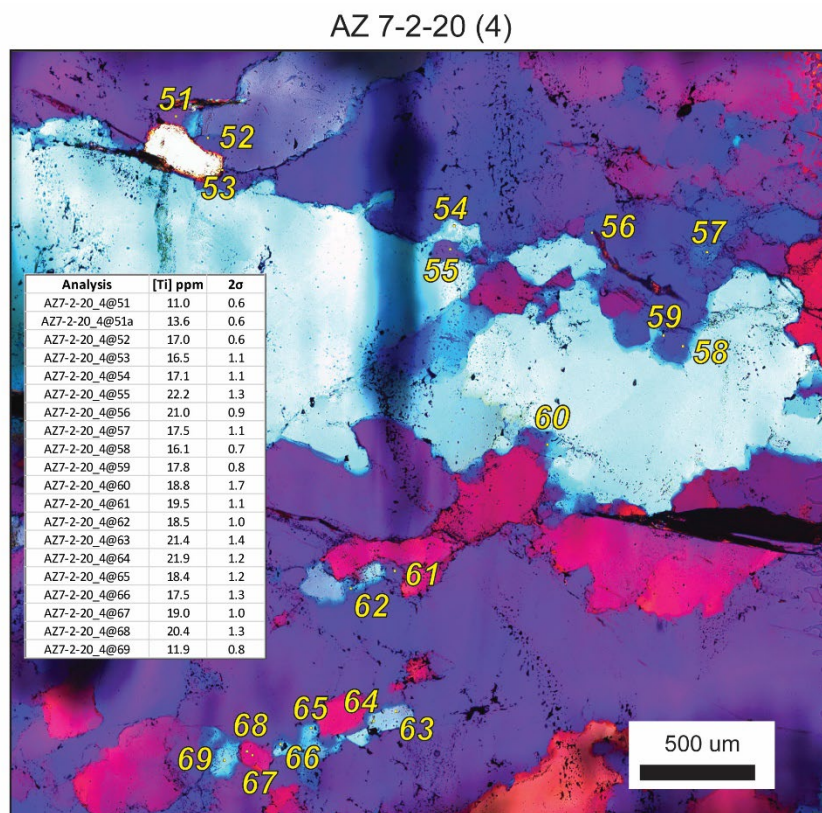


Figure DR8. (*continued*)

DR5 – Analytical model of diapir ascent velocity details

Stokes flow solution

The steady-state velocity of a spherical diapir can be modeled using the Stokes flow solution. In this formulation, velocity is given by:

$$U = \frac{a^2 g (\rho_h - \rho_d)}{3 \mu_h} \quad (3)$$

where U is velocity, a is diapir radius, g is acceleration due to gravity, ρ_h is host density, ρ_d is diapir density, and μ_h is host viscosity (Turcotte and Schubert, 2002). Diapir velocity scales with density difference. Conceptually, the density difference we model is due to magmatism and partial melting, and the accompanying conductive heat loss to the host would lower the host viscosity allowing diapir rise. Diapir density is calculated as a function of melt fraction expressed as:

$$\rho_d = \rho_h - M * (\rho_h - \rho_{d^*}) \quad (4)$$

where M is melt fraction, and ρ_{d^*} is the density of the melt when solid (Gerya, 2010). This formulation is the density-driven case.

Diapir ascent velocity can also be formulated as a function of thermal expansion and temperature (i.e., temperature-driven case) given by:

$$U = \frac{a^2 g \rho_h \alpha (T_d - T_h)}{\mu_h} \quad (5)$$

and

$$(\rho_h - \rho_d) = \rho_h \alpha (T_d - T_h) \quad (6)$$

where α is the coefficient of thermal expansion, T_d is the diapir temperature, and T_h is the host temperature. The values of T_h and T_d are estimated based on the mylonite deformation temperatures (~500–600 °C) determined by Ti-in-quartz thermometry (T_h) and a near-solidus temperature range for Eocene monzogranites of the Harrison Pass pluton in the southern Ruby Mountains (~700–800 °C; Barnes et al., 2001; T_d). The full list of parameters and sources are listed in [Table 5](#).

Table 5. Material properties used for diapir ascent models

Parameter	Value	Reference
a [m]	10,000	Half width of presently exposed mylonite zone (This study)
ρ_h [kg m ⁻³]	2,700	Average density of gneiss (Turcotte and Schubert, 2002)
ρ_{d^*} [kg m ⁻³]	2,500	Density of molten granite/felsic crust (Gerya, 2010)
M	0-0.75	Range of lower crust melt fractions (Rey et al., 2009)
ρ_d [kg m ⁻³]	2,700-2,550	$\rho_d = \rho_h - M * (\rho_h - \rho_{d^*})$ (Gerya, 2010)
μ_h [Pa s]	10 ¹⁸ -10 ²⁰	Range of lower crustal viscosities (Rey et al., 2009)
α [K ⁻¹]	3 x 10 ⁻⁵	Turcotte and Schubert (2002)
T_d [°C]	700-800	Near-solidus temperature of monzogranite (Barnes et al., 2001)
T_h [°C]	500-600	Quartz mylonite deformation conditions (This study)

For the temperature-driven case, a temperature difference of 200–300°C at a host-crust viscosity of 10¹⁹ Pa·s and 10²⁰ Pa·s yields ascent rates of 16–25 km/Myr and 1.6–2.5 km/Myr ([Fig.](#)

DR10). For the density-driven case, a melt fraction of 0.1–0.3 at a host-crust viscosity of 10^{19} Pa·s and 10^{20} Pa·s yields ascent rates of 21–62 km/Myr and 2.1–6.2 km/Myr (**Fig. DR11**).

To relate ascent velocities to strain rates derived from microstructural observations, we calculate 1D strain rates of pure and simple shear zones (**Fig. DR9**). Pure shear strain rates are calculated using:

$$\dot{\epsilon} = U/w \quad (7)$$

where U is the ascent velocity and w is the original width of the shear zone. Simple shear strain rates are calculated using:

$$\dot{\gamma} = U/w \quad (8)$$

where U is the ascent velocity and w is the original width of the shear zone. For a pure shear zone shortening parallel to the top of the ascending diapir at 200–300°C at a host-crust viscosity of 10^{19} and 10^{20} Pa·s, we calculate strain rates of $1.1\text{--}1.6 \times 10^{-13} \text{ s}^{-1}$ and $1.1\text{--}1.6 \times 10^{-14} \text{ s}^{-1}$. For an inclined simple shear zone deforming tangential to the edge of the ascending diapir at 200–300°C at a host-crust viscosity of 10^{19} and 10^{20} Pa·s, we calculate strain rates of $3.7\text{--}5.6 \times 10^{-13} \text{ s}^{-1}$ and $3.7\text{--}5.6 \times 10^{-14} \text{ s}^{-1}$. For the density driven case with a melt fraction of 0.1–0.3 at a host-crust viscosity of 10^{19} Pa·s and 10^{20} Pa·s, the pure shear zone deforms at $1.3\text{--}3.9 \times 10^{-13} \text{ s}^{-1}$ and $1.3\text{--}3.9 \times 10^{-14} \text{ s}^{-1}$ and $4.6\text{--}13.9 \times 10^{-13} \text{ s}^{-1}$ and $4.6\text{--}13.9 \times 10^{-14} \text{ s}^{-1}$ for the simple shear case. These results suggest diapir ascent at rapid but geologically reasonable ascent rates can drive shear deformation at strain rates comparable to the rates derived from our microstructural observations.

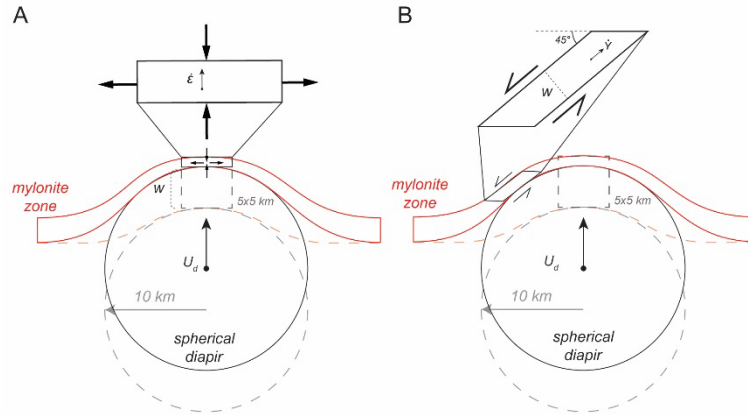


Figure 9. Geometry of Stokes flow diapir ascent velocity and shear zone orientation for the pure shear (A) and simple shear (B) zones.

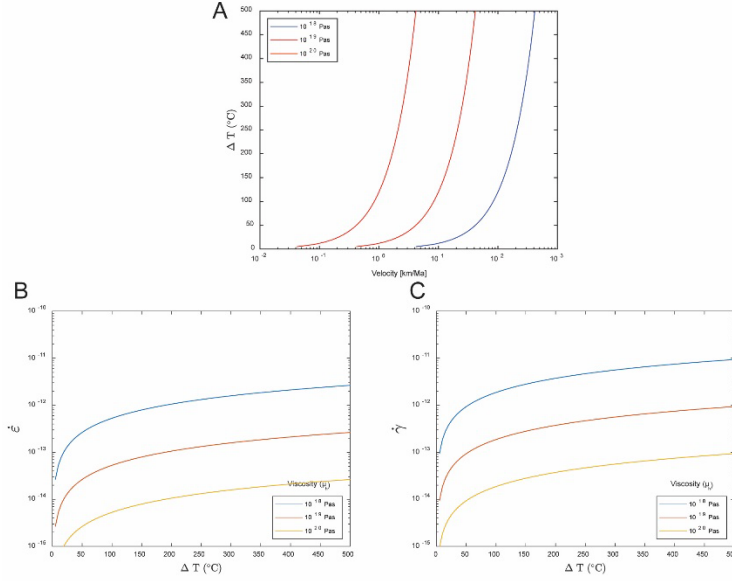


Figure 10. Temperature-driven Stokes flow model results. A) Plot of velocity as a function of ΔT for three viscosity cases. B) Plot of pure shear strain rate as a function of ΔT for three viscosity cases. C) Plot of simple shear strain rate as a function of ΔT for three viscosity cases.

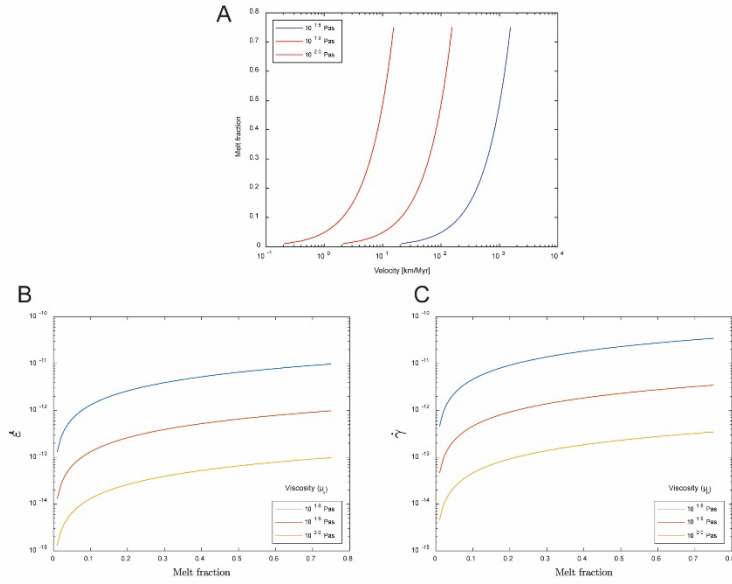


Figure 11. Density-driven Stokes flow model results. A) Plot of velocity as a function of melt fraction for three viscosity cases. B) Plot of pure shear strain rate as a function of melt fraction for three viscosity cases. C) Plot of simple shear strain rate as a function of melt fraction for three viscosity cases.

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