Estimating the temperature of equilibration of quartz in the Tuolumne Intrusive Suite

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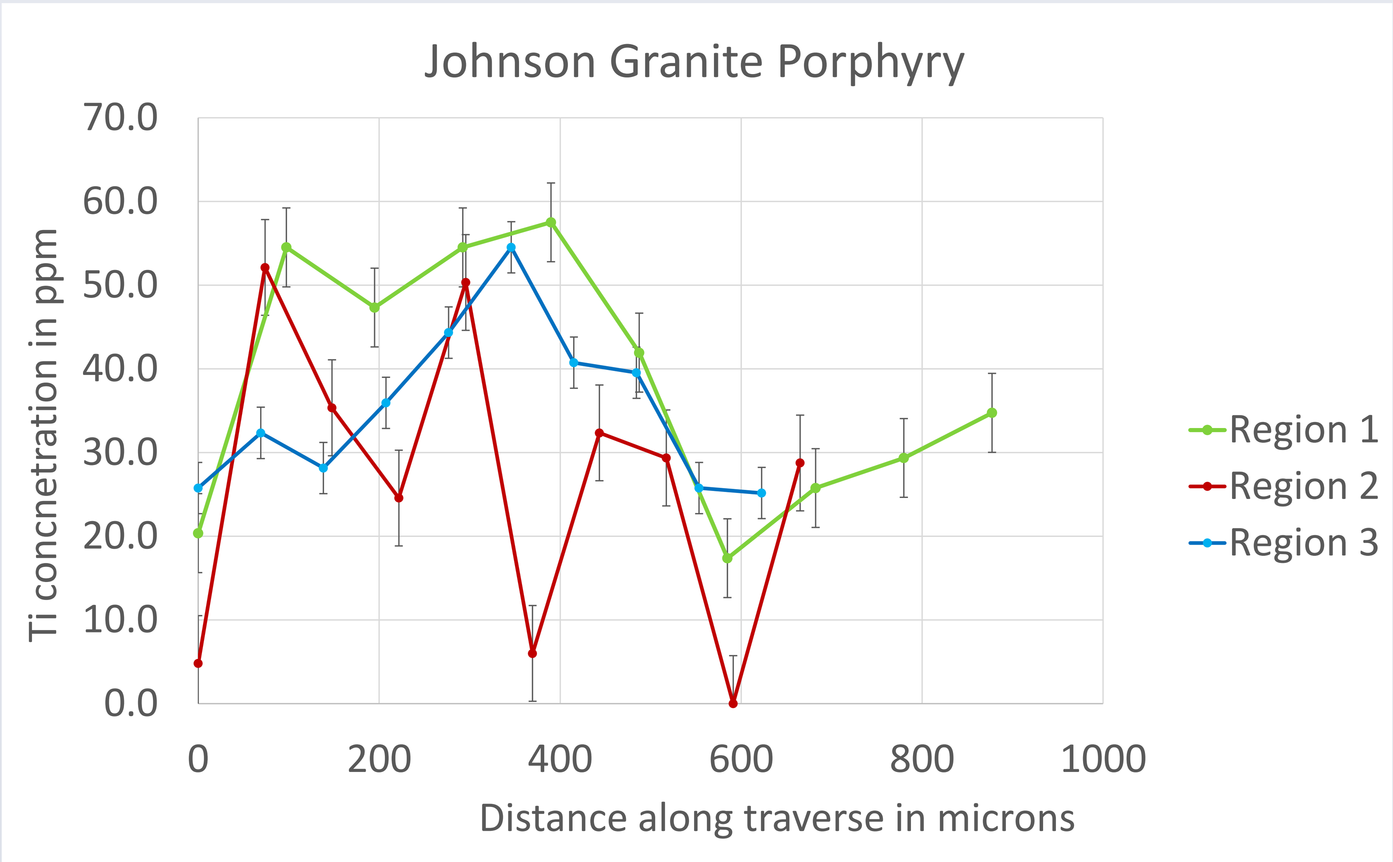
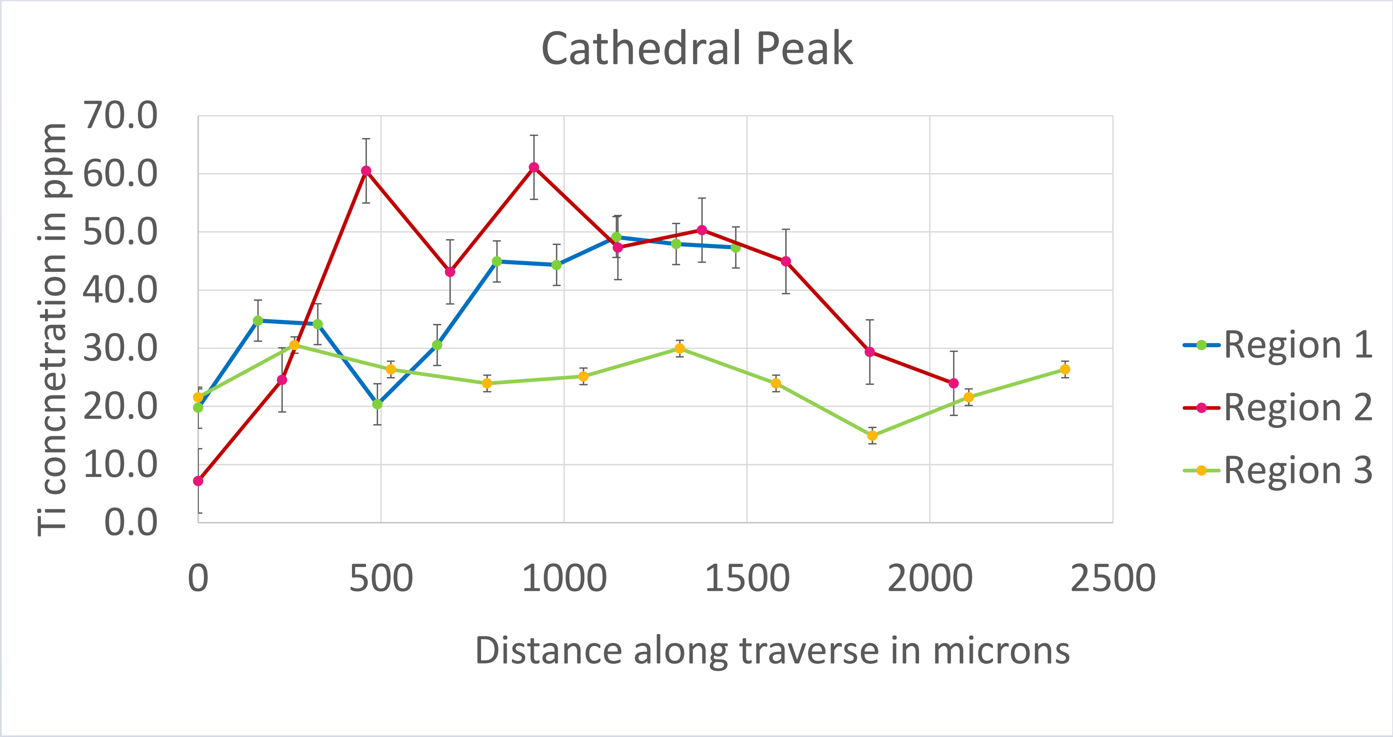
GEOL394 Spring 2015

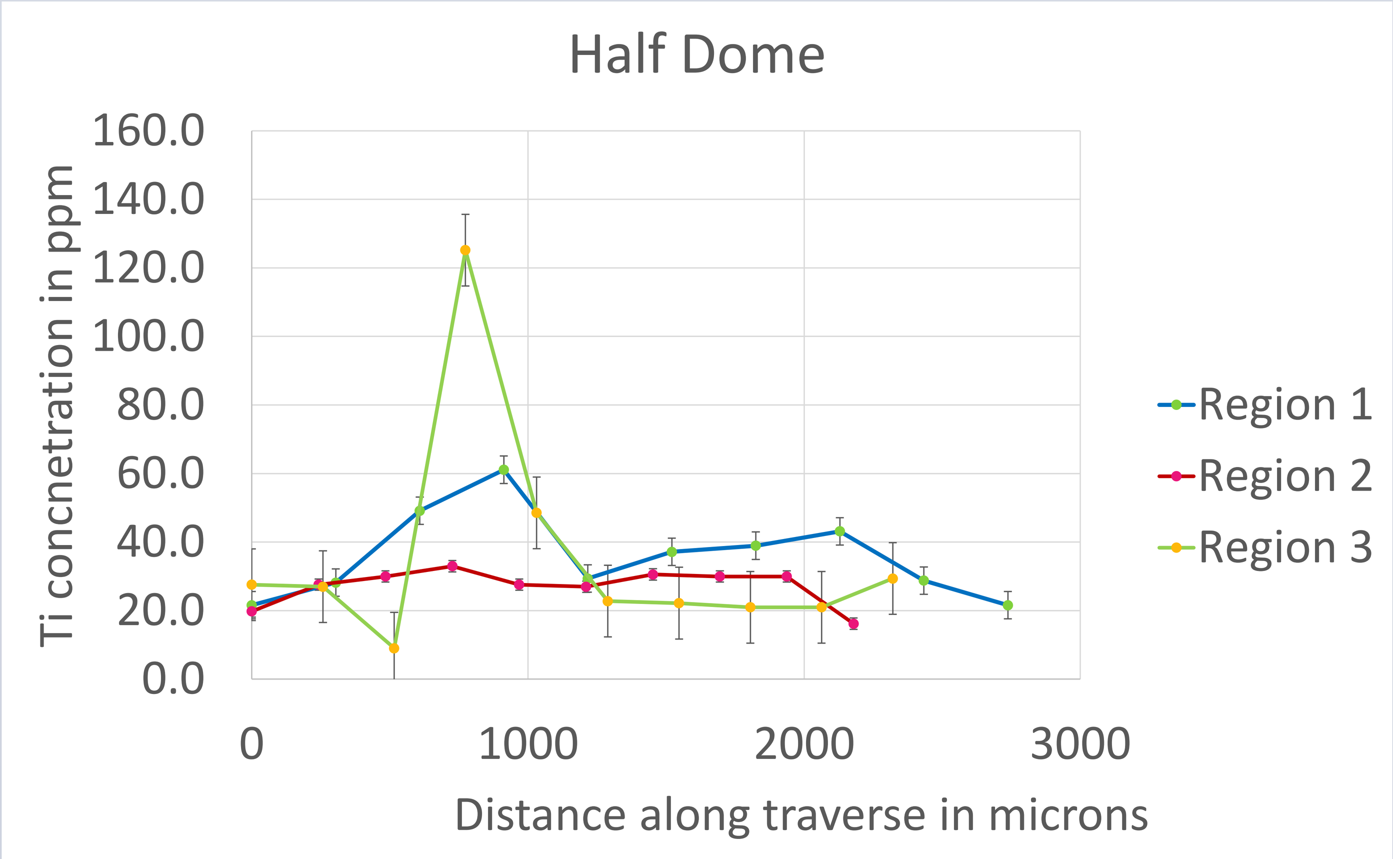
ABSTRACT

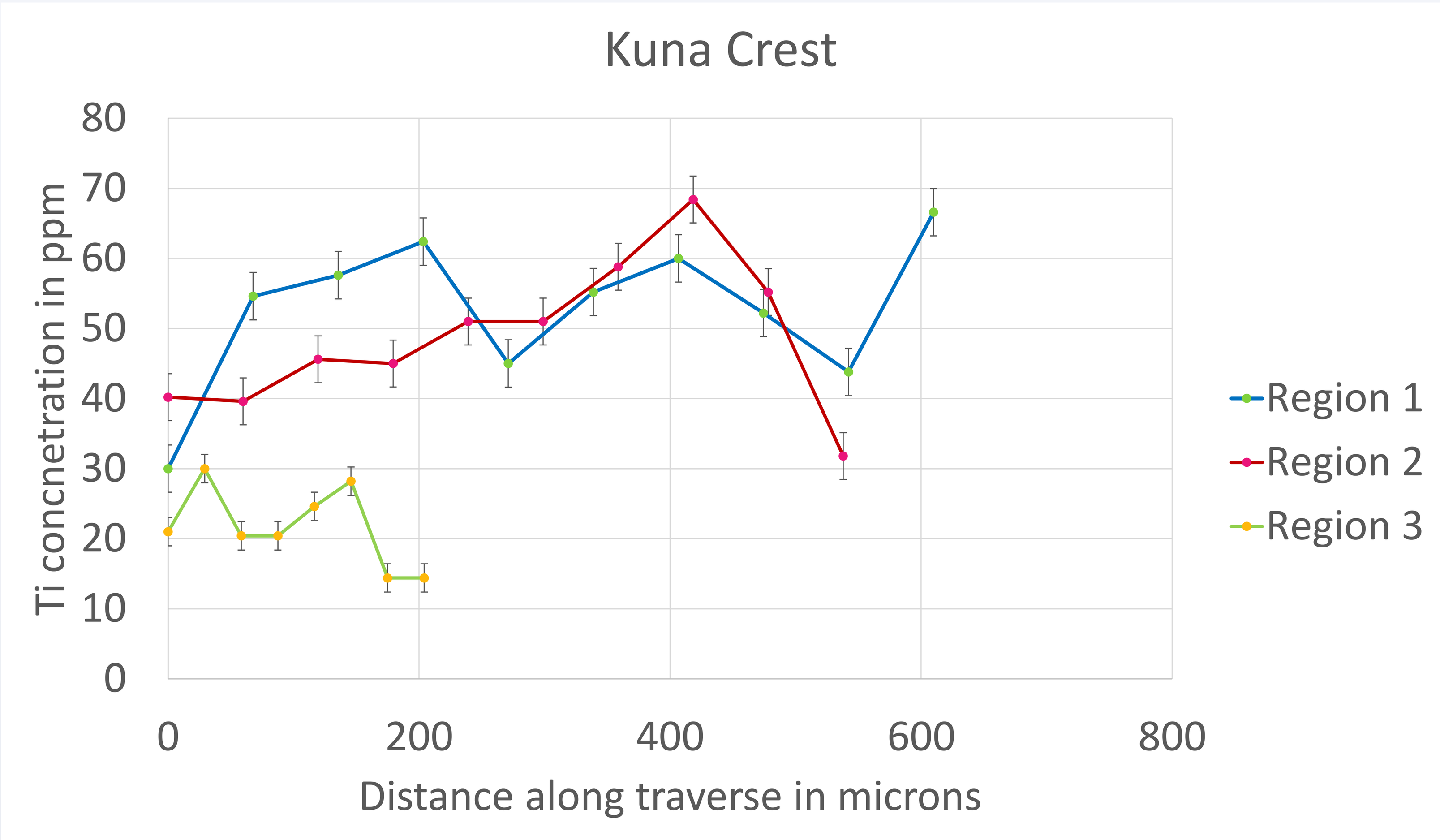
Three quartz crystals from one rock from each pluton (Johnson Granite Porphyry, Kuna Crest, Cathedral Peak, and the Half Dome) of the Tuolumne Intrusive Suite were analyzed via electron probe microanalysis to measure the concentrations of titanium in each quartz crystal. Wark and Watson (2006) found that the concentration of titanium substitutions for silicon in SiO_2 records the temperature conditions during formation, either magmatic (above 750˚C) or sub-solidus (below 750˚ C). I hypothesized before any analysis that the titanium concentrations in each sample would record magmatic temperatures for each pluton. The following equation calibrated by Wark and Watson (2006) describes the relationship: $T\,°(C) = \frac{-3765}{\log\left(X_{Ti}^{qtz}\right) - 5.69} - 273$, estimated to be accurate within 5 ˚C, where X_{Ti}^{qtz} is the titanium concentration in quartz in weight by ppm. Further research by Thomas et al. (2010) suggested a more accurate method of determining the temperature, taking into account the pressure at which the rocks formed and the activity of rutile in the system. The thermometer calibrated by Thomas et al. (2010) with pressure and rutile activity taken into account was found to be $RTlnX_{TiO_2}^{quartz} = -60952 + 1.520 * T(K) - 1741 * P(kbar) + RTlna_{TiO_2}$, where R is the universal gas constant, T is temperature, X is the mole fraction of TiO_2, P is the pressure in kilobars, and a is the activity of rutile in the system. The equation was solved for T and rewritten as $T(K) = \frac{60952 + 1741 * P(kbar)}{-RlnX + 1.52 + Rlna_{TiO_2}}$. The activity of rutile of these rocks was calculated by use of the rhyolite-MELTS program; the program calculated the affinity of rutile A_{rutile} of the system, which was then used to calculate the activity *a* of rutile using the equation $a_{TiO_2} = \exp(\frac{A_{rutile}}{RT})$ (Gualda and Ghiorso, 2014).

PLOTS OF ANALYSES









SUMMARY TABLES

Johnson Granite Porphyry			
	Average weight % TiO2	Average [Ti] (ppm)	Average temperature (°C)
Region 1	0.0064	38.34	754.57
Region 2	0.0044	26.36	635.49
Region 3	0.0059	35.22	747.65

Cathedral Peak			
	Average weight % TiO2	Average [Ti] (ppm)	Average temperature (°C)
Region 1	0.0062	37.32	699.28
Region 2	0.0066	39.23	697.65
Region 3	0.0041	24.44	653.70

Half Dome Equigranular			
	Average weight % TiO2	Average [Ti] (ppm)	Average temperature (°C)
Region 1	0.0060	35.88	681.41
Region 2	0.0045	27.13	653.10
Region 3	0.0059	35.34	662.61

Kuna Crest			
	Average weight % TiO2	Average [Ti] (ppm)	Average temperature (°C)
Region 1	0.0088	52.47	751.74
Region 2	0.0081	48.58	741.57
Region 3	0.0036	21.64	645.46

DISCUSSION OF RESULTS

The results of the analysis were inconsistent with my hypothesis that the concentrations would yield magmatic temperatures of equilibration. The average temperatures of three crystals from the Kuna Crest sample calculated using the titanium concentrations in each crystal and the thermobarometer calibrated by Thomas et al. (2010) was found to be 751.74 ˚C, 741.57 ˚C, and 645.46 ˚C respectively. For the three crystals from the Johnson Granite Porphyry rock, the temperatures were 754.57 ˚C, 635.49 ˚C, and 747.65 ˚C. The Cathedral Peak crystals yielded temperatures of 699.28 ˚C, 697.65 ˚C, and 653.70 ˚C. The Half Dome equigranular crystals output temperatures of 681.41 ˚C, 653.10 ˚C, and 662. 61˚C. All temperatures were near or well below 750 ˚C, the temperature at which quartz was expected to crystallize out of this system. I believe the system underwent hydrothermal alteration due to the presence of hornblende, which suggests a water content of at least 4% (Naney, 1983).

ACKNOWLEDGEMENTS

I would like to sincerely thank Dr. Philip Piccoli and Dr. Richard Ash for their assistance, guidance, and patience during the length of this project.