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# Redox effect on estimating crystallization pressure of granites

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## Summary

This study uses selected granite samples to evaluate the effect of redox conditions, expressed as iron number Fe# [= $Fe_2O_3/(FeO+Fe_2O_3)$, in mole%], on estimation of crystallization pressure (P) of granites using the Qtz-geobarometer (Yang, 2017). The results indicate that calculated P decreases significantly with increasing Fe# for metaluminous and peraluminous granites, but much less so for peralkaline granites. Given a metaluminous or peraluminous granite sample has fixed silica content, the calculated P values are a polynomial function of Fe#. The difference in P at Fe# between 0.1 (reduced) and 1.0 (oxidized) is as high as 428 MPa, much higher than the uncertainty of the geobarometer. However, a peralkaline granite sample displays much less difference in P at Fe# between 0.1 and 1.0, likely within the uncertainty. Therefore, redox conditions need considered when estimating P of metaluminous and peraluminous granites with lower-silica concentrations, and may not do so for peralkaline granites.

## Methods

Based on the existing experimental data on the haplogranite system, Yang (2017) proposed two polynomial equations of using CIPW normative Qtz and/or (Ab+Or) composition to estimate crystallization (or emplacement) pressure of granite intrusions. However, it is noted that many compositional factors (e.g., CaO, MgO, $Fe_2O_3/FeO$, F, Cl, $CO_2$) would have affected the estimation results of the Qtz-geobarometer. This study focuses on the effect of redox conditions expressed as the iron number Fe# as defined by $Fe_2O_3/(FeO + Fe_2O_3)$ ratio (unit in mole%). Because the CIPW normative compositions (including Qtz, Ab, and Or) of igneous rocks is indirectly affected by Fe#, they would influence the estimation of crystallization pressures. Therefore, the Qtz-geobarometer needs adjusted, especially for hornblende-bearing granites with relatively low silica contents. First, we uses representative examples to evaluate how the Fe# to influence the pressure estimations, and then recommend a new practical procedure using whole-rock composition to achieve a better pressure estimate. Basically, the procedure consists of five steps: 1) determine alkalinity of the sample, 2) calculate Fe#, 3) convert measured $Fe2O3^T$ value to $Fe_2O_3$ and FeO values, 4) use the adjusted $Fe_2O_3$ and FeO values to compute CIPW normative compositions, and 5) calculate granite crystallization pressure using the Qtz-geobarometer.

## Results, Observations, Conclusions

We have used selected natural and experimental granite samples (Whalen, 1993; Scaillet et al., 2016; Yang et al., 2019) to evaluate the effect of redox conditions, expressed as iron number Fe# [= $Fe_2O_3/(FeO+Fe_2O_3)$ in mole%], on crystallization pressure (P) of granites estimated by the Qtz-geobarometer (Yang, 2017). The results indicate that the calculated P decreases significantly with increasing Fe# for metaluminous and peraluminous hornblende-bearing granites particularly with lower silica contents, but much less so for peralkaline granites. Given a metaluminous or peraluminous granite sample has a fixed silica content, the calculated P values are a polynomial function of

Fe#. The difference in P at Fe# between 0.1 (reduced) and 1.0 (oxidized) is as high as 428 MPa (Figure 1), much higher than the uncertainty of the Qtz-geobarometer. However, a peralkaline granite or highly evolved sample displays much less difference in P at Fe# between 0.1 and 1.0, most likely within the uncertainty of the geobarometer. Therefore, redox conditions need considered when estimating P of metaluminous and peraluminous hornblende-bearing granites with low silica contents, and may not do so for peralkaline or highly evolved granite intrusions. A new procedure is recommended for estimating Fe# from whole-rock data that only provide either $Fe_2O_3^{Total}$ or $FeO^{Total}$ in wt.%, which has implications for both the estimation of crystallization pressures and the IUGS igneous rocks classification as well based on CIPW normative compositions.

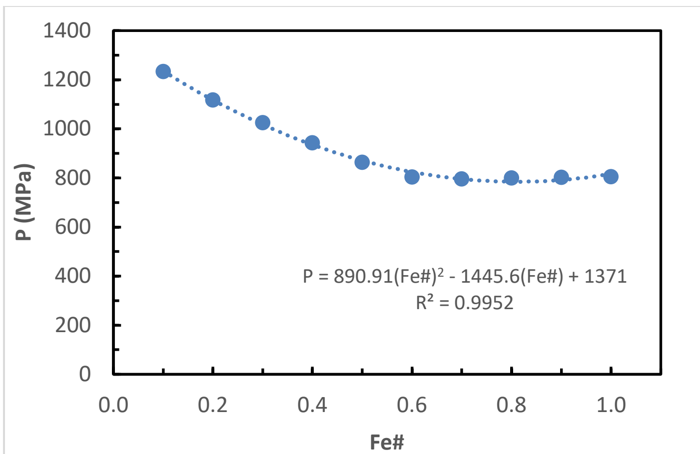


**Figure 1**. Plot of granite crystallization pressure (P in MPa) as a function of Fe#. P calculated for sample-10 from Scaillet et al. (2016) using the Qtz-geobarometer of Yang (2017). R denotes correlation coefficient.

## Novel Information

Redox conditions exhibit a considerable influence on the estimation of granite crystallization pressures for metaluminous to moderately peraluminous granitic systems when using the Qtz-geobarometer. The lower silica contents are dealt with, the higher degree of the redox conditions is manifested on the pressure calculation. Thus, it is necessary to modify the Qtz-geobarometer when it is applied to these rocks. A new procedure is recommended to achieve a better pressure estimation. Such a redox effect, however, on a peralkaline granite system or highly evolved granites may not need to be considered.

## Acknowledgements

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#### References

Scaillet, B., Holtz, F., Pichavant, M., 2016. Experimental constraints on the formation of silicic magmas. Elements, v. 12, p. 109-114.

Whalen, J.B., 1993. Geology, petrography, and geochemistry of Appalachian granites in New Brunswick and Gaspésie, Quebec. Geological Survey of Canada Bulletin 436, 124 p.

Yang, X.M., 2017. Estimation of crystallization pressure of granite intrusions. Lithos, v. 286-287, p. 324-329.

Yang, X.M., Drayson, D., Polat, A., 2019. S-type granites in the western Superior Province: A marker of Archean collision zones. Canadian Journal of Earth Sciences, v. 56, p. 1409-1436.