

Figure S1 Pseudosection Models for Rutile – Titanite – Ilmenite Stability

Petrological modeling of the rutile-titanite-ilmenite phase relation was conducted for 4 tonalitic gneiss samples whose chemistry is plotted in Gilotti and McClelland (2011). The XRF-derived bulk composition and the adjusted bulk composition used for phase equilibrium modeling are presented in Table S3. Isochemical phase equilibrium models or pseudosections were built using Perple_X ver.6.9.0 (Downloaded 2019) within the 11-component system MnNCKFMASHTO (MnO-Na₂O-CaO-K₂O-FeO-MgO-Al₂O₃-SiO₂-H₂O-TiO₂-O₂). CaO content is adjusted by subtracting CaO bound in pure apatite. The initial resolution keywords were changed to 3/16 and 1/12 to decrease the number of total pseudocompounds during calculation. Pseudosections for samples 03-116, 03-129, 03-148 and 03-173 for the range P=0.5–4 GPa and T=500–1000 °C are given in Figures S1a-d.

Solid solution models for the minerals clinopyroxene (including Na-poor clinopyroxene and omphacite), amphibole (Green et al., 2016), garnet, white mica, biotite, chlorite (White et al., 2014), feldspar (Fuhrman & Lindsley, 1988) and spinel (White et al., 2002) are used. The solid solution of omphacite (Green et al., 2016) was used because the major areas of titanite-present fields were in equilibrium with kyanite. Garnet contains small amounts of spessartine, thus the spessartine endmember was restricted to 10 mol% in the solution model. Lawsonite, kyanite, zoisite, coesite and quartz were considered to be pure phases. The Ti-bearing phases rutile and titanite were also treated as pure phases. The ilmenite solid solution model (White et al., 2000) with Green et al. (2016) modification was used, along with corrected interaction parameters in Perple_X (May, 2020). Titanite from exhumed UHP rocks typically contains the Al(F,OH)-TiO substitution (e.g. Franz and Spear, 1985; Troitzsch and Ellis, 2002), which has not been developed for modeling in the program yet. The modeling setup reflects the current capacity for Ti-bearing accessory phases.

The stability of titanite depends on *P*, *T* and other parameters such as X_{H₂O} and oxygen fugacity (e.g., Harlov et al., 2006; Markl & Piazzolo 1999; Xirouchakis & Lindsley, 1998). Pseudosections modeled with 0.5, 1, and 2 wt% H₂O and O₂ equivalents of oxidizing 0%, 10% and 20% iron were used to test their impacts on titanite-out boundaries. An oxygen content equivalent to oxidize 10% of total Fe as Fe³⁺ in the rock and 1 wt% pure H₂O were selected to model the final rutile-ilmenite-titanite phase relations because pseudosections produced with these parameters yielded a higher upper-temperature limit of titanite that is consistent with temperatures estimated by Zr-in-rutile thermometer. A component of CO₂ is not considered; a pseudosection on the sample 03-173 shows that the upper temperature titanite-out boundary is not sensitive to CO₂, although the presence of CO₂ affects the relative phase assemblages within the titanite-bearing fields.

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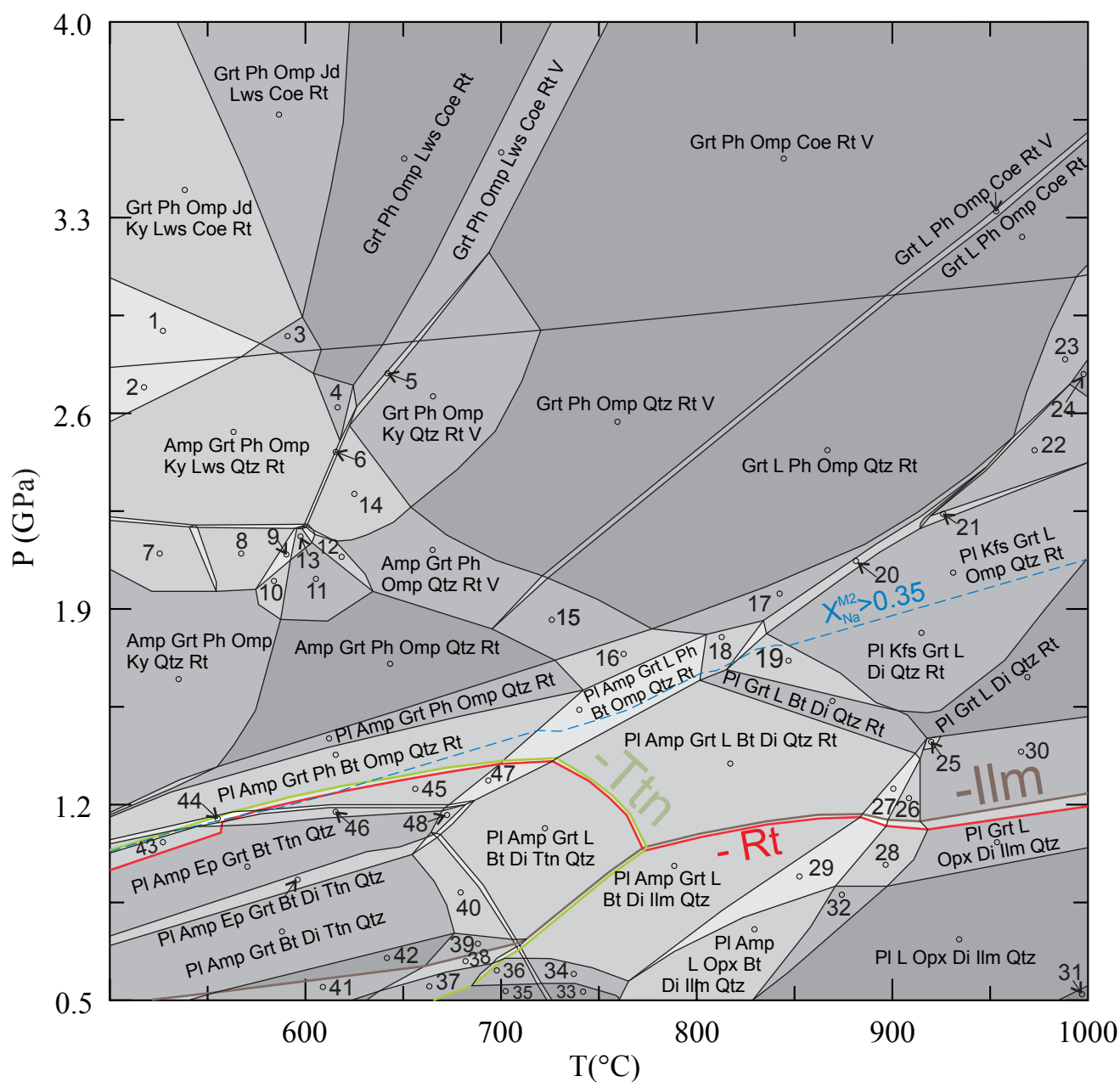
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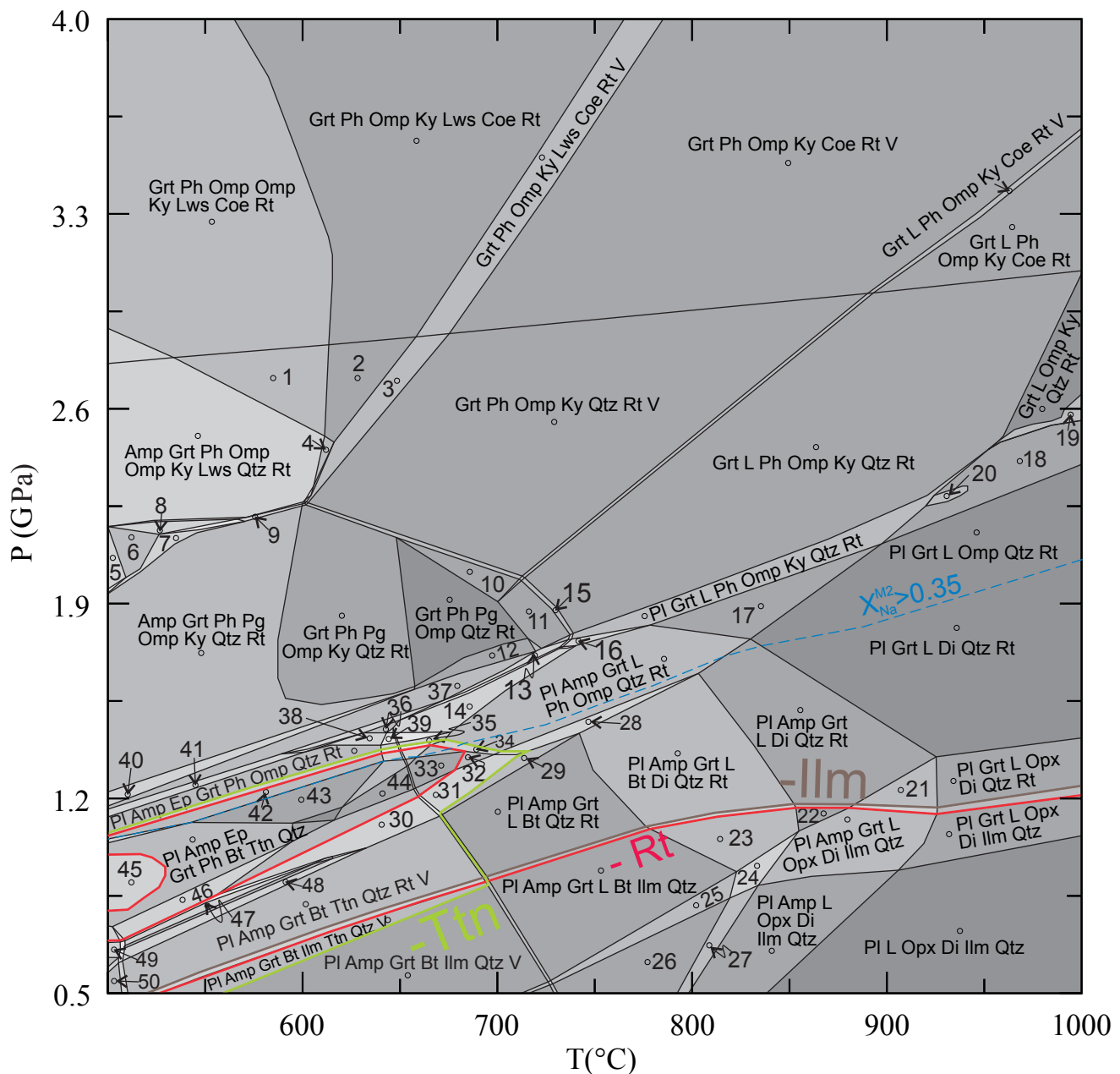
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Figure S1a. 03-116



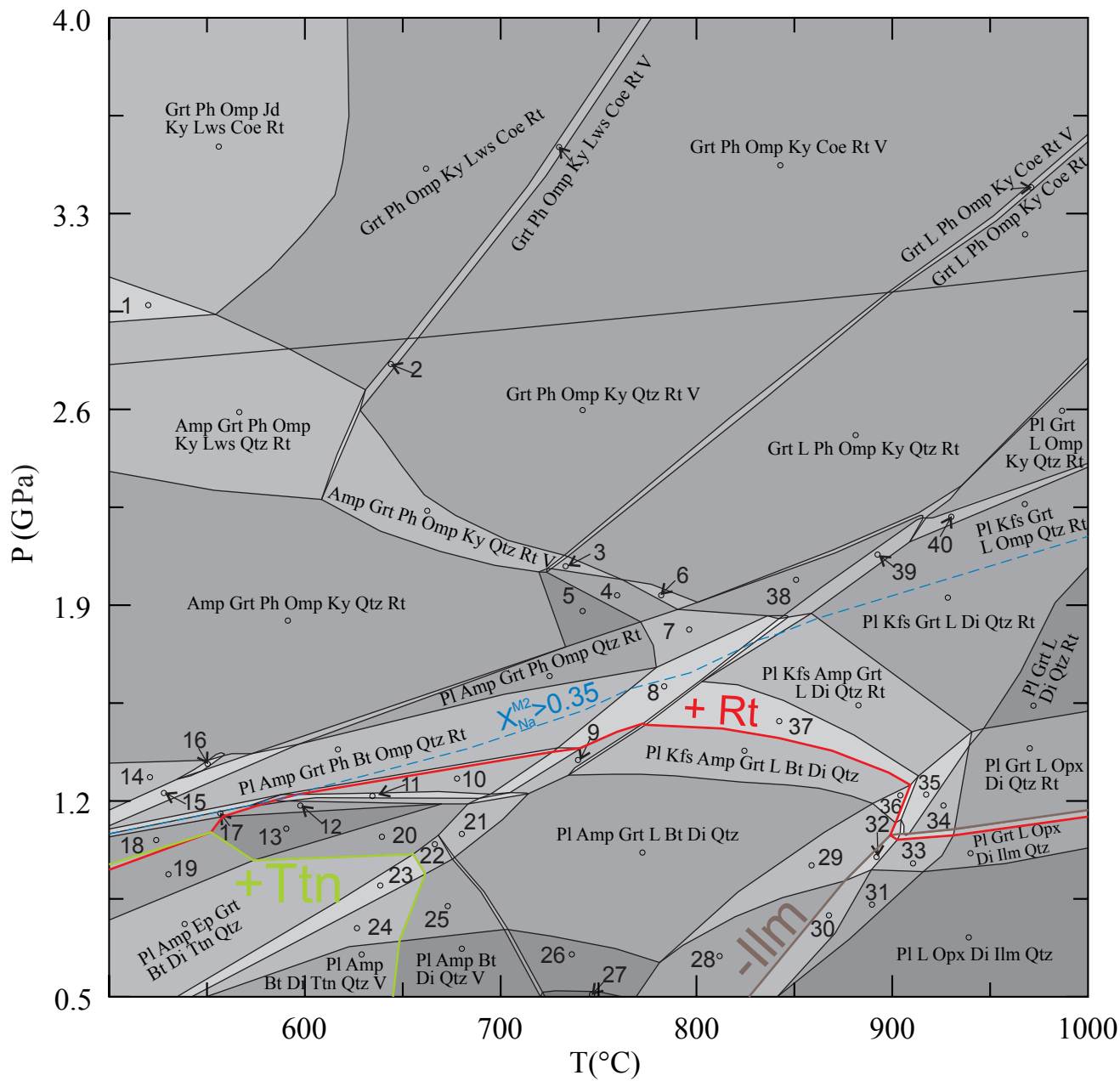
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Figure S1b. 03-129



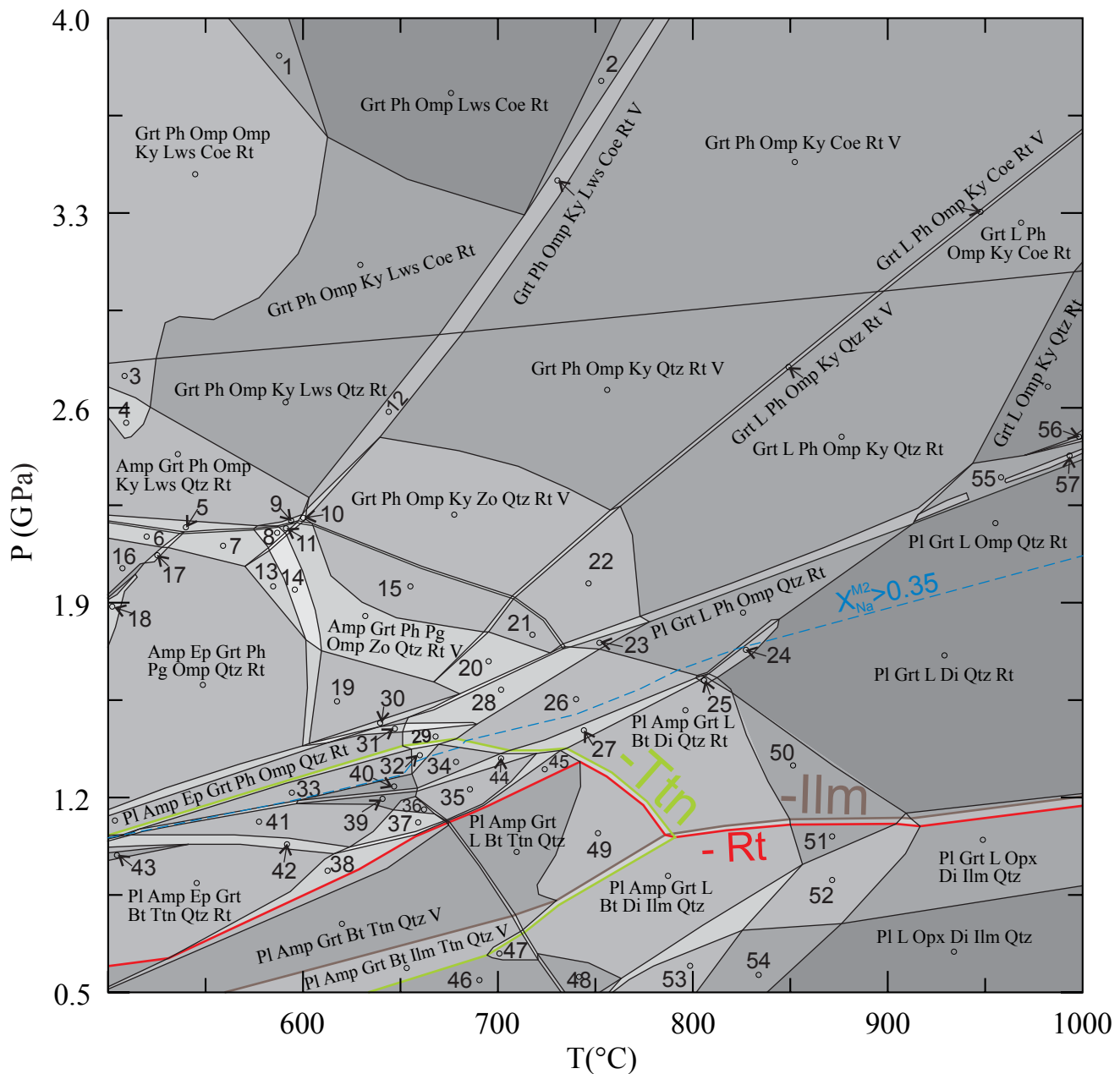
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| 3 Grt Ph Omp Ky Lws Qtz Rt V | 20 Pl Kfs Grt L Omp Ky Qtz Rt | 37 Pl Amp Grt Ph Pg Omp Qtz Rt |
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Figure S1c. 03-148



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Figure S1d. 03-173



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