Pseudosection-derived *P-T* estimates for Saidu, Kashala, Marghazar and Manglaur formations, Swat area, NW Himalayas

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Conventionally, the *P-T* estimation or geothermobarometry is based on well-calibrated geo-thermometers and geo-barometers with specified assumptions. For example, envisaging the garnet-biotite thermometer, both of these minerals are required to be in contact to assume Fe-Mg exchange reaction having occurred (DiPietro, 1991). If unable to find such an assemblage in a rock mass, then this technique fails. A relatively new technique, namely, *P-T* pseudosection is making more space in the literature due to its robustness and elimination of the assumptions that are commonly made in the conventional techniques coupled with the introduction of the Rayleigh Fractionation method for determination of the effective bulk rock composition at different growth stages of porphyroblasts and hence the accompanying metamorphism (Evans, 2004).

A *P-T* pseudosection is a mean of retrospection of the conditions of metamorphism that a rock records through time. It is a map of stable mineral assemblages which nucleate during metamorphism in a *P-T* space (Sayab, 2006; White et al. 2008). It is based on a fixed bulk rock XRF composition of a given rock sample. In this study, we constructed *P-T* pseudosections of the representative key samples from different formations including, Z53 from the Marghazar formation, Z23 from the Manglaur formation, Z8/Z12 from the Kashala formation and M22 from the Saidu formation. The latest version of THEMOCALC (ver. 3.33; Powell and Holland, 1988; updated 26 October 2009) with an internally consistent data set of Holland and Powell (1998; data set tcds55, updated 22 November 2003) was used. The pseudosections are modelled in the chemical system (MnO-Na_2O-CaO-K_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O) MnNCKFMASH. Garnet intersecting composition isopleths (X_{Fe}, X_{Mn}, X_{Ca}) are used for geothermobarometry which are based on the electron microprobe (EPMA) analysis from the garnetcore, inner core and rim regions and plotted in divariant fields using THERMOCALC. In addition, the average thermobarometry calculations for samples Z12 and Z61 are conducted using the average *P-T* mode of THERMOCLAC (Powell and Holland, 1994).

For sample Z53, the garnet core is estimated to have grown at 6.3–6.7 kbar/535–540^{o}C.The garnet core compositional isopleths in samples M22 intersect at 4.6–4.9 kbar/507–513^{o}C. Intersection of compositional isopleths for sample Z23 from core, median and rim regions correspond well with respect to mineral assemblage in garnet and pseudosection stability fields. The garnet core isopleths (X_{Mn}, X_{Fe}, X_{Ca}) uniquely interest in the Grt-Bt-Pl-Chl field at 4.0–4.2 kbar/495–500^{o}C. The garnet median region isopleths intersect in Grt-Bt-Pl-Chl-Zo field at 5.3-5.8 kbar/522–526^{o}C, in agreement with the appearance of zoisite inclusions in this region. *P-T* pseudosection for sample Z8 exhibit narrow stability fields as compared to other pseudosections and this may be due to the presence of a variety of metamorphic mineral assemblage including garnet, zoisite,staurolite, kyanite and rutile. For sample Z8, the garnet core composition isopleths intersect at 5.4-6.8 kbar/543-570°C in Grt-St-Pl-Chl, Grt-St-Pl-Chl-Zo and Grt-St-Chl-Zo fields. The relationship of three (X_{Mn}, X_{Fe}, X_{Ca}) intersection isopleths with these fields is in excellent agreement, where staurolite and zoisite inclusions are present in the garnet. The *P-T* conditions of matrix minerals along with garnet rim yielded 9.2±1.4 kbar/595±19°C with 2σ errors, and are acceptably consistent with the observed mineral assemblage (Grt-Zo-St-Ky-Chl).For sample Z12, the calculation by THERMOCALC of the *P-T* conditions using the composition of garnet rim and the matrix minerals average 10±0.8 kbar/618±28°C with 2σ errors. Average *P-T* conditions for sample Z61 revealed 8.6 ± 2.0 kbars/ 747±32 °C based on the garnet rim along with K-feldspar, muscovite and biotitegeothermobarometry.

The results are interesting, firstly because garnet isopleths fall in the stability field of modelledmineral assemblages which are also observed under the microscope. Secondly, the samples host two sets of garnet porphyroblasts with truncated and continuous inclusion trails with respect to the matrix. Garnet isopleths geothermobarometry reveal initially an isothermal increase in pressure (in samples hosting porphyroblasts with truncated trails) followed by further increase in pressure and temperature (in samples with porphyroblasts with continuous trails) eventually culminating at the peak of metamorphism. This *P-T* history suggests progressive burial due to subduction as a result of continued plate convergence. The *P-T* trajectory recorded by sample Z61 is dramatic and points to the phase of decompression with further rise in temperature but a slight drop in pressure. This decompression seems to be associated with the extension due to the reactivation of Main Mantle Thrust (MMT) as a north-directed normal faultfollowing crustal over-thickening as recorded by the sigma type K-feldspar porphyroclasts/blasts showing north-side-down shear sense (Shah et al. 2011).

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