

## Do preserved mineral compositions reflect peak-pressure metamorphic conditions?

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Chemical zoning established during prograde metamorphic garnet growth is commonly used to infer  $P$ - $T$  conditions during orogenesis. Records of specific mineral reactions may be retained as small lengthscale compositional zoning steps. These are characteristic of  $P$ - $T$  conditions but are rapidly lost by diffusion during subsequent high- $T$  events. Here we examine several possible exhumation  $P$ - $T$ -time paths (from 700°C at 1.5 GPa) in terms of the preservation of both  $\mu$ m-scale and crystal-scale growth zoning features. The initial crystal zoning profile plays an important role in the rate of chemical re-equilibration, because we calculate composition-dependent diffusivities. However, all but the fastest exhumation paths ( $> ca. 5 \text{ mm yr}^{-1}$ ) result in significant modification of the internal zoning profiles of garnet crystals smaller than  $ca. 1 \text{ cm}$  diameter.

Deviation between the growth composition of a garnet crystal and the preserved composition following exhumation clearly changes apparent  $K_D$  values between co-existing crystal pairs and can yield inappropriate thermobarometer results (with errors exceeding 100°C and 2 kbars in some cases). We quantify the likely uncertainties associated with common mineral thermobarometers when applied to rocks (i) experiencing one of three exhumation geometries of cooling and decompression, (ii) experiencing exhumation at a variety of rates and (iii) containing a range of crystal sizes. For much of the explored range of exhumation-times (1 to 100 Myrs) and crystal sizes (100  $\mu$ m to 1 cm),  $P$ - $T$  paths involving significant isothermal decompression result in demonstrably different zoning profiles to those involving monotonic  $P$  and  $T$  decrease. Such zoning profiles are therefore diagnostic of  $P$ - $T$  path type.

## Reservoir porosity enhancement by multiple stages of TSR in East Sichuan Basin gas fields, China

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It is well known that high  $\text{H}_2\text{S}$  in East Sichuan Basin gas fields was originated from TSR [1, 2]. However, different from other TSR provinces, dolomite reservoirs in the East Sichuan have been measured to have porosity up to 28.2%, and experienced burial down to  $>7000\text{m}$  [3, 2], suggesting that the high porosity in local areas was generated during deep burial, likely during TSR [3], and that dissolved ions must have been migrated out. This is impossible unless there exist multiple stages of TSR because TSR in nature generally occurs in a closed system. The proposal is supported by the following lines of evidence: 1) no anhydrite was found in Upper Permian reservoirs, however, where up to 34.7%  $\text{H}_2\text{S}$  by volume was detected, suggesting that reactant sulfates or resultant  $\text{H}_2\text{S}$  was external; 2) in the Lower Triassic reservoirs, fracture-filling anhydrite has  $\delta^{34}\text{S}$  values about +39‰, the value being significantly higher than contemporary seawater. Coexisting with the anhydrite are isotopically light  $\text{H}_2\text{S}$  and elemental sulphur with  $\delta^{34}\text{S}$  values of +2.0 to +7.9‰. This suggests that at least part of TSR occurred between excessive dissolved sulphate and limited hydrocarbon, and thus unreacted sulphate is isotopically heavy [4], and precipitated as anhydrite during migration. 3) Based on burial history rebuilding, TSR may have taken place at temperatures  $>130^\circ\text{C}$  during the period from Late Triassic to Middle Jurassic, and during Early Cretaceous; lateral and cross formational fluid flow must have taken place during the end of Jurassic to earliest Cretaceous as a result of tectonic activities. 4) Some reservoir bitumen was observed in the centre of pore, suggesting porosity enhancement occurred after solid bitumen filling. Thus, multiple stages of TSR and fluid flow may have resulted in dissolution of anhydrite and dolomite, and thus high porosity for the reservoirs.

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