

Orogenic timescales from zoned minerals via geospeedometry

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Forward models coupling growth of zoned metamorphic minerals with diffusional relaxation of intra-crystalline chemical gradients allow interpretation of the metamorphic durations experienced during orogenesis. Here we demonstrate the utility of this approach by examining garnet porphyroblasts from the western Himalaya, where two major crystalline thrust sheets (the Lesser and Greater Himalaya) reached similar metamorphic grade but consistently exhibit contrasting styles of chemical zoning in garnet. We constrain metamorphic histories for these thrust packages, modelling garnet crystal growth and chemical re-equilibration in each. We obtain good model fits to measured chemical zoning profiles, with best-fit results suggesting that the Lesser and Greater Himalayan sequences experienced characteristically different metamorphic timescales and *P-T* path geometries. Although parts of both sequences reached staurolite- to sillimanite-grade, the inferred primary heating mechanism was different for each; timescales are consistent with a significant component of conductive heat transfer from the Greater to the Lesser Himalaya during overthrusting.

Results also suggest that the initial growth compositions of garnet crystals from both Himalayan sequences were lost long before peak metamorphic conditions were reached, explaining previous difficulties in obtaining consistent estimates of early prograde *P-T* conditions. Generalised results suggest that this is true for most probable temperature, timescale and crystal size ranges typical of regional metamorphism, leading to the possibility of partial 'back correction' of preserved compositions to obtain improved *P-T* information. Furthermore, although satisfactory zoning profiles of Fe, Mg, Mn and Ca can be obtained for most samples, far weaker fits for Ca in those rocks reaching lowest peak temperatures (less than *ca.* 625 °C) support earlier studies suggesting that Ca might be poorly disseminated through pelitic rocks at low-grade conditions.

Porosity enhancement by methane-dominated TSR in East Sichuan

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H₂S, thiols, thiaadamantanes and thiolanes have been reported from TSR-affected petroleum pools [1, 2]. However, there exist debates on whether methane was involved in TSR and porosity was enhanced or not. Deep burial dolomite is found to have significantly higher porosity and H₂S content than limestone in the Lower Triassic Feixiangguan Formation, East Sichuan Basin. We propose that anhydrite and dolomite may have reacted to generate MgSO₄ pair ions, which were further reduced dominantly by methane to generate H₂S [3] and thus secondary porosity. Dolomite and anhydrite instability during late-stage diagenesis is evidenced by supra-large pore space in silt-crystalline dolomite and replacement by TSR calcite with high precipitation temperatures and δ¹³C values from -10.3 to -18.2‰. Some reservoir bitumen was observed in the centre of pore, suggesting that at least pore space between solid bitumen and dolomite was generated after the bitumen precipitation and that dolomite dissolution occurred most likely during TSR. An episodic openness due to subsequent tectonic activities may have occurred during TSR and thus dissolved ions may have left out of the system. A simplified calculation shows that it is impossible for a gas with dryness coefficient >0.90 to have significantly positive shift in δ¹³C₁ values (e.g. >1‰) as a result of methane generation from TSR by heavy hydrocarbon gas. In contrast, the shift must have produced from methane oxidization based on the model of residual methane [4]. For East Sichuan basin gases, a shift of +2.52‰ in δ¹³C₁ value and molar C₁/C₂ ratios from 267 to 1396, may have produced from oxidization of more than 80% ethane with oxidized ethane/methane ratios not more than 0.04. Relationship between TSR degree and methane δ¹³C value in the studied area is expressed as an exponential function, which is expected from the model of methane oxidization [3], supporting a methane-dominated TSR in the East Sichuan and likely other areas which show significantly positive shifts in methane δ¹³C value [5].

This work is financially supported by NSFC No. 40839906.

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