Magmatism, thermal pulses and Barrovian metamorphism

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Barrovian metamorphism in collisional orogens is commonly attributed to heat transfer during thermal relaxation and exhumation of overthickened crust. However, the high temperatures (*T*) needed to produce migmatites and granulite facies rocks are difficult to explain given typical exhumation rates [1, 2]. High-*T* conditions could be achieved via repeated thrust stacking or deformational heating. Here, however, we explore the metamorphic consequences of syn-metamorphic magma intrusion into collisional orogens. We use 2-D numerical models incorporating the effects of fluid flow, endothermic dehydration reactions, latent heats of fusion and crystallization, and exhumation. Mafic- or intermediate-composition magmas intrude as repetitive sills (e.g. 'hot zone' model [3]) at deep crustal (35-50 km) or mid-crustal (15-35 km) levels into the thickened crust.

The modeling makes testable predictions regarding the nature and timing of peak metamorphism. **(A)** Peak-*T* conditions are reached in the upper greenschist and amphibolite facies nearly synchronously, consistent with geochronology at the Barrovian type locality, Scotland [4]. **(B)** For mid-crustal intrusion, Barrovian and HT/LP Buchan metamorphism are produced penecontemporaneously, again consistent with the Scottish field relations [4, 5]. **(C)** Peak heating is predicted to occur in brief (~1 Myr or less) thermal pulses during magmatic intrusion, corresponding to the short timescales recorded by intracrystalline diffusion in apatite and garnet from Scotland [6]. **(D)** Regions of model high-*T* metamorphism are centered on the highest-flux magmatic zones. In Scotland, high-grade conditions coincide spatially with syn-metamorphic intrusions, principally the Newer Gabbros. **(E)** Metamorphic field *T* gradients in Scotland can be extremely steep; such gradients are shown to be a natural consequence of metamorphism in areas of magmatic heating. Magmatic heat input can explain many of the first-order peak metamorphic phenomena observed in the Barrovian type area.

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Paleoclimate of Upper Triassic India: New observations from the Rewa Gondwana basin

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Upper Triassic warming is evident at different places such as the Colorado Plateau and Upper Triassic-Lower Jurassic formations of the Newark Supergroup, southwestern USA,[1] Mercia Mudstone Group, England and Keuper of Germanic basin to name a few, though a wet climate is predicted for Australia and China [2] because of the presence of extensive coal deposits. In India, thick successions of Upper Triassic (Carnian) sediments are known from two major Gondwana basins such as the Maleri Formation of the Pranhita-Godavari basin and the Tiki Formation of the Rewa basin. The former is a red-bed fluvial succession and presence of smectites, pedogenic signatures, poor floral content, lowland faunal assemblage and absence of evaporites suggest a low seasonal rainfall in a semi-arid climate for the Maleri ecosystem [3]. The current work focuses on the latter formation, that is the Tiki Formation of India.

The Tiki Formation comprises red mudstone units with numerous calcic paleosol profiles. Pervasive red colouration of the fine clastics and occurrence of paleosol profiles indicate that the Tiki flood plain was subjected to prolonged subaerial exposure in a hot semi-arid climate. Micromorphology of the nodular carbonates reveals distinctive features which confirms the pedogenic origin of the nodules. 42 such samples of carbonate nodules were analyzed for carbon and oxygen isotopic ratios. pCO$_2$ was calculated [4] and found to be higher compared to present day atmospheric CO_2 levels. ^{18}O depletion is also evident which may be due to many factors. An overall analysis shows that the Upper Triassic paleoclimate of India as deduced from the Tiki carbonates was hot and semi-arid with high seasonal rainfall.

[1] Cleveland et. al. (2008) *PPP* **257**, 421–444. [2] Tanner & Lucas (2006) *GSA* **416**, 53–74. [3] Sarkar (1988) *Sedim. Geol.* **55**, 263-282. [4] Cerling (1984) *EPSL* **71**, 229–240.