Metamorphism in the Variscides: A typical result of subduction followed by collision?

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When we look at the high mountains of regions with active mountain-building, such as the European Alps or Himalaya, the forces associated with continent collision are immediately obvious. Also apparent are the remnants of former intercontinental ocean basins now preserved in ophiolite complexes and outlining the suture zone between the once separated continental blocks. The metamorphic evolution of the Alps and Himalaya is by no means over. The thickened continental crustal roots (65 km or more) will not remain stable nor will the high mountains be retained for eternity. What will happen to these orogenic belts and how will the distribution of metamorphic rocks visible today be modified by processes in the future? These questions are critical to our interpretation of older metamorphic belts – older belts where the mountains are long eroded, where the lithospheric roots are no longer in a state of disequilibrium and where the lack of 3-dimensional exposure really hinders the reconstruction i.e. an older belt like the Variscides.

The metamorphic evolution of these young collisional belts (better considered as 'experiments in progress') does, however, give pointers to what should be expected in other areas *before* final collapse and return to lithospheric equilibrium. In the Himalaya, an early ultra-high pressure metamorphism with coesite-bearing eclogites represents deep subduction of continental crust as the last event of the subduction evolution – the oceanic crust was now consumed – and the initiator process of the collision phase. The collision phase led to an initial Barrovian-style metamorphism typically of high amphibolite facies well documented in kyanite-staurolite-bearing garnetiferous metapelites. This was succeeded by a later high temperature overprint in the sillimanite field at lower pressures – a stage associated with migmatisation and with the intrusion of leucogranites at the top of the crustal sequence. There are also pointers to the presence of high temperature conditions today. The tectonically very active syntaxial regions of Nanga Parbat and Namche Barwa exhibit very rapid exhumation rocks already metamorphosed during one or more of these earlier stages but with a high temperature overprint only a few million years old. Rapid exhumation around gneiss domes in the Karakoram also testify to the present-day high temperature conditions in the crust and also to the tectonic instability this drives. The key point is that the probable future development in this region will be a widespread high temperature-low pressure overprint of rocks already metamorphosed at different grades during the earlier stages. How does this compare with the Variscides?

Despite the numerous papers categorising the Variscan orogenic belt as something special and quite different from the younger Alpine belt at its southern margin, many recent contributions have pointed out very important features that are directly comparable to the Alps. Such features are the presence of ophiolites; localised blueschists; eclogite facies metamorphism and large scale allochthonism: all now seen to be integral parts of an upper Palaeozoic orogeny. The dominant metamorphism is of high temperature-low pressure type associated with common migmatites, granites and cordierite-sillimanite-K-feldspar-bearing paragneisses. This high temperature metamorphism has led to a major re-equilibration of earlier metamorphic features and so only a very careful search of samples with relict mineral grains or compositions has allowed a reconstruction of the metamorphic evolution of the orogen. The result is surprising. There are three major styles of metamorphism distinguishable in the rocks. A high pressure stage is recorded by eclogite facies rocks which show different degrees of recrystallisation dependent on the grade of the surrounding low pressure evolution: in the Saxothuringian Zone this regional low pressure metamorphism was at lower temperature than in the Moldanubian Region and the respective eclogites record this effect also. However, despite the sillimanite-grade melt-related low-pressure metamorphism there is a wide body of evidence showing that many of the paragneisses were earlier kyanite- and/or staurolite-bearing garnet micaschists i.e. rocks showing typical Barrovian, medium pressure metamorphism. Collecting the evidence together we can see that the trend of changing metamorphic styles and, in reality, temperature gradients, is no different in the Variscan to that recorded in the less advanced Himalaya or Alps. This evolution trend from high-pressure to low-pressure thermal patterns via medium-pressure conditions may be a fundamental character of collision-type orogens and is a good example of the dynamic nature of orogenesis.