Exhumation dynamics of high pressure rocks during Caledonian orogenesis: A geochronological perspective

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Abstract

The evolution of the Caledonian orogeny constituted Cambrian to early Silurian closure of the Iapetus ocean, followed by Silurian to Devonian collision between the Laurentia and Baltica. Within the tectonostratigraphy of the Scandinavian Caledonides, the Seve Nappe Complex includes predominantly continental high pressure and ultra-high pressure rocks. The unique rock record provides direct evidence for the subduction and exhumation of the passive margin of Baltica in the late Cambrian to Late Ordovician periods beneath Iapetus ocean volcanic arc(s). More specifically, both the Vaimok and Tsäkkok lenses of the Seve Nappe Complex in Norrbotten, Sweden, possess evidence of (ultra-)high pressure metamorphism in the Early Ordovician period. In contrast, other (ultra-)high pressure exposures of the Seve Nappe Complex farther southwest in Jämtland, Sweden, are thought to have attained peak metamorphism in the Middle to Late Ordovician period. In the Southwestern Caledonian Basement Province of Svalbard, high pressure metamorphism of the comparatively more oceanic Vestgötabreen Complex is synchronous with the Norrbotten localities. However, despite the similar timing of (ultra-)high pressure metamorphism between Norrbotten and Svalbard, the Silurian to Devonian tectonic histories of these regions is markedly different. In Norrbotten, and the Scandinavian Caledonides in general, this period is marked by dominant southeast-vergent thrusting during collision, whereas the Caledonian rocks on Svalbard were transported along major sinistral strike-slip faults. Altogether, the (ultra-)high pressure localities exposed in Norrbotten and Svalbard provide a direct geodynamic record for the mechanisms of the Iapetus ocean closure. Yet, the dynamics and possible spatial correlations for subduction of these localities preceding peak pressure metamorphism, and subsequent exhumation from mantle depths, are not well resolved. As a result, the current understanding of the evolution of the Caledonian orogen is limited. Without a detailed examinations of these processes, a more comprehensive and realistic model for the Caledonian orogeny cannot be realized. The aim of the thesis is to resolve the timing of subduction and exhumation of the (ultra-)high pressure Vaimok and Tsäkkok lenses in Norrbotten, as well as the Vestgötabreen Complex on Svalbard. The work presented here ultimately improves the understanding of the evolution of the Arctic Caledonides, as well as the subduction and exhumation mechanisms of continental and oceanic crust in general. To achieve this, metasedimentary rocks that host high pressure lithologies (i.e., blueschists and eclogites) were targeted for application of the following modern geochronological techniques: 1) zircon U-Pb geochronology and trace element geochemistry depth-profiling; 2) in-situ monazite Th-U-total Pb geochronology; and 3) in-situ white mica $^{40}Ar/^{39}Ar$ geochronology. The results of these analyses were combined with structural

observations and mineral chemistry studies to resolve the temporal evolution of deformation and metamorphism that ultimately record subduction to the peak (ultra-)high pressure conditions and subsequent synorogenic exhumation. Altogether, the thesis provides a prime example of applications of small spatial resolution geochronology in resolving large scale tectonic processes. In the Vaimok lens, monazite Th-U-total Pb geochronology revealed that these rocks were subjected to high pressure in the late Cambrian period, consistent with previous studies that indicate that ultra-high pressure metamorphism was achieved in the Early Ordovician period. Depth-profiling analyses of zircon from the Vaimok lens metasedimentary rocks indicate exhumation in the Early to Middle Ordovician period. In-situ $^{40}Ar/^{39}Ar$ geochronology of white mica from the Tsäkkok lens metasedimentary rocks provides a robust record of Early Ordovician exhumation directly following high pressure metamorphism. Monazite and white mica ages also illustrate that exhumation of the Vestgötabreen Complex on Svalbard was coeval with the Tsäkkok lens from similar pressure and temperature conditions, a record which was later overprinted during Silurian to Devonian strike-slip tectonism. Altogether these results indicate that subduction of the Baltican passive margin was protracted for parts of the Seve Nappe Complex in Norrbotten (i.e., the Vaimok lens). Peak pressure metamorphism was followed by rapid Early Ordovician exhumation of both Norrbotten and Svalbard localities, suggesting that they belonged to the same subduction system that was dismembered due to the later-stage difference in compressional vs. strike-slip geodynamics along strike of the orogen. Regardless, the Early Ordovician exhumation of these localities is in direct contrast with the presumed timing of subduction leading up to the documented Middle to Late Ordovician peak pressure metamorphism for the localities to the southwest in Jämtland. If these localities in the Seve Nappe Complex also represent the same subduction system, it would suggest that either a late Cambrian to Early Ordovician record of subduction and exhumation has gone undocumented for Jämtland, or different tectonic regimes governed the history of the Jämtland and Norrbotten due to complex subduction geometries. Therefore, the knowledge gained from the PhD thesis helps elucidate the evolution of the Arctic Caledonides, which in turn provides a foundation for tectonic models of Caledonian orogenesis.