Monazite geochronology of UHP and HP metamorphism, deformation, and exhumation, Nordøyane, Western Gneiss Region, Norway

MICHAEL P. TERRY,1,* PETER ROBINSON,1,2 MICHAEL A. HAMILTON,3 AND MICHAEL J. JERCINOVIC1

1Department of Geosciences, University of Massachusetts, Amherst, Massachusetts 01003, U.S.A.
2Geological Survey of Norway, N-7491 Trondheim, Norway
3Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario, Canada K1A 0E8

ABSTRACT

U-Th-Pb monazite geochronology is combined with previous structural analysis and quantitative estimates of metamorphic conditions to date the thermotectonic evolution of UHP and HP plates (820 °C, 39 kbar; 780 °C, 18 kbar) metamorphosed during the Late Silurian-Early Devonian collision between Baltica and Laurentia. The Upper Plate contains a microdiamond-bearing, kyanite-garnet-graphite gneiss and associated kyanite eclogites, independently indicating probable diamond-forming conditions. In situ dating of monazite in the microdiamond sample, using the SHRIMP II at the Geological Survey of Canada, yielded ages of 415 ± 6.8 Ma for those included in garnet and 398 ± 6 Ma for those in the matrix. These ages compare to 408.0 ± 5.6 and 397.5 ± 4.4 Ma determined using the electron microprobe at the University of Massachusetts. Both methods also identified complexly zoned detrital cores up to 150 micrometers in diameter with ages of 1100–950 Ma and scattered grains with ages of 900–500 Ma, but no ages of 1680–1650 Ma equivalent to the local Baltica basement were found. Agreement between the two techniques allowed evaluation of monazite age domains (198 analyses) from the microdiamond rock and a kyanite-garnet-sillimanite mylonite produced from it, using a combination of high-resolution element imaging and trace-element analysis of U, Th, Pb, and Y. This comparison yielded three mean ages of 407.0 ± 2.1 Ma, 394.8 ± 2.3 Ma, and 374.6 ± 2.7 Ma.

Combining this geochronology with previous P-T estimates, we propose that the UHP unit reached its maximum depth of 125 km, at a maximum age of 407 Ma when monazite was included in garnet, and experienced 65 km of exhumation at an average rate of 10.9 mm/year during top-southeast thrusting that brought it into contact with the HP unit. Following these events, both units were exhumed together at an average rate of 3.8 mm/year until reaching a depth of 37 km at 395 Ma, where these rocks experienced extensive re-equilibration, and top-west and left-lateral shearing. After 395 Ma, these units continued to be exhumed at an average rate of 0.8 to 1.4 mm/year until 375 Ma, the time of last equilibration of asymmetric monazite porphyroclasts in the mylonite. The exhumation histories of these units record a change in mechanism from synollisional exhumation through late- to post-orogenic collapse that was a consequence of plate reorganization.

INTRODUCTION

Knowledge of the precise timing of structural features and growth of metamorphic minerals provides crucial information for understanding the mechanisms involved in the production and exhumation of metamorphic rocks during continental collision. This information can be acquired by in-situ isotopic age-dating of monazite using the ion microprobe and chemical age-dating with the electron microprobe, which allow preservation of critical textural relationships associated with metamorphic and structural evolution of the rock. Textural relationships and recognition of them can be enhanced dramatically by trace-element compositional mapping of monazite. The purposes of this paper are to present results from these combined approaches to UHP rocks and to examine potential tectonic implications when combined with careful petrologic and structural analysis.

* E-mail: terry@geo.umass.edu

GEOLOGIC SETTING AND SAMPLE DESCRIPTION

The Western Gneiss Region, Norway, is a giant tectonic window exposing large areas of Baltica Proterozoic basement beneath a sequence of Scandian (late Silurian-early Devonian) thrust nappes. It is interpreted as a region where the basement of Baltica and tectonic cover have been subducted beneath the overriding Laurentian plate, and is a classic area of exposure and petrologic study of mafic rocks metamorphosed to eclogite. The nappes surrounding the Western Gneiss Region also occur deeply infolded in narrow complex synclines within it (Robinson 1995), where they have commonly undergone extreme tectonic thinning and complex ductile deformation, followed by development of mylonites, ultramylonites, and brittle faults associated with later phases of tectonic exhumation. Detailed mapping and petrologic studies of Nordøyane (“the north islands”) allowed subdivision of the geology into northern, central, and southern segments (Terry and Robinson 1998; Terry 2000; Terry et al. 2000). Each segment contains different Proterozoic basement types, plus narrow infolded synclines.