A new UHP metamorphic complex in the ~1.8 Ga Nagssugtoqidian Orogen of West Greenland

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ABSTRACT

The Nagssugtoqidian Orogen is a ca. 1.8 Ga belt of east-west trending, highly deformed rocks that bisects central Greenland. Although a variety of data have suggested this belt marks the location of a continent-continent collision zone, evidence of subduction has been lacking. We report here mineralogical evidence from four samples within a well-defined lithologic unit of metabasic and metasedimentary ocean floor rocks of a previously unrecognized UHP metamorphic episode. The UHP episode is recorded by remnants of orthopyroxene exsolved from majoritic garnet, graphitized diamond, exsolution of rutile from garnet and pyroxenes, exsolution of magnetite from olivine, and complex exsolution textures in ortho- and clinopyroxenes (including omphacite). Associated with these mineralogical features is an unusual occurrence of quartz needles in Mn-rich fayalite. From textural characteristics, we infer that the quartz needles exsolved from the fayalite. To our knowledge, olivine with exsolved silica has not been reported. We note, however, that experimental studies have shown that \( \beta \)-spinel can incorporate excess silica. We therefore speculate these quartz needles may be silica that exsolved from Mn-rich ahrensite, the Fe analog of ringwoodite, upon decompression and inversion to fayalite. If correct, this occurrence would be the first reported sample of naturally occurring olivine (fayalite) that inverted from ahrensite. Corroborating an early UHP history are reaction relationships that delineate a path through high-pressure and high-temperature conditions during decompression. \( P-T \) conditions inferred for the UHP episode are \(~7\) GPa at \( \sim 975^\circ \text{C} \). The unusually low \( T \) for this UHP system at \( \sim 1.8 \) Ga may reflect either very rapid subduction rates at that time, or unexpectedly cool mantle conditions. Preservation of the UHP assemblages probably is due, in large part, to the exceptionally low \( a_{180} \) during decompression and cooling. These UHP rocks establish that the location of the subduction and suture zones that must have existed prior to and during the collision of continents was along what is now the northern edge of the Nordre Strømfjord shear zone.

Keywords: UHP metamorphism, majorite, diamonds, Nagssugtoqidian, pigeonite, ahrensite, Paleoproterozoic, exsolution

INTRODUCTION

Since the first discovery (Chopin 1984) of coesite in alpine metamorphic rocks, ultrahigh-pressure (UHP) metamorphism has been recognized in more than 20 localities around the world (see summaries in Chopin 2003, and Ernst and Liou 2008). All of these sites are within metamorphic terrains younger than 1000 million years, reflecting the rarity of preserving mineral assemblages that are inherently highly thermodynamically unstable. Even though rare and of minuscule areal extent, these sites have profoundly affected conceptual models of global geodynamic processes, and have raised important new questions regarding the behavior of continental crust during continent-continent collisions, the representativeness of modern day tectonic structures and collisions, and the mechanics of subduction and exhumation (Ernst and Liou 2008). However, recognizing such sites is fraught with challenges. In most instances the remnant mineralogy providing evidence of UHP metamorphism is preserved only at the micrometer scale, and is ambiguous unless associated with multiple UHP indicators.

We report here multiple lines of evidence that establish the presence of a UHP metamorphic complex in the Nordre Strømfjord shear zone (NSSZ), which is located within the Nagssugtoqidian Mobile Belt of West Greenland. Prior to this discovery, this mobile belt had been considered a classic example of upper amphibolite to granulite facies deep crustal regional metamorphism (Davidson 1979; Hansen 1979; Glassley and Sørensen 1980; Glassley 1983; Mengel 1983). Although that regional metamorphic model does reflect the last significant metamorphic event these rocks experienced, the UHP mineralogy we describe here unequivocally demonstrates that, for at least some of the lithologies within the NSSZ, a significant chapter in the metamorphic history has been missed.

In addition, these results demonstrate that the metamorphic and tectonic processes that result in UHP metamorphism extend at least as far back as ca. 1.8 Ga. Finally, we report observations that may be evidence of the first terrestrial example of Fe-rich ringwoodite in a UHP terrain.