Microstructural insights into the tectonic history of the southeastern New England Appalachians; porphyroblast-matrix structural analysis and insitu geochronology of rocks from the Merrimack Terrane, Connecticut and the Narragansett Basin, Rhode Island.

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Thesis submitted by
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STATEMENT OF SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any other form for another degree or diploma at any university of other institution of tertiary education. Information derived from published or unpublished work of others has been acknowledged in the text and a list of references is given.

Benjamin Heath Rich   Date

Statement on the Contribution of Others

Tim Bell developed the technique central to this study. He initiated this project, spent many hours working with me on a dual microscope and edited all drafts. Funding for fieldwork and analyses was provided from an ARC Large grant to T.H. Bell and a JCU Doctoral Merit Research Scheme grant to Rich. Stipend support was received from a JCU School of Earth Sciences Scholarship and a JCU Postgraduate Research Scholarship.

Bob Wintsch provided an invaluable introduction to southeastern New England field geology. He identified both study areas as of potential interest and continued to provide valuable insight through correspondence and reviews of the first chapter.

Kevin Blake managed the facilities in the James Cook University Advanced Analytical Centre and his expertise and assistance with electron microprobe analysis is gratefully acknowledged. Nick Lisowiec will be a co-author on chapter 4 if it is submitted for publication. Nick tutored me on monazite analysis, corrected the gathered data and applied statistical analysis.

The Connecticut Geological and Natural History Survey and the Rhode Island Geological Survey provided bedrock geology quadrangle maps. The Narragansett Bay National Estuarine Research Reserve provided field accommodation on the serene Prudence Island.

Critical reviews by R. Wintsch and D. Aerden greatly improved chapter 1 which has been submitted for publication in the Journal of Structural Geology.

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Introduction and Thesis Outline

Constraining the arrival time of the late Proterozoic Avalon terrane to North America has been the focus of many New England Appalachian tectonic studies. Avalon is thought to underlie much of present day New England including the Putnam-Nashoba, Merrimack, Central Maine and Bronson Hill terranes, and thus, its arrival time is pivotal to the development of any tectonic model for the region. Some workers have argued it was the Middle Ordovician accretion of the Avalon terrane that was driving force behind the Taconic orogeny (Robinson and Hall, 1980; Skehan and Rast, 1990). Other workers have suggested that the arrival of Avalon in the Early Devonian was responsible for the Acadian orogeny (Osberg, 1978; Williams and Hatcher, 1983). Recently, work focussed around the inliers of the Avalon terrane has indicated that at least some late stages of accretion occurred during the late Palaeozoic Alleghanian orogeny (Wintsch and Sutter, 1986; Getty and Gromet, 1992a; Wintsch et al., 1992).

Coupled with recent studies into the timing of accretion of the Avalon terrane, has been an investigation into the extent of Alleghanian metamorphism in New England. The Alleghanian orogeny is thought to have been driven by the collision of Africa into North America during the creation of the super-continent Pangea (Mosher, 1983). Until recently late Palaeozoic Alleghanian metamorphism was considered to be restricted to the Avalon terrane. Persuasive evidence for high grade Permian metamorphism within Avalon is provided by multiple isotopic studies of the crystalline late Proterozoic basement (Wintsch and Aleinikoff, 1987; Zartman and Hermes, 1987; Dallmeyer and Takasu, 1992). To the west of the Avalon terrane is a remnant of a volcanic arc known as the Putnam-Nashoba terrane. This belt of high-grade rocks has been shown to record early Palaeozoic metamorphism (Wintsch et al., 1992; Acaster and Bickford, 1999) and has been interpreted to define the eastern limit of Acadian metamorphism (Robinson et al., 1998). As a result, the possibility of high-grade Alleghanian metamorphism extending west of the Avalon terrane has historically been regarded as unlikely.

However, evidence for Alleghanian metamorphism in New England to the west of the Putnam-Nashoba has slowly been mounting. Several studies focussed around the domal inliers of Avalon, the Pelham and Willimantic, revealed shear controlled high-grade Alleghanian metamorphism at these basement-cover rock boundaries (Robinson et al., 1992; Moecher and Wintsch, 1994). Moecher (1999) hypothesised that an approximately 5-km-thick zone of ductile Alleghanian deformation underlies the cover rocks of the Putnam-Nashoba, Merrimack, Central Maine and Bronson Hill terranes along their boundary with the underlying Late Proterozoic Avalon Terrane. More recently, Late Palaeozoic U-Pb ages of sphene and 40Ar/39Ar cooling ages of amphibole and muscovite (Wintsch et al., 2003) from rocks of the Bronson Hill terrane in Connecticut and Massachusetts have demonstrated that the metamorphic effects of the Alleghanian orogeny were not restricted to the Avalon terrane. Prograde Alleghanian sphenes crystallised during the Late Pennsylvanian which nullifies any argument that the amphibole ages may be sluggish Permian cooling from the Acadian orogeny.

Identification of prograde Late Palaeozoic metamorphism within the Bronson Hill terrane raises the possibility that pervasive Alleghanian deformation may be more wide spread within New England than workers have previously contemplated. The terranes that lie between the Bronson Hill and Avalon terranes, namely the Central Maine, Merrimack and Putnam-Nashoba, could all conceivably preserve significant Alleghanian metamorphic histories. This study focuses on the Merrimack terrane, which prevailing opinion deems underwent pervasive metamorphism during the Acadian orogeny (Robinson, 1983). The Narragansett Basin in Rhode Island was chosen for comparison with the Merrimack Terrane as the metasediments provide a unique structural history of purely Alleghanian collisional orogenesis (Quinn, 1971). The Narragansett Basin is a composite graben system with Pennsylvanian age sediments that sit unconformably on the crystalline basement rocks of the Avalon Composite Terrane (Mosher, 1983; Lyons, 1984). In order to constrain the arrival time of Avalon with North America, a combined microstructural - insitu geochronology approach has been utilised to determine whether the two terrains have a coupled tectonic history. The results of this study of bulk orogenic shortening directions preserved within the Merrimack terrane and the Narragansett Basin combined with U-Pb insitu chemical dating of monazite have provided insights into the tectonic history of the region.

This thesis consists of four sections (A to D). Each of the four sections has been, or will be, submitted as individual papers to international journals. Details of the submission process appear on the first page of each section.

Section A is a detailed microstructural analysis of porphyroblasts from the Rhode Island Formation in the south central zone of the Narragansett Basin, Rhode Island. Two extended periods of deformation and metamorphism about two differently trending foliation intersection/ inflection axes in porphyroblasts (FIAs) were defined. SSW-NNE trending FIAs (Set 1) formed first followed by WSW-ENE trending FIAs (Set 2). The FIA trends suggest the direction of maximum bulk shortening changed from WNW-ESE to NNW-SSE during amphibolite facies metamorphism within the Central Zone of the basin and this is compared with results from previous structural studies from the region.

Section B deviates slightly from the general focus of this thesis to further analyse microstructures preserved in rock samples from the Narragansett Basin because they so persistently show a consistent asymmetry, which is quite unusual. The two distinct FIA trends preserved by porphyroblasts in the Rhode Island Formation can not be explained by a vorticity-induced porphyroblast rotation model but can be explained by the progressive bulk inhomogeneous shortening non-rotation model. Each FIA trend is defined by a consistent asymmetry of the curved inclusion trails, the formation of which requires a completely consistent bulk shear. An argument is presented that shear must have accompanied crenulation cleavage development to form and preserve these unusual microstructural geometries.

Section C is a detailed microstructural analysis of porphyroblasts from the Scotland Schist in the Merrimack Terrane, Connecticut. Structures preserved in porphyroblasts define four periods of deformation and metamorphism about four differently trending FIAs in porphyroblasts. FIA sets 1 to 4 are oriented WNW-ESE, SW-NE, NNW-SSE and WNW-ESE, respectively. WSW to NNE directed bulk orogenic flow accompanied high grade metamorphism. Pennsylvanian metamorphism appears pervasive throughout the Scotland Schist of the Merrimack Terrane in SE New England. This is in contrast to previous work that has suggested post-Acadian metamorphism within the cover sequence was limited to narrow fault controlled zones.

Section 4 documents Late Palaeozoic U-Th-Pb ages of monazite from rocks of the Merrimack Terrane in eastern Connecticut which reflect an Alleghanian overprint on Acadian metamorphosed rocks. Monazite growth was dated using an insitu chemical method and identifies high grade metamorphism occurred in association with compressional deformation at 311 ± 3 Ma. The effect of late Alleghanian (Permian) deformation and metamorphism recorded within the Narragansett Basin to the east was not recorded by the Merrimack Terrane. This is strongly supported by the lack of correlation between the FIA sets for the two regions.

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Volume 2: Tables, Figures and Appendices

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