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Microstructural Analysis of the Rhode Island Formation, Narragansett Basin, MA

BY ELIZABETH CONNELL

Elizabeth Connell conducted her research with funding from an ATP Summer Grant under the mentorship of Dr. Michael Krol.

Abstract

The Narragansett Basin is a Pennsylvanian-age transtensional basin that formed within the Avalon Terrane approximately 320 Ma. The Narragansett Basin consists of different stratigraphic units, with the Rhode Island Formation being the most extensive (Towe, 1959). Following deposition and lithification, the Rhode Island Formation experienced several phases of intense deformation and metamorphism as a result of Africa colliding with the eastern margin of North America. The Alleghanian Orogeny created the supercontinent Pangea, culminating around 280 Ma (Winstch et al., 1992).

This project investigated the lithologic and microstructural characteristics of the lower portion of a 1500 foot deep drill core obtained along the eastern margin of the Narragansett Basin near Somerset, MA. The core consists of a sequence of alternating layers of sandstone and siltstone, with minor amounts of coal.

Microstructural analysis reveals evidence of both low temperature and higher temperature deformation episodes that affected the Rhode Island Formation. The low temperature episode is defined by a dominant pressure solution cleavage and locally developed pressure fibers. The presumably older, high temperature episode is dominated by crystal-plastic deformation that is preserved as statically recrystallized quartz. Mineral assemblages near the bottom of the core contain abundant biotite and biotite/chlorite pseudomorphs after garnet. This suggests metamorphic temperatures in excess of ~450-500°C for the lower portion of the core in agreement with the quartz microstructures.

Introduction

This paper examined the lower portion of a drill core from Somerset, MA (from a depth of 750 feet to a depth of 1500 feet) obtained along the eastern margin of the Narragansett Basin (Fig. 1). We document the microstructures preserved in rocks of the Rhode Island Formation and identify the types of deformation mechanisms that operated during an intense phase of the Alleghanian Orogeny. Rocks and minerals respond to deformation in various ways depending on the dominant deformation mechanism. By studying the microstructures we were able to decipher the type of mechanism(s) that operated during deformation and metamorphism. On the basis of the type of microstructures and mineral assemblages present, we can infer the temperature-pressure conditions that existed during this episode of deformation.

The predominant deformation mechanism was pressure solution. Pressure solution is a selective process that involves the dissolution, transport, and re-precipitation of material through an intergranular fluid, in response to high compressive stresses (Davis and Reynolds, 1996).

Surficial studies have documented the style of deformation that affected rock of the Narragansett Basin mainly in Rhode Island (e.g. Mosher et al., 1987). Mosher et al. (1987) showed that rocks in the southern portion of the Narragansett Basin in Rhode Island experienced intense deformation and high grade metamorphism.

Little attention has been paid to the rocks of the Narragansett Basin in eastern Massachusetts and in particular within the subsurface. Our results have helped to provide new information concerning the mechanisms and conditions of deformation and metamorphism that occurred during this intense period of tectonic activity. Ultimately our results will help refine current tectonic models for the geologic evolution of eastern Massachusetts.

Geologic setting

The Narragansett Basin is a Pennsylvanian-age basin that formed within a transtensional tectonic environment approximately 320 Ma (Fig. 1). The Narragansett Basin consists of a variety of lithostratigraphic units, of which the Rhode Island Formation is the most extensive in terms of thickness (Towe, 1959). The basin was a locus of sedimentation as material was transported from the northeast via rivers and streams. Deposition resulted in an accumulation of >15,000 feet of clastic sediment. Following deposition and lithification, the basin experienced several phases of intense deformation and metamorphism during the Alleghanian Orogeny. This event was a result of the collision between Africa and the eastern margin of North America, creating the supercontinent Pangaea, about 280 Ma (Winstch et al., 1992).

Methodology

The drill core studied was extracted in Somerset, MA and is approximately 1500 feet in length. This research project concentrated on the lower 750 feet of drill core, while the upper 750 feet of drill core was examined by a fellow Bridgewater State College student, Ashlee Kirkwood. Lithologies were logged and a stratigraphic column was constructed that displays rock type and thickness versus depth (Fig. 2). During mesoscopic analysis, samples were selected for petrographic study based on their appearance and textures. Samples were cut using a diamond-tipped rock saw and trimmed into small rectangular chips. After being polished, these chips were sent to a commercial laboratory where they were mounted to glass slides and ground to a thickness of 30 microns.

Results

Mesoscopic Lithologic Analysis

The lower portion of the drill core contained a sequence of alternating layers of sandstone and siltstone, with minor amounts of coal (Fig. 2). Sedimentary bedding is inclined about

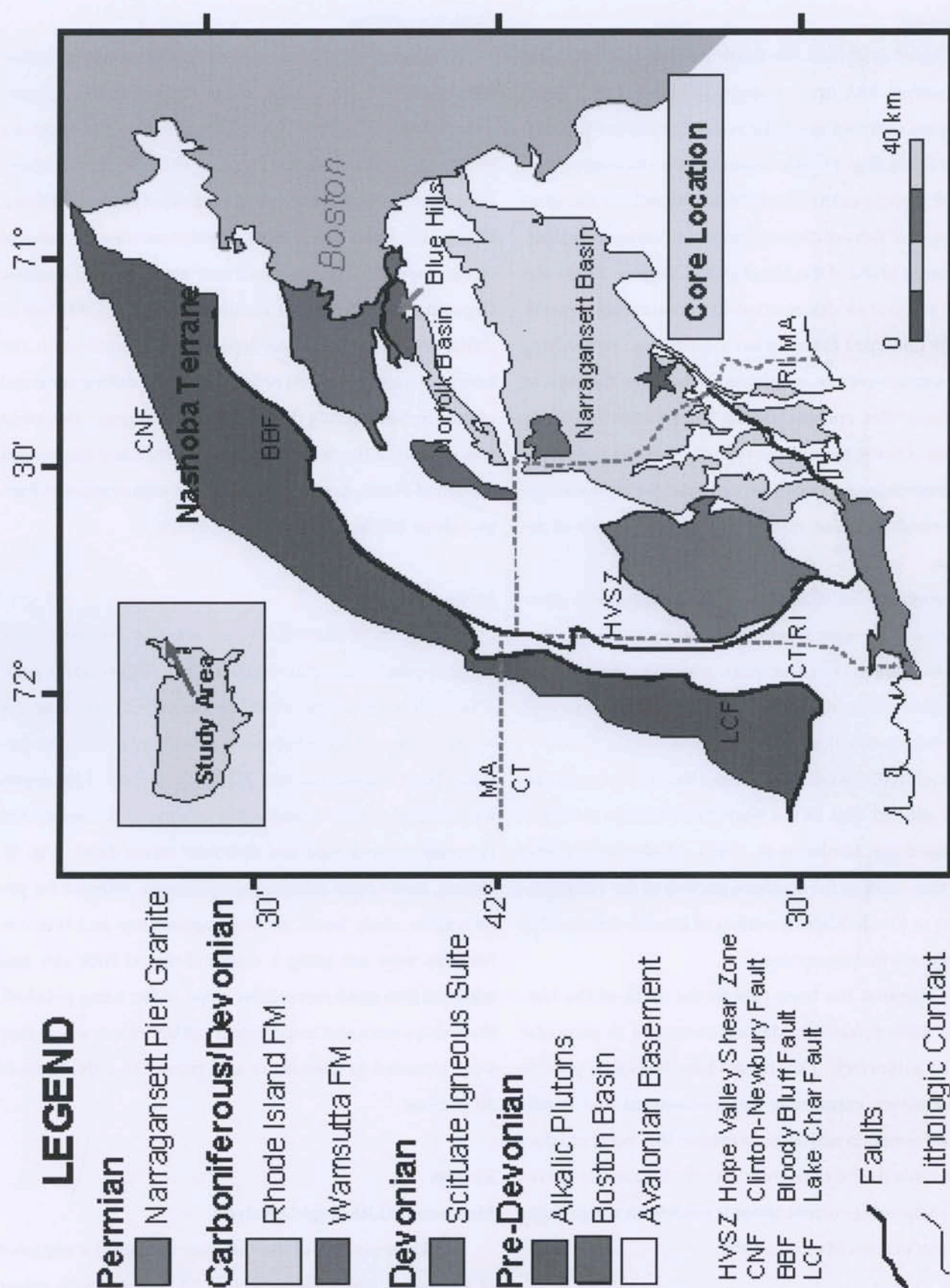


Figure 1. Generalized tectonostratigraphic map of eastern New England.

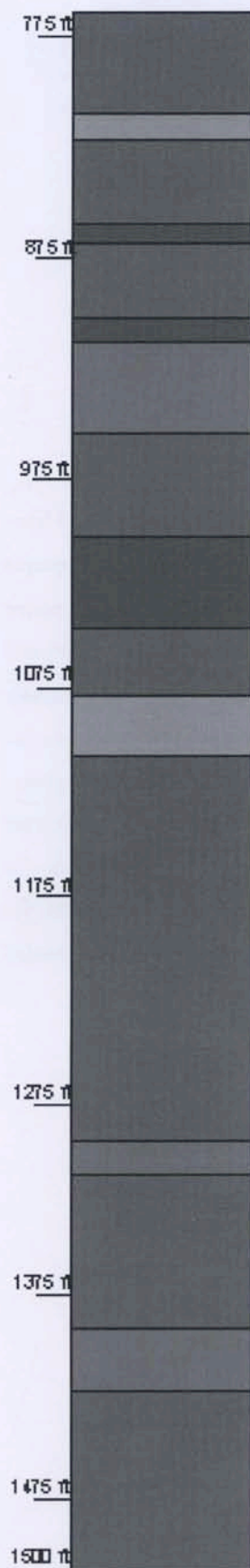


Figure 2 - Generalized stratigraphic column of Somerset drill core.

15-20° from the horizontal. Sandstone that is present is typically fine-grained with siltstone being extremely fine-grained. Thicknesses of individual units ranged from only inches to 10's or 100's of feet. Several calcite veins occur throughout the core and crosscut sedimentary layering at relatively high angles.

Petrographic Analysis

The following data reflects the mineralogy and microstructures obtained through petrographic analysis of samples that provide information pertaining to the geologic evolution of the Narragansett Basin; photomicrographs accompany the data to provide a visual example. XPL = crossed polarized light; PPL = plane polarized light.

Sample SOM-56-1:

This sample is a fine-grained, well sorted sandstone obtained from a depth of 872' that contains quartz and an abundance of opaque grains. Figure 3 shows an example of slaty cleavage and pressure fibers developed on an opaque grain.



Figure 3 - XPL (4X)

Sample SOM-83-1:

This sample is a fine-grained, well sorted sandstone obtained from a depth of 1269' that contains quartz, muscovite, and biotite. Figure 4 shows an example of well-developed crenulation cleavage within the mica-rich layers, and considerably less within quartz-rich layers.



Figure 4 - XPL (4X)

Sample SOM-86-1:

This sample is a very fine-grained siltstone obtained from a depth of 1317' that contains quartz, biotite, and opaque grains. Figure 5 shows pressure fibers surrounding an opaque grain which indicates low temperature metamorphism and deformation. Biotite is present in figure 6 which is generally indicative of higher temperature metamorphic conditions. Therefore, there may have been two distinct temperature changes or events that occurred to have both characteristics present in the same sample. One can infer that the rock was brought up to a very high temperature (~350°C - 500°C) at which the biotite began to grow and as the rocks were cooled the pressure fibers developed during compression.



Figure 5 - XPL (10X)

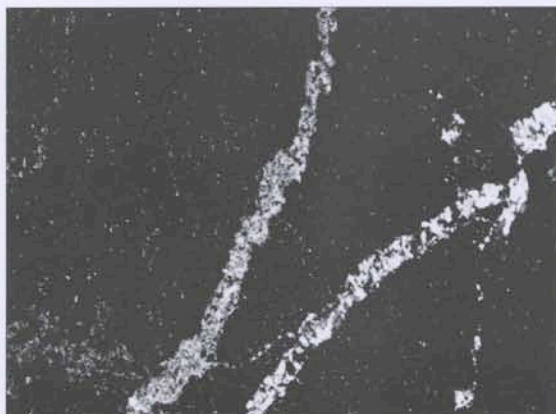


Figure 6 - XPL (4X)

Sample SOM-96-2:

This sample is a fine-grained, well sorted sandstone obtained from a depth of 1424' that contains quartz, biotite, and chlorite. Figure 7 shows chlorite pseudomorphs after garnet that also display an asymmetric shear fabric. In this sample the low temperature pressure solution overprints the high temperature fabric. Figure 8 shows chlorite and biotite after garnet. The presence of the pseudomorphs in both Figures 7 and 8 is indicative of retrogression following high temperature metamorphism.



Figure 7 - PPL (4X)



Figure 8 - PPL (10X)

Sample SOM-96-3

This sample is a fine-grained, well sorted sandstone obtained from a depth of 1422' that contains quartz, biotite, clay, and opaque grains. Figure 9 shows a biotite skeleton that is breaking down, as well as parasitic folds. The folds bend around the biotite, indicating that the biotite was there first. One could infer that the biotite was originally a garnet and was later converted; after the rocks were heated up to a temperature where garnet could grow, they began to cool and the folds formed on the retrograde side of the cooling path.



Figure 9 - XPL (4X)

Conclusion

The lower portion of the Somerset, MA core preserved evidence for two distinct thermal events. A high temperature metamorphic event that locally achieved garnet-grade conditions, and a low temperature deformation episode that is defined by locally developed pressure fibers and a dominant pressure solution cleavage.

After conducting a mesoscopic analysis of the drill core lithology and a detailed petrographic analysis of the mineralogy and microstructures we conclude that the lower portion of the core (from a depth of ~750 feet to a depth of 1500 feet) experienced both low temperature and high temperature deformation and metamorphism.

Low temperature deformation is identified by locally developed pressure fibers and the presence of a well-developed crenulation cleavage. The high temperature metamorphism is recognized by the abundance of biotite as well as biotite/chlorite pseudomorphs after garnet. In addition, the presence of statically recrystallized quartz also suggests elevated temperatures persisted after the high temperature metamorphism. The presence of garnet, a metamorphic mineral, suggests that temperatures in these rocks exceeded 450°C - 500°C.

The high temperature metamorphism is presumably older than the low temperature metamorphism. The relative ages of these events can be established on the basis of the preserved mineral assemblages and microstructures. The low temperature event records evidence of pressure solution and development of a crenulation cleavage. These features would most likely have been obliterated when subjected to higher temperatures. However, the biotite/chlorite pseudomorphs suggest temperatures were high enough to grow garnet and upon cooling retrograded to biotite/chlorite. It is unclear whether these events represent separate episodes of deformation and metamorphism or if they reflect a transition from high temperature metamorphism to lower temperatures during cooling, but continued deformation.

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