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Microstructural Analysis of a Drill Core from the Rhode Island Formation: Upper 750 Feet

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Microstructural Analysis of a Drill Core from the Rhode Island Formation: Upper 750 Feet

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Ashlee Kirkwood is a Senior at Bridgewater State College majoring in Earth Science. She wrote this paper to document the data from her ATP summer research grant work. She worked on the research project in the spring, summer and fall of 2005, under the mentorship of Dr. Michael Krol. Ashlee hopes to teach Earth Science at the High School level after graduating. Currently, she works for Mad Science; a company that offers after-school programs, workshops, and summer programs to young children who enjoy science.

Abstract

The Narragansett Basin located in eastern Massachusetts is characterized by a thick sequence of Pennsylvanian-age clastic sediment. Following deposition the basin experienced several phases of deformation during the Late Paleozoic Alleghanian Orogeny.

This study investigated the upper portion of a 1500 foot drill core from Somerset, Massachusetts. The core is characterized by an alternating sequence of organic-rich siltstones and sandstones with subordinate amounts of conglomerate and coal. Microstructural analysis reveals these rocks experienced low grade metamorphism and deformation dominated by pressure solution. Evidence for pressure solution is preserved as dissolved microfold limbs and formation of crenulation cleavage. Quartz typically displays sutured grain boundaries and undulose extinction suggestive of crystal plastic deformation, which indicates temperatures in excess of 350°C. The lack of higher temperature microtextures and the low grade mineral assemblages indicates temperatures did not exceed ~450°C.

Introduction

The Narragansett Basin represents a Late Paleozoic graben that formed within the Avalon Terrane during active faulting ~320 million years ago (Mosher, 1983). As the basin developed, erosion of surrounding mountains resulted in the accumulation of over 15,000 feet of sedimentary rock. The most extensive unit within the Narragansett Basin is the Rhode Island Formation. It consists of over 10,000 feet of interlayered sandstone and conglomerate with minor shale and trace amounts of coal (Skehan, 2001; Robbins, 2005; Craig 2005). Following deposition, the basin experienced several phases of intense deformation and metamorphism related to the collision of Africa and North America approximately 280 Ma (Winstch et al., 1992).

Although much is known about the surface geology of the Narragansett Basin in Rhode Island, little work has been done in the subsurface, especially in eastern Massachusetts. This project documents the microstructures and deformation mechanisms that affected rocks found in a drill core from Somerset, MA. The role of pressure solution is more prevalent in these rocks than previously recognized.

This study investigated the effects of deformation associated with the Alleghanian Orogeny on the various lithologies within the Somerset drill core. Documenting the mineralogy and microstructures provides information on the mechanisms that operated during deformation and allows us to infer the temperature-pressure conditions during this tectonic event. This project concentrated on the upper ~750 feet of drill core (total depth of core was ~1500 feet). A companion paper by Elizabeth Connell, investigated the lower ~750 feet of the Somerset drill core.

Results

The project began with an examination and lithologic analysis of the core (Figure 1), followed by the preparation of more than 30 rock samples from various depths for petrographic analysis. Once cut, samples were sent to a commercial thin section preparation laboratory.

Lithologic Analysis

The rock sequence contained within the upper half of the core is predominately siltstone. Lesser amounts of sandstone and coal are present in equal proportions throughout the core and small veins of quartz were encountered at a depth of ~350 feet, which cross-cuts the sedimentary layering. Small pyrite grains are visible on portions of the darker organic-rich coal. Some mesoscopic deformation is visible in the core, in the form of folds.

Petrographic Analysis

Matrix minerals in all samples from the Somerset core are extremely well sorted and well rounded. Sandstone is differentiated from siltstone and coal samples due to the size of matrix grains, as well as the overall color of the sample (Figure 3). Most samples consist primarily of elongated quartz grains and aligned platy minerals, such as muscovite and biotite (Figure 3). Varying amounts of pyrite are commonly found throughout the core, with grains predominately larger than the surrounding matrix. Numerous samples contain calcite and quartz as either interstitial grains or cross-cutting veins. These veins are oriented at high angles to the lithologic layering.

Samples that contain large amounts of organic matter appear less competent and exhibit more intense deformation with the formation of a well-developed crenulation cleavage (Figure 4). At a depth of ~550 feet, a subordinate amount of chlorite is observed, usually in small veins adjacent to quartz layers (Figure 5). Crenulation cleavage and distinct folding of layers is common within rocks of the drill core (Figures 2, 4 and 5). Some samples contained large amounts of calcite that were significant in size (Figure 6). Below ~250 feet, dissolution of microfold limbs becomes more prominent. Quartz that occurs in veins displays fibrous elongation, which is growth controlled (Figure 7). It also displays slight undulose extinction, suggestive that the grains were not affected by any post-formation deformation.

Overall, there appears to be a correlation between deformation intensity and lithology. Lithologies that contain greater amounts of organic matter display more pronounced deformation features such as folds and cleavage development, whereas quartz-rich sandstone lithologies do not. The intensity change observed is probably in response to lithologic contrasts, and not related to increasing or decreasing stresses affecting these rocks.

Summary

In some samples the opaque minerals appear to have formed after deformation, as there is no preferred orientation, compared to the surrounding matrix. Other samples contain opaque grains which do have an orientation, typically parallel to the elongated quartz and muscovite, which suggests they are pre-to-syn deformational. Rocks that are rich in organic material display more intense deformation due to a lower mechanical competency. Deformation intensity does not correlate with depth, because different lithologies alternate throughout the core. Thus, we conclude that deformation in these rock samples reflects a lithologic control.

Quartz that occurs in veins shows undulose extinction, so we conclude that quartz precipitated while the rocks were subjected to elevated temperatures to cause the slight crystal-plastic deformation in the quartz. A significant amount of chlorite within these rocks suggests low-grade metamorphism perhaps attaining lower greenshcist-facies conditions. Due to the type and amount of deformation observed, it can be concluded that during metamorphism, the rocks in the upper half of the core experienced temperatures between 350°C – 450°C.

On the basis of the mineral assemblage and microstructures present, rocks of the Narragansett Basin experienced a phase of intense deformation during compression tectonism associated with the Alleghanian Orogeny. This episode resulted in the development of a crenulation cleavage, microfolds, and minor crystal-plastic deformation in quartz. Rocks were deformed predominately by a pressure solution mechanism with material dissolved and re-precipitated elsewhere. Following this compressional event, the Narragansett Basin was subjected to two phases of extensional deformation. Rocks were brittlely deformed and fractures opened, which allowed hydrothermal fluids to infiltrate through the rocks. These veins represent a younger episode and may be associated with the breakup of Pangea in the Mesozoic.

Acknowledgements

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I would also like to thank Dr. Krol, not just for extensive guidance during this project, but for his continued efforts to help me through the sometimes troubled waters of earth science, and life.

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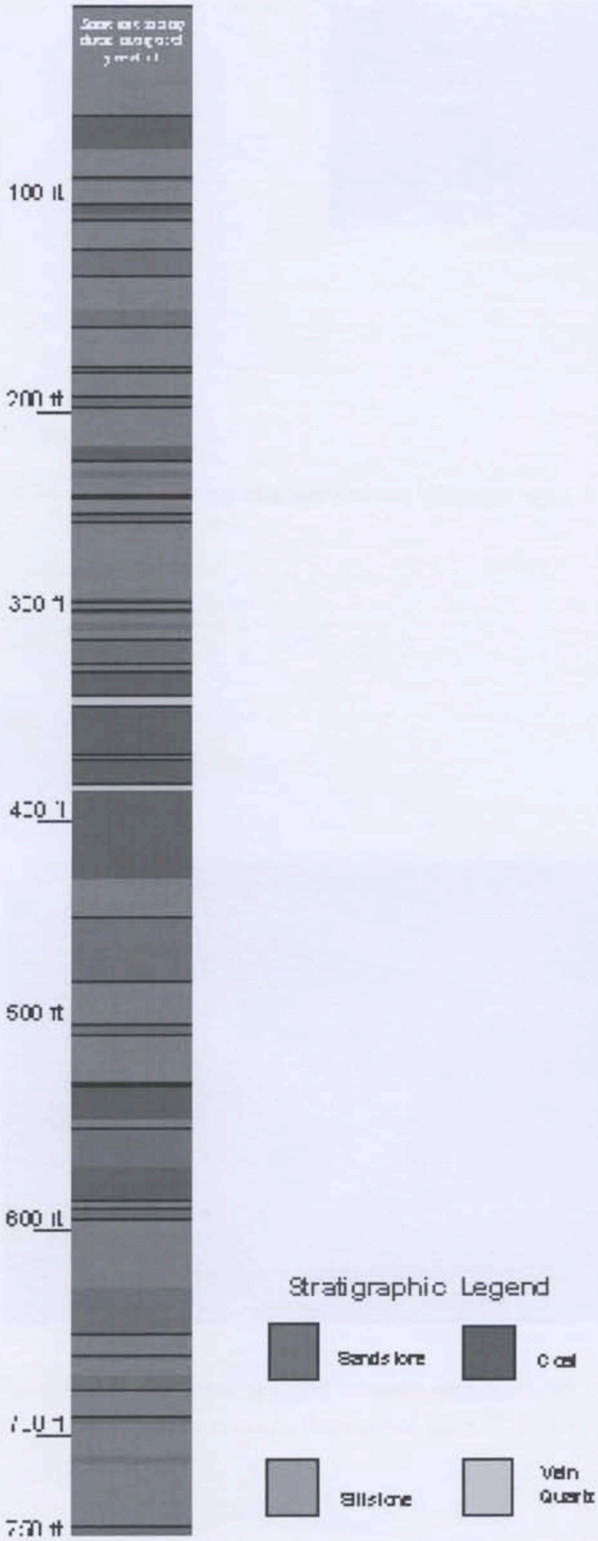

Figure 1. Generalized Stratigraphic Column of the Somerset Drill Core.

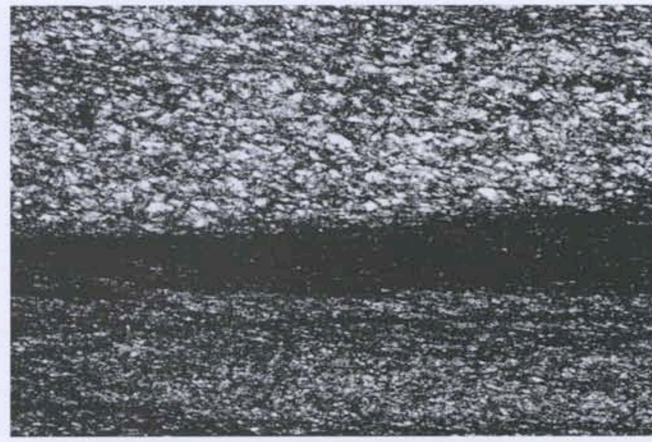

Figure 2. Visible layering with well-developed slaty cleavage.

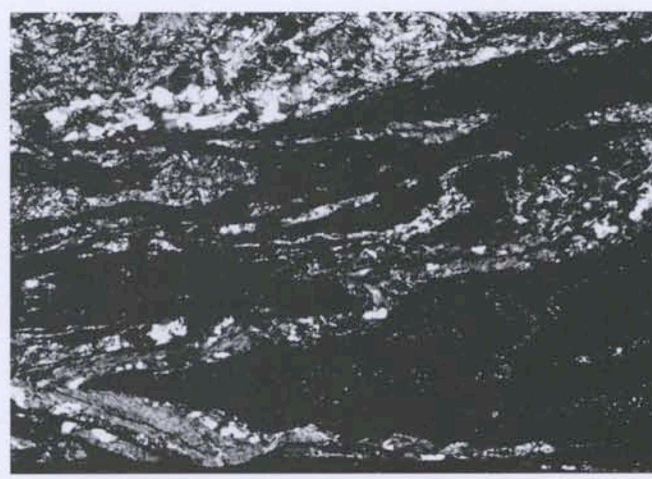

Figure 3. Elongation of quartz grains that defines the foliation; alignment of muscovite.

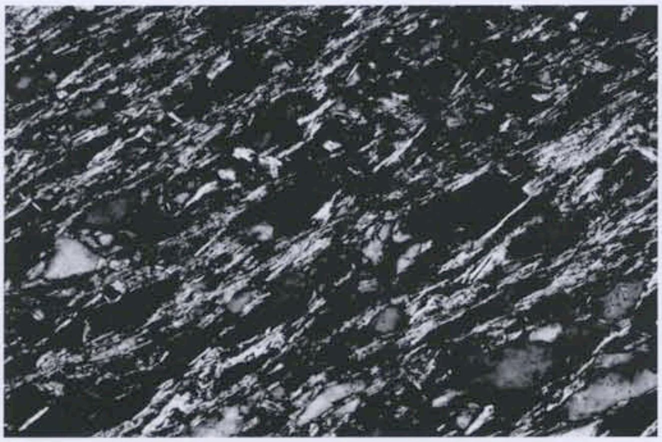

Figure 4. Visible deformation of quartz and chlorite rich layer. Black matter is organic.

Figure 6. Large interstitial calcite grains with quartz.

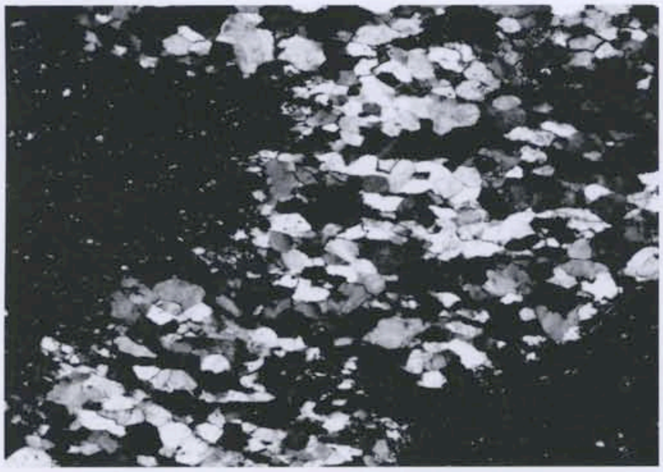

Figure 5. Folded quartz layer; note lack of significant crystal grain deformation indicative of temperatures < 350°C.

Figure 7. Tensional stress preserved in two generations of quartz veins (gypsum plate). Note the fibrous habit of quartz grains in veins.