Brittle Structures and the Grantham Fault Within the Southern Half of the Grantham Quadrangle, New Hampshire

Paper No. 65-11

Ryan Sutliffe, Aaron Rice, and Rory R. McFadden
Department of Geological Sciences, Salem State University, Salem, MA

Abstract

The 7.5-minute Grantham quadrangle located in the southwestern New Hampshire contains rocks of the Bronson Hill Anticlinorium (BHA), the Croydon Dome, and the New Hampshire Plutonic Suite. These rocks were metamorphosed and deformed during multiple Paleozoic orogenies. The bedrock geology has been covered in areas of lower elevations by surficial deposits. The Grantham Fault, a Mesozoic normal fault separates the Bronson Hill Anticlinorium and the Croydon Dome from the Bethlehem Gneiss, part of the New Hampshire Plutonic Suite. The brittle geologic history of this area is recorded in parting fractures, fractures that are perpendicular to foliation, and symmetric fractures. The fracture analysis has provided evidence for the fracture system of the field area.

The Grantham Fault is characterized by kink folding and silicified zones of almost pure quartz that are chaotic in orientation. There are small areas of the silicified zones that are brecciated. The portion of the quadrangle east of the Grantham Fault is Devonian Bethlehem Gneiss, which has a generally subhorizontal foliation with 48% of these foliations displaying parting displacement. Parting fractures are observed at almost every outcrop, but there are also fractures that are perpendicular to foliation commonly influencing the topography. The outcrops closer to the fault are more variable in fracture orientation. Many of these fractures are perpendicular to foliation. Steeply dipping fractures that strike approximately 185 degrees are prevalent near the Grantham Fault. West of the Grantham Fault there is a diversity rock types, represented by the Ordovician Ammonoosuc Formation, Silurian Clough and Fitch Formations, Devonian Littleton Formation, and the Croydon Dome rocks. These formations have a greater number of fractures that are perpendicular to foliation, as well as symmetric fractures that have spacing of approximately 1 m. A much lower percentage, approximately 20 percent, of these foliations have parting fractures.

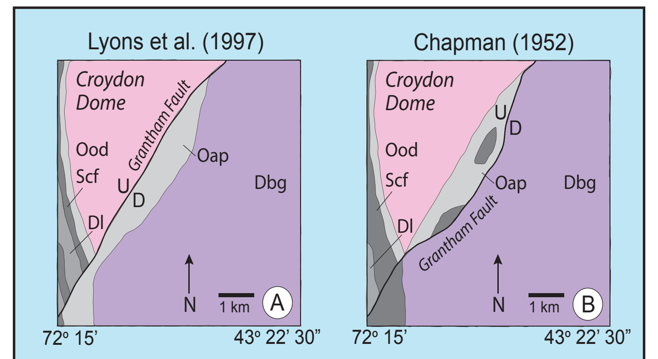


Figure 1. the two possible locations of the Grantham Fault. A) Schematic geologic map based on New Hampshire bedrock geologic map (Lyons et al., 1997). B) Schematic geologic map based on Sunapee 15′ quadrangle geologic map (Chapman, 1952).

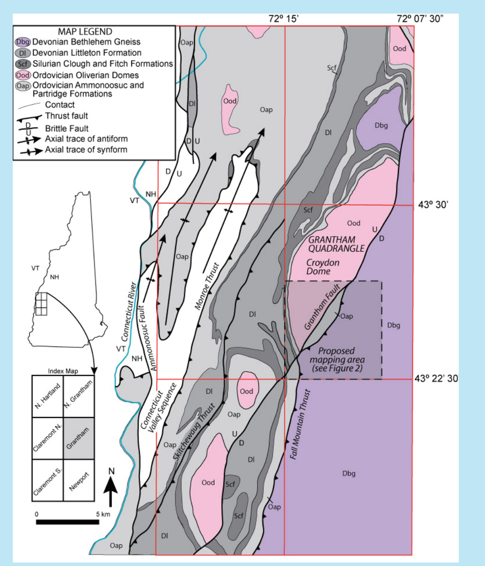
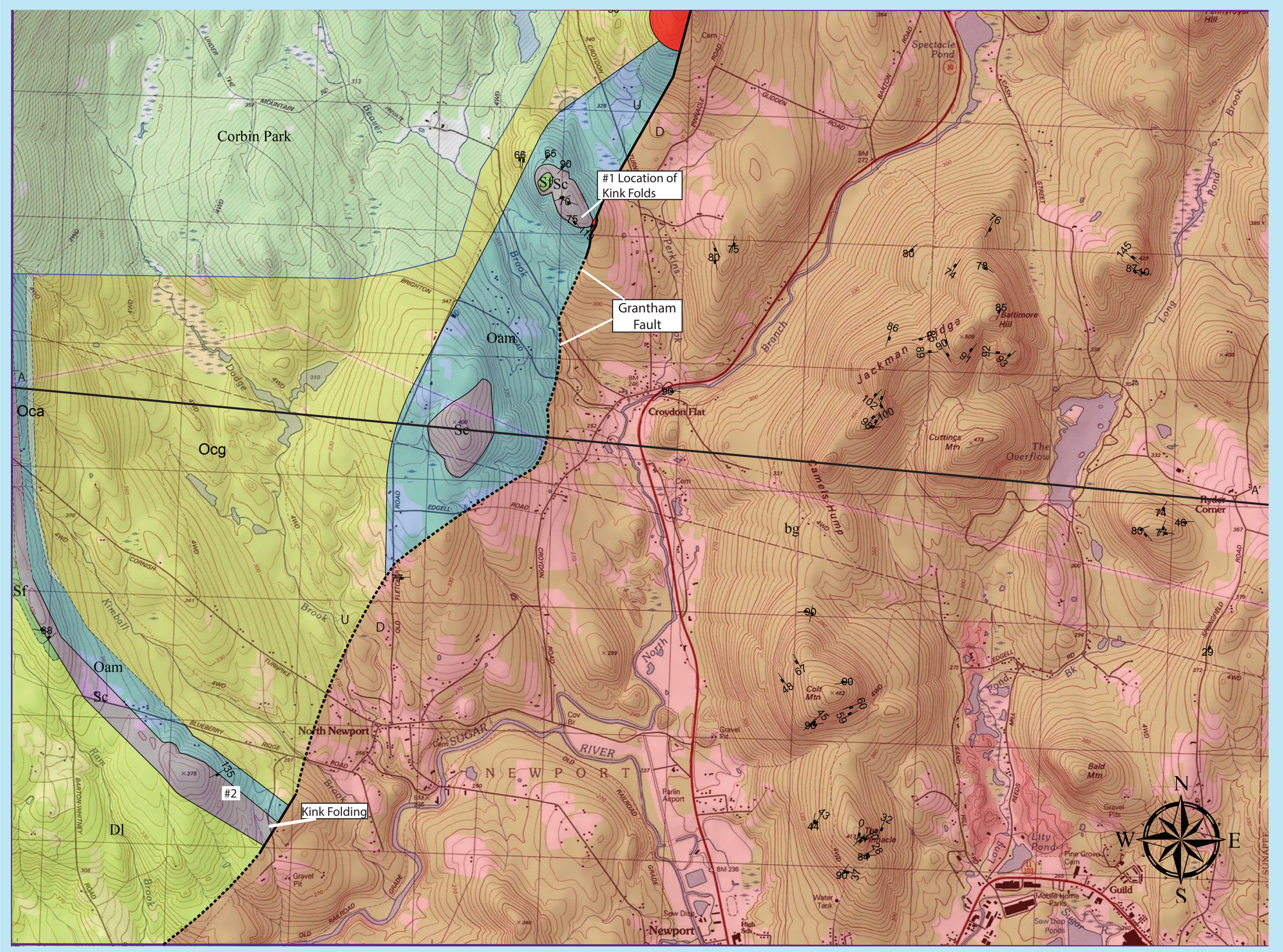
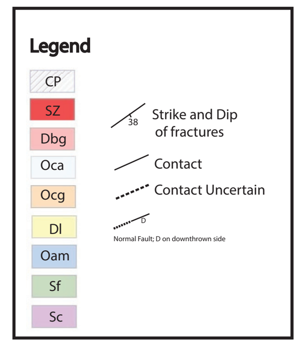
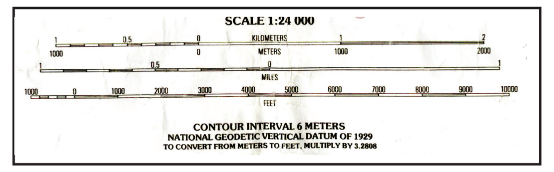


Figure 2. Generalized tectonic map of the Bronson Hill Terrane in western New Hampshire. Gray shades represent the Bronson Hill metasedimentary units. Red lines represent 7.5′ quadrangles. Map modified from Walsh et al. (2012) and Lyons et al. (1997).

Geologic Map of Southern Portion of Grantham Quadrangle







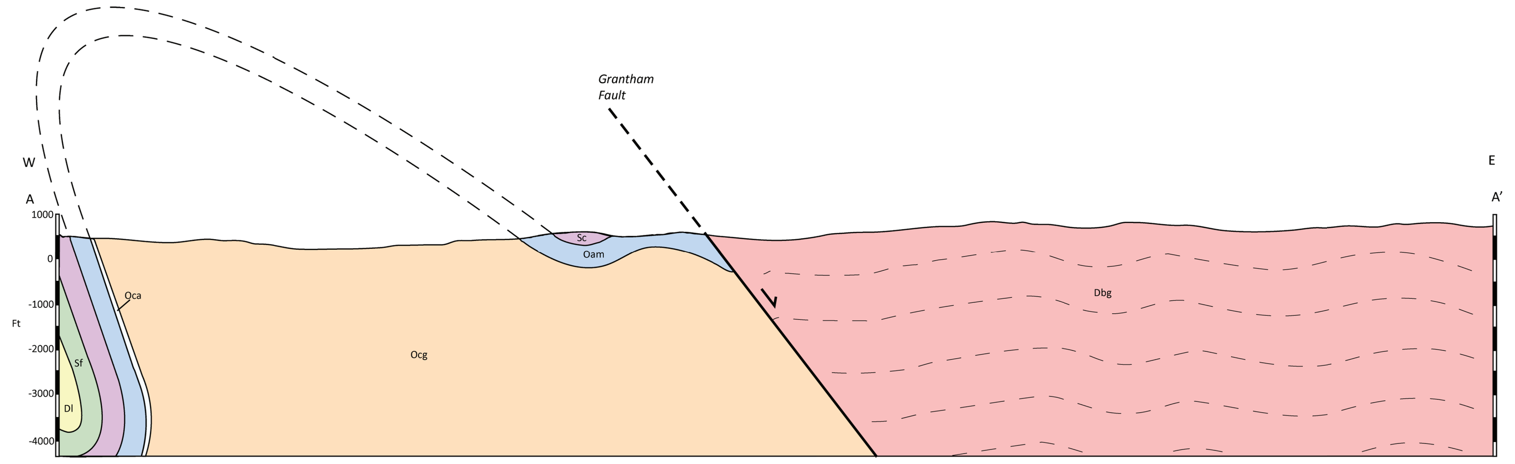


Figure 10. Cross-section from A-A'

Geologic History

The lithologies associated with this map were deposited during Paleozoic orogenic events. The Mesozoic low angle Grantham Fault and brittle structures are younger in age. New England was reactivated by extension and/or minor shearing during the early Jurassic and early Cretaceous rifting of the central and northern North Atlantic basin (McHone, 1992). By comparison major folds and thrust faults of New England were produced by Paleozoic orogenic compression. For example, the Grantham Fault is localized by the margin of the Bronson Hill anticlinorium. This fault was activated by the rifting that happened during the Mesozoic. Evidence of the rifting has also been seen to the south of the field area with the opening of the Connecticut River Basin. The faulting associated with the Bronson Hill Anticlinorium is generally trending in a north-south direction and bounds the Connecticut River Basin. This extensional even has been characterized by the up side of the Grantham Fault (Ordovician metasediments) and the down side of the Grantham Fault (Bethlehem gneiss). The extension has created this normal fault. The fractures associated with the Bethlehem gneiss are very young in age and are related to the unloading as shown by parting surfaces.

Grantham Fault

The location of the Grantham Fault was one of the major concerns of this research. Two possible locations for the Grantham Fault are shown in fig 1. The current New Hampshire bedrock geologic map (fig. 1A) shows the fault to the northwest of the metasediments, which provides correlation for these formations to the south of the field area. By showing the fault in this location, these rock units would be identified as Ordovician Rangeley and Partridge. The second location for the fault is in reference to previous mapping done in this field area (Chapman 1952). The fault is located to the southeast of the metasediments and is identified as the Ordovician Ammnoosac and Silurian Clough and Fitch. In order to properly map this area, the Grantham Fault needed to be clearly identified.

Evidence

Kink folds (fig. 3)- Hinge of 05, 035 found on #1 on geologic map. These kink folds provide us with evidence of deformation along a fault. The specific angle of the hinge shows that the fault block moving down is the Bethlehem gneiss formation.

Silicified Zones (fig. 4)- Fluid moved up the fault as movement was happening. This fluid crystallized at the surface forming large outcrops of almost pure quartz. This quartz is chaotic in orientation. There is also evidence of brecciation in portions of the quartz furthermore showing movement. This are mapped as dark red on geologic map.

Figure 3. Kink folding associated with Grantham Fault and movement.

Figure 4. Silicified Zone associated with Grantham Fault.

Lithologies

Dbg	Devonian Bethlehem gneiss. Medium to fine grained granodiorite. Biotite, qtz, feldspars, muscovite. Foliation marked by biotite. Crenulation foliation. Lineation marked by qtz. Gneiss texture. Pegmatite inclusions. Forms high country. Drop wall of the Grantham Fault.
Ocg	Oliverian Croydon Group. Fine to medium grained. Qtz, biotite, amphibole (hornblende), K-feldspar. Weakly foliated with foliation marked by biotite. Western boundary of the Croydon Dome defined by Augen gneiss (Oag). K-feldspar+ granite inclusions, augen, felsic gneiss. Low-lying swamp-pond area.
Dl	Littleton Formation. Lack of outcrop evidence South of the Crydon Dome. Boulders scattered with starolite schist, small amounts of silliminite.
Sf	Silurian Fitch. Fine to medium grained. Qtz, carbonate, calc silicate, magnetite, garnet, chlorite, actinolite, epidote. Marked by pot marks; "Ant-hole" weathering.
Sc	Silurian Clough. Fine to medium grained. Qtz, biotite, muscovite, silliminite. Quartz-mica schist and layers of felsic gneiss, quartz pebble conglomerate, and quartzite. Dominate ridge former in the area.
Oam	Ordovician Ammonoosuc Volcanics. Fine to medium grained. Amphibole,biotite,muscovite, qtz. Amphibole-biotite gneiss and layers of Quartz-mica schist.

Refrences

Chapman, C.A., 1952, Structure and petrology of the Sunapee quadrangle, New Hampshire: Bulletin of the Geological Society of America, 63, p. 381–426.

Lyons, J.B., Bothner, W.A., Moench, R.H., and Thompson, J.B. Jr., 1997, Bedrock geologic map of New Hampshire, U.S. Geological Survey, scale 1:250,000.

Mchone, J.G.,1992, Mafic dike suites within Mesozoic igneous provinces of New England and Atlantic Canada: Geological Society of America, Special Paper 268, p. 1-11.

Walsh, G.J., Aleinikoff, J.N., and Dorais, M.J., 2011, Bedrock geologic map of the Grafton quadrangle, Worcester County, Massachusetts: U.S. Geological Survey Scientific Investigations Map 3171, 1 sheet, scale 1:24,000, 39-p text.

U.S. Geological Survey 2013, Fact Sheet112-02 -Fractured-Rock Aquifers:Understanding an Increasingly Important Source of Water, <http://toxics.usgs.gov/pubs/FS-112-02/>

Fractures

Parting fractures, fractures perpendicular to foliation, symmetrical fractures, and fractures have been recorded and two specific groups could be characterized. Figure 5 shows a breakdown of fractures mapped and they type of fractures associated with each lithology.

Rock Units West of the Grantham Fault (fig. 6)

Oam, Ocg, Sc, and Sf all have fractures that dip more steeply the closer you get to the Grantham Fault. The strikes of the fractures closer to the fault are striking about 185 degrees which is equivalent to the faulting pattern associated with the Bronson Hill Anticlinorium (McHone, 1992). There is also a smaller amount of parting associated with these lithologies. Additionally there are a much greater number of fractures that are perpendicular to foliation. Figure 8 shows the poles to planes of the specific fractures mapped.

Rock Units East of the Grantham Fault (fig. 7)

Dbg has a much higher number of parting surfaces associated with unloading. Parting is observed at almost every outcrop. The dip angle of these fractures is shallow ranging anywhere from 5 degrees to 40 degrees in places. As you move towards higher elevations, slabs of rock break off along parting surfaces. There is some variation as you get closer to the fault with dip angles of 77 degrees in places. Figure 9 shows the poles to planes of the specific fractures mapped.

There could possibly be two different controls on the fracture pattern of these rocks or a combination of both. 1) These rocks vary in different lithologies and that way that they were deposited. This could mean that the difference in fracture data is simply based on unit difference. 2) The rocks that are closer to the Grantham Fault are undergoing brittle deformed by the fault. The dip angles of these fractures are much steeper closer to the fault and the strikes of these fractures are more systematically north-south.

Formation	Number of measurements that exhibit parting along the foliation planes	Total number of foliation measurements	Percentage of parting fractures	Percentage of fractures not associated with parting
Devonian Bethlehem gneiss (Dlbg)	101	141	71%	29%
Ordivician Ammonoosuc (Oam)	11	1	9%	91%
Silurian Clough (Sc)	14	7	50%	50%
Ordivician Crydon Dome (Ocg)	0	0	0%	100%
Silurian Fitch (Sf	0	0	0%	100%

Figure 5. Breakdown of fractures mapped and percentage of parting surfaces

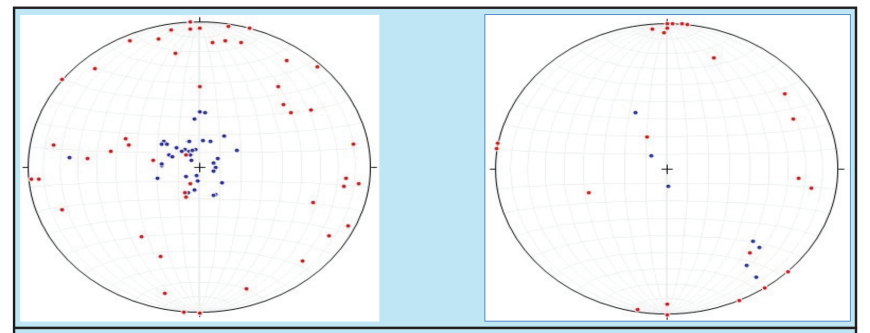


Figure 9. Rock Units East of the Grantham Fault (Dbg).

Figure 8. Rock Units West of the Grantham Fault (Oam,Ocg,Sc, and Sf)

Poles to planes are seperated by paring fractures (Blue) and fractures not associated with parting in (Red). There is a big diffrence depending on the lithology and location.

Figure 6. This is a typical outcrop associated with rock units west of the grantham fault. There is much more variation with fracture data. This outcrop is shown

Figure 7. This a typical outcrop associated with the rock units east of the Grantham Fault. It is clear that there is paring associated with the Behtlehem gneiss. This is observed at almost every outcrop.

The Role of Fracture Analysis Data and Ground Water

In addition to the investigation of the Grantham Fault the brittle history and fracture pattern of the quadrangle was recorded. Ground water is one of the Nation's most important natural resources. Historically, sand and gravel aquifers were the first to be discovered and used, but as the demand for water has gone up the investigation of fractured-rock aquifers has become much more important. According to the USGS, "The increased population growth in New England will put more of a demand on the use of fractured-rock aquifers, where water moves through the rock." Fractures form complex paths for fluid to move through rock. Mapping rock types and fractures enables a link to be established between fracture orientation, the interconnectivity of fractures, and fracture length with the availability of water (USGS Fractured). This groundwater is used to provide water for communities as well as for land use. The data focused on the lithological differences that influenced the fractures as well as the location of the fractures in comparison to the faulting associated with the area. The parting associated with specific lithologies shows rocks breaking along the weakest points of the rock.

Conclusions

The current New Hampshire bedrock geologic map has been mapped wrong. Chapman (1952) mapped the units correctly as the Ordivican Amnoosac, Silurian Clough and Fitch.

The Grantham Fault is located between the metasediments and the Bethlehem gneiss. Evidence has been documented as kink folds, silicified zones, and brittle fractures. The location of the fault is different to that of the New Hampshire bedrock geologic map.

There is a combination of influences with the fracture data. There is much more variation with fractures West of the Grantham Fault and this is because of not only the fault, but differences and lithologies as well.

The correct identification of the metasediments also means that the Ordivican Partridge formation is not in this field area. This is important to the possible contamination of the ground water table because of the rusty schist layering in the Partridge.