Mapping Cross-Cutting Joints in Cape Ann to Establish Past Stress Orientations

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Geological Sciences

Abstract

The Cape Ann Granite, part of the Cape Ann Plutonic Complex, ranges from 431 to 424 Ma. It is a massive, medium to coarse grained alkali granite. Previous studies indicate that the Cape Ann Granite intruded prior to the beginning of the Acadian Orogeny, when Avalonia accreted to Laurentia.

In Gloucester and Rockport, Massachusetts, the Cape Ann Granite is cross cut by multiple faults and joints. Our study focuses on mapping and recording joint orientations in the Cape Ann Granite. These are then subdivided into joint sets based on their orientation after plotting them on a rose diagram. Based on our understanding of the spatial relationship between newly developed joints and the principal stress axes σ1 (maximum principal stress), σ2 (intermediate principal stress) and σ3 (minimum principal stress), inferences can be made about the orientation of the paleo-stresses necessary to create the observed patterns of joints. Additionally, the relative timing of various joint sets can be investigated by looking at relative cross cutting relationships. In fact, joints do not cross-cut older joints but rather terminate along pre-existing joints.

Mapping the Joints

- A Digital Elevation Model (DEM) created from LiDAR data covering the Cape Ann study area is extracted from Caltopo (www.caltopo.com).
- The DEM is then exported to Google Earth Pro (GE). Joints are mapped in GE and confirmed using the shade relief in the DEM. Inferred joint sets are marked by color.
- All linear data marking joint orientations is compiled from GE onto a Microsoft Excel spreadsheet.
- Confidence levels are assigned to each mapped joint from 1 to 3, where 1 represents joints that are identified with a high confidence level, while 3 is indicative for low confidence.

Purpose

By establishing joint sets in the Cape Ann Granite in Gloucester and Rockport, Massachusetts, inferences can be made regarding the relative timing of the intrusions and the paleo-stresses that might have formed them.

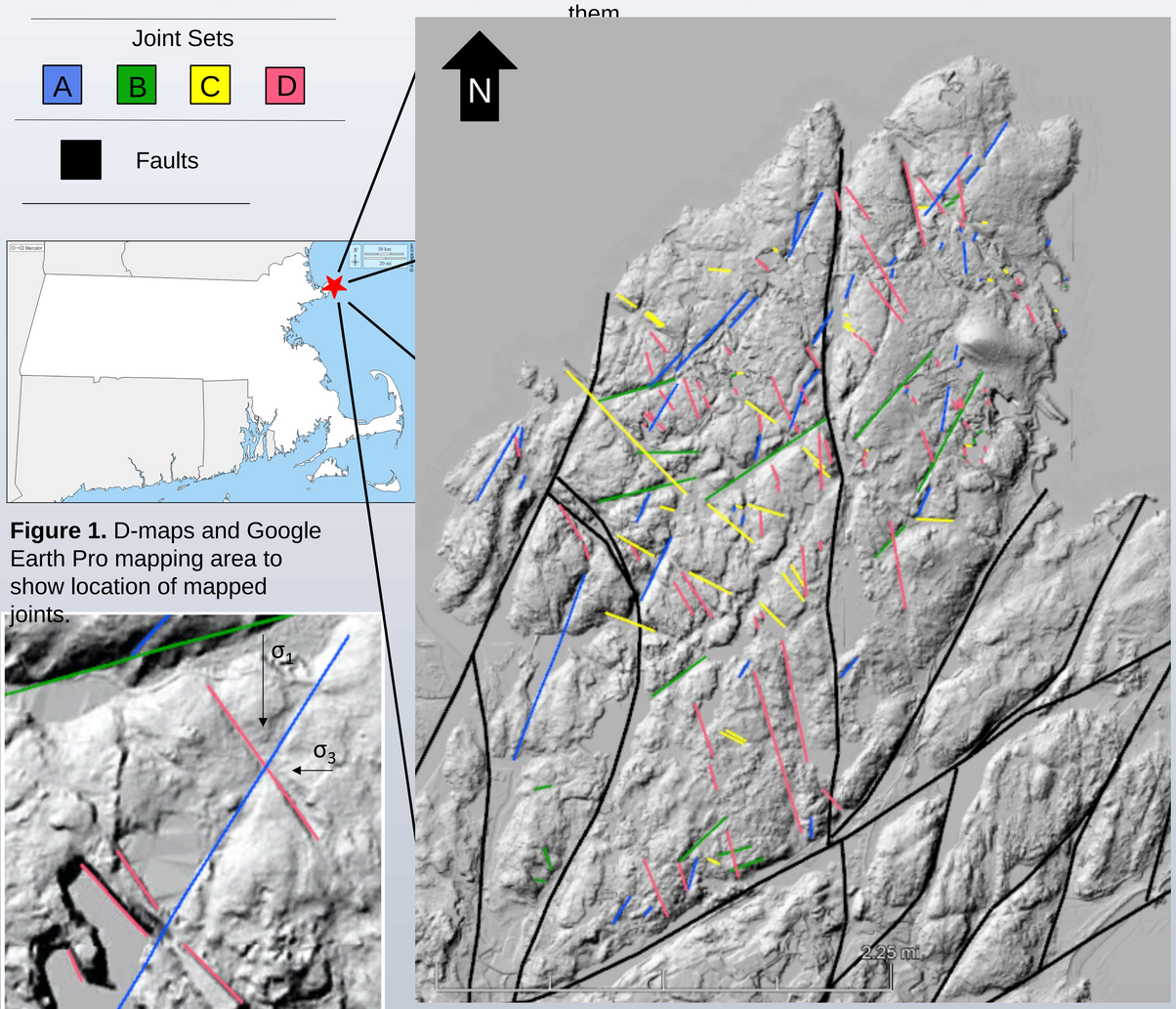


Figure 1. D-maps and Google Earth Pro mapping area to show location of mapped joints.

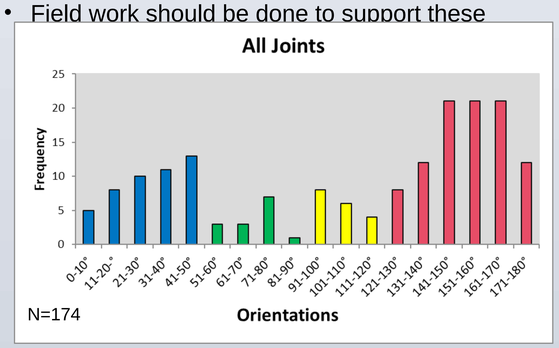
Figure 2. represents σ1 (maximum principal stress) and σ3 (minimum principal stress) .

Data Analysis

- All joints mapped in GE are saved into a KML file which is later uploaded to ArcGIS Pro as a layer and projected to WGS 1984 UTM Zone 19 N coordinate system. In ArcGIS Pro, the spatial statistical tool called "*Linear Directional Mean"* is used to extract joint lengths and trends. This data is assembled into the Excel file.
- Rose Diagrams are created from the joint orientations using *Stereonet* 10.0 for all joints. Rose diagrams are a tool to visualize the trends of the joints in two dimensions. Joint sets are identified within the Rose Diagram and compared to the user identified joint sets created during the mapping process.

Discussion and Conclusion

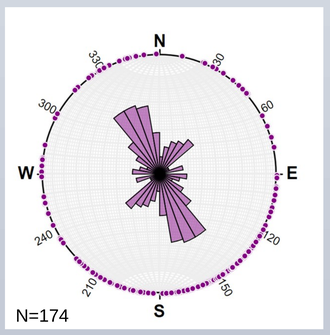
- 4 sets of joints are defined in the mapping area of the Cape Ann Granite based on their orientations.
- Based on their cross-cutting relationships it seems that joint set B is the oldest, and the timing of sets A and D were simultaneous.
- The upper bounds of sets A and D both need more analyzing through more extensive mapping and groundtruthing to further understand this relationship.
- Based on the spatial relationships and distribution of these 4 sets within the map it is evident that there is at least one more set to be defined within set D.
- Field work should be done to support these



Figures 3a and 3b

3a. Histogram constructed in Excel, color coded to see separation of joint sets.

3b. Rose Diagram plotting all mapped joints showing separate sets.



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