

Impact of Red River Gorge's structural geology on cave passage orientation

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Abstract

Cave Hollow is located in Lee County, Kentucky, within the Red River Gorge Geological Area. This research was conducted in order to determine if the structural geology of Red River Gorge (RRG) has an impact on the formation of caves in Cave Hollow. ArcGIS Pro was used to identify linear features in LIDAR data that could be representative of structural features such as faults and fractures. The orientation of these observed lineaments was compared to previously collected azimuth data for caves, faults, and joints within the study area. An analysis of variance (ANOVA) was used to test for differences in azimuth data for cave passages, faults, joints, and observed lineaments. Azimuth data was not significantly different across the four categories ($P > 0.05$). The dominant orientations of the cave passages in the study area are NE or NW, which is consistent with the dominant orientations of the lineaments found using LIDAR data. This information can be used to conclude that structural features such as faults, joints, and fractures ultimately have an impact on cave passage orientation within Cave Hollow.

Methods

Cave passage data including azimuth, inclination, and passage size was collected from Cave Hollow Cave (CHC) during an initial cave survey. The survey data from CHC was entered into Compass Cave Survey and Mapping software to generate a georeferenced 3D model of CHC. This process was repeated with data from several other previously surveyed caves (Boat, Creekview, Escher, Lost Sole, Old Landing Pit, Petshop, Sinking Fork, and Stillhouse).

A 5 foot resolution DEM from KyFromAbove was used to create a slope analysis layer. This was used to manually identify lineaments (unknown linear features on imagery) that could potentially represent structural geology features such as faults or fractures within a ~10 kilometer radius of CHC. Any found lineaments were compared to a hillshade layer and a world imagery layer to prevent incorrectly marking things such as roads or trails. Each lineament was ranked with a confidence value between 1-5.

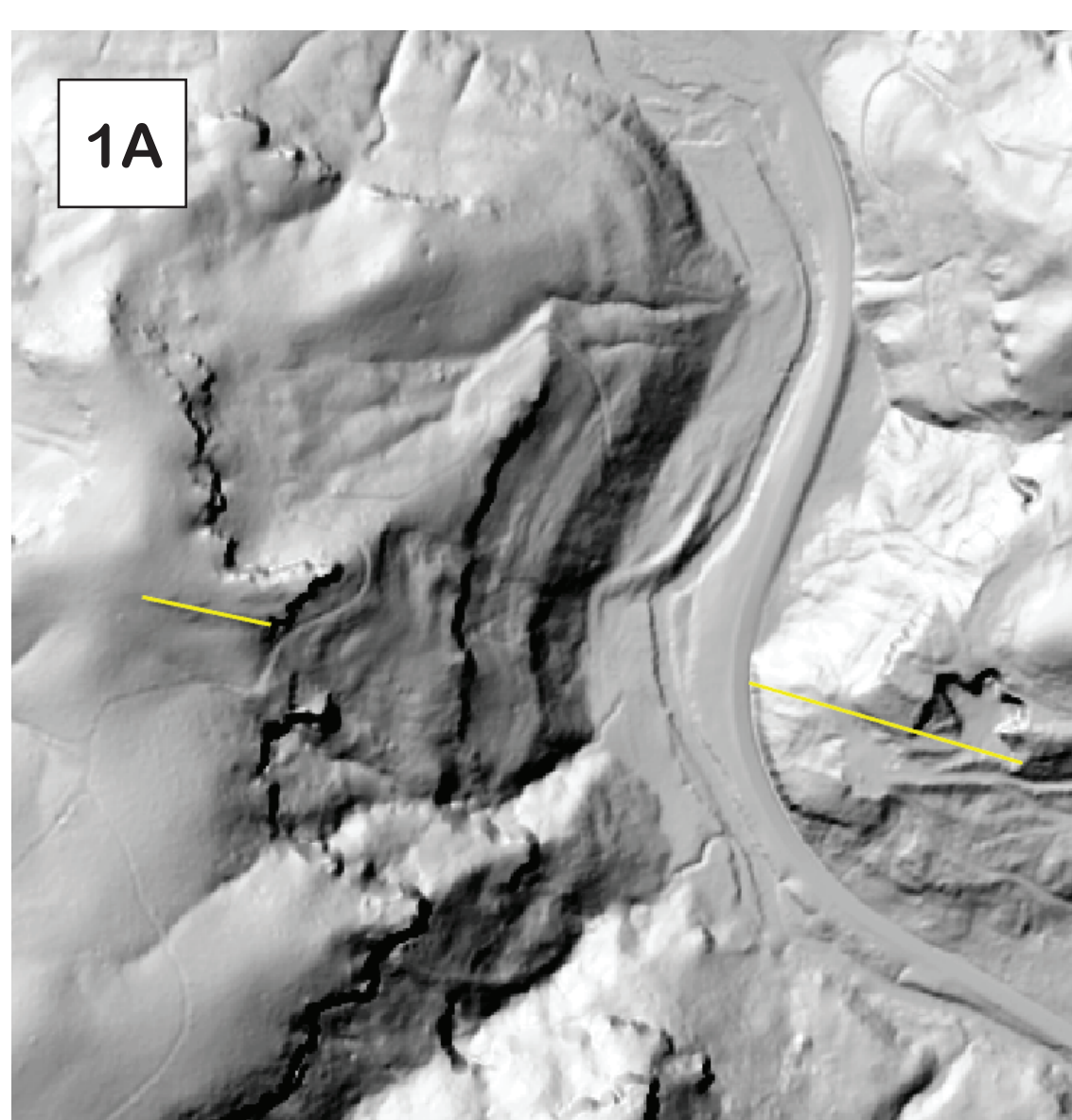


Figure 1A depicts lineaments with high confidence ratings. The yellow line drawn on the right side of the image is a lineament with a confidence ranking of 5. Lineaments with a confidence ranking of 5 represented known faults. This lineament is an outcrop where the Glencairn Fault is visible. The yellow line on the left side of the image is a lineament with a confidence ranking of 4. Lineaments with a ranking of 4 were obvious on the imagery and usually clustered with other highly ranked lineaments.

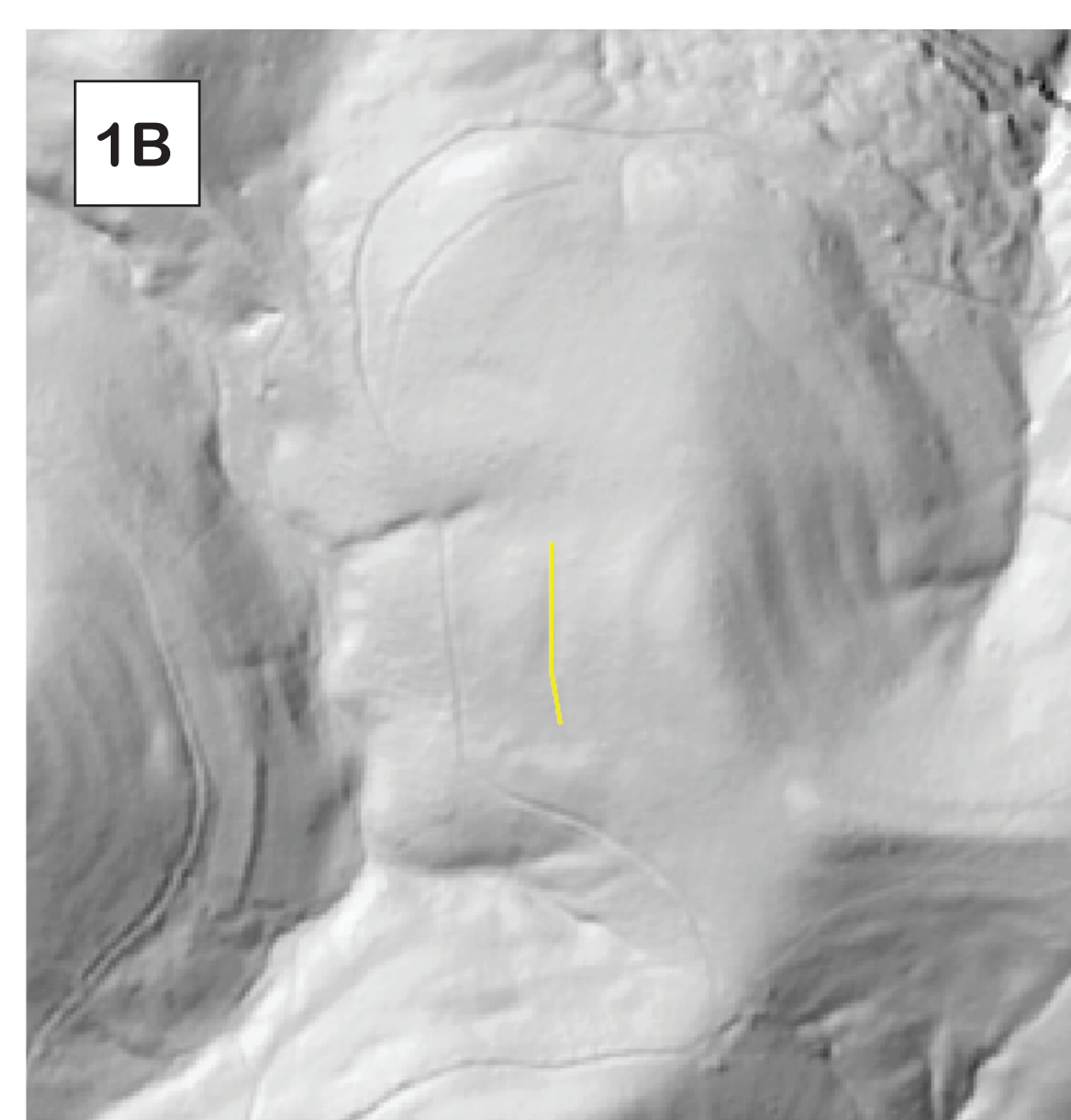


Figure 1B depicts a lineament with a confidence ranking of 1. Lineaments with a ranking of 1 were typically representative of linear features that were small, isolated, and difficult to see on imagery. Other nearby features, such as roads, trails, or outcrops, are also taken into account.

Previously collected data from Kentucky Geological Survey for both joint orientation in RRG and major faults in Kentucky was clipped to the extent of the study area. The azimuth data for joints, faults, found lineaments, and caves was used in RStudio to run an ANOVA and a Tukey HSD test.

Study Area

Red River Gorge Geological Area is situated on the Cumberland Plateau region of the Appalachian Mountains. RRG is widely known for its sandstone arches; however, RRG also has a high amount of karst features including caves, which could be attributed to RRG's proximity to the Pottsville Escarpment (George 1985).

This research was conducted in the Cave Hollow area of RRG due to the high density of previously surveyed caves. Cave Hollow is located in Lee County, Kentucky, roughly 5 minutes away from the Estill County border. The caves in the study area are formed in the St. Louis Limestone and are overlain by the Corbin Sandstone.

The Irvine-Paint Creek Fault System passes through the study area approximately 15 kilometers N of Cave Hollow. The Glencairn Fault is located approximately 15 kilometers NE of Cave Hollow.

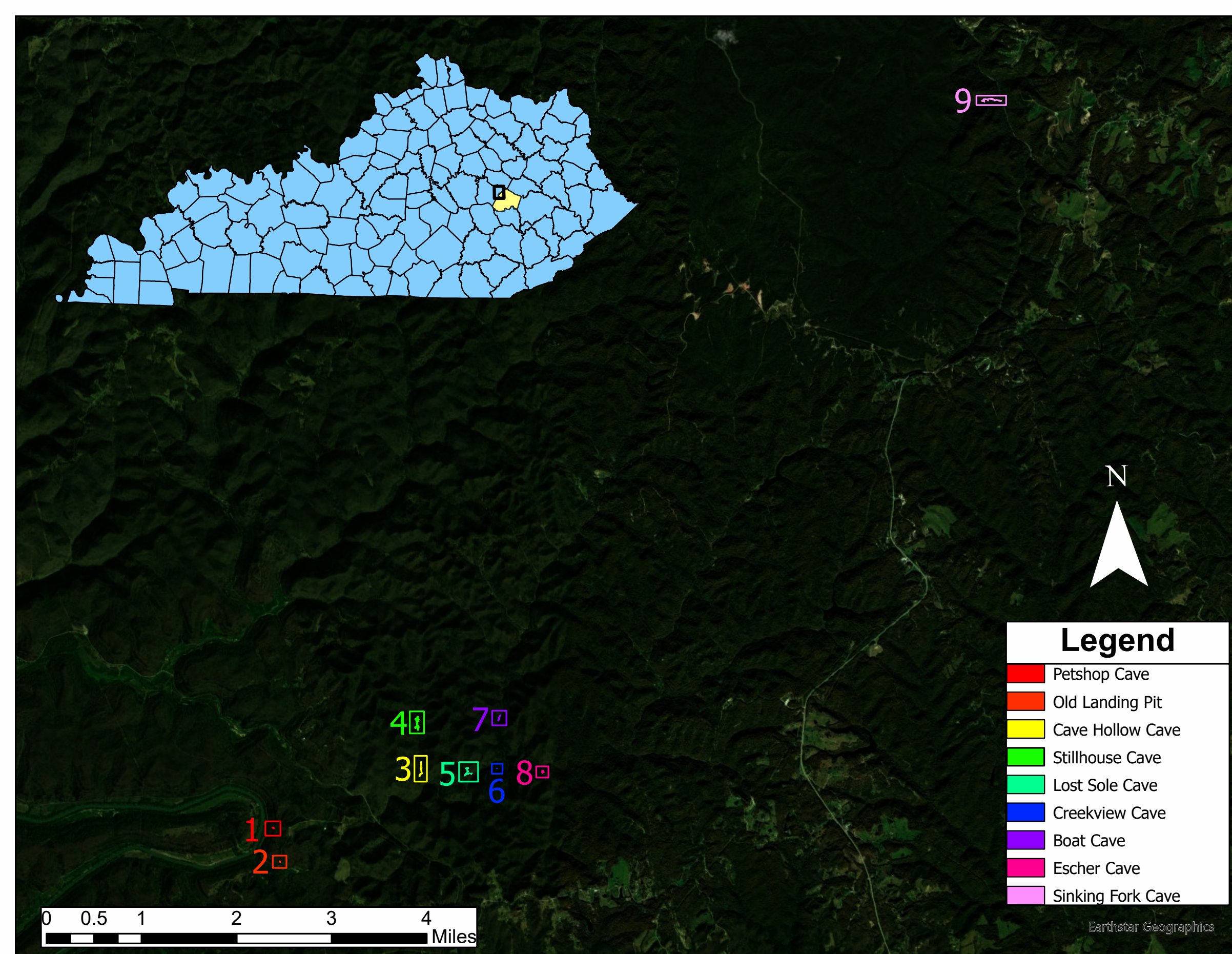


Figure 2. Map of the caves used for passage azimuth data within Cave Hollow.

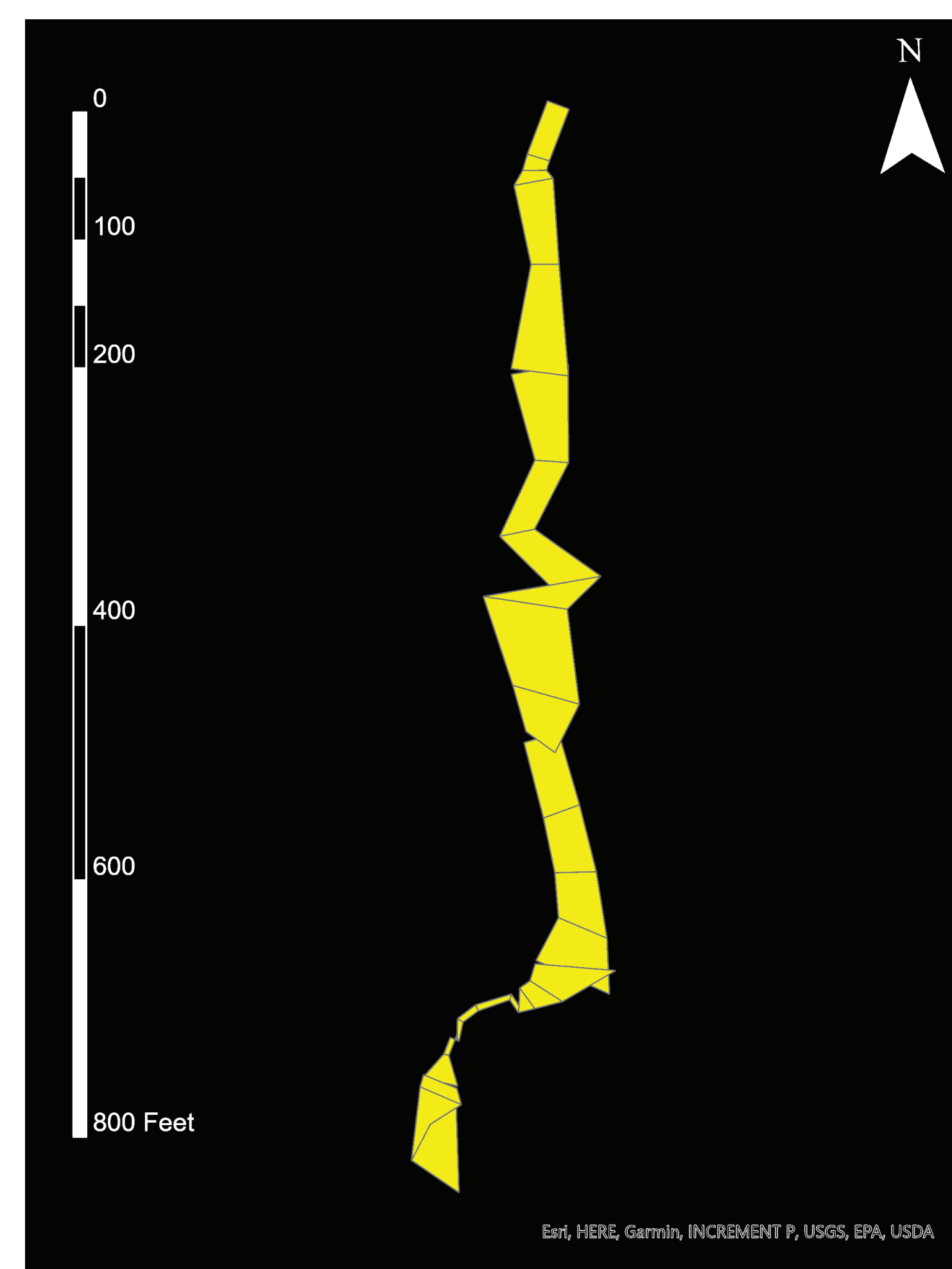


Figure 3. Polygon of Cave Hollow Cave (number 3 on Figure 2) generated using Compass Cave Surveying and Mapping Software. Cave survey data is put into the software and the provided measurements are used to generate polygons representative of cave passage.

Results

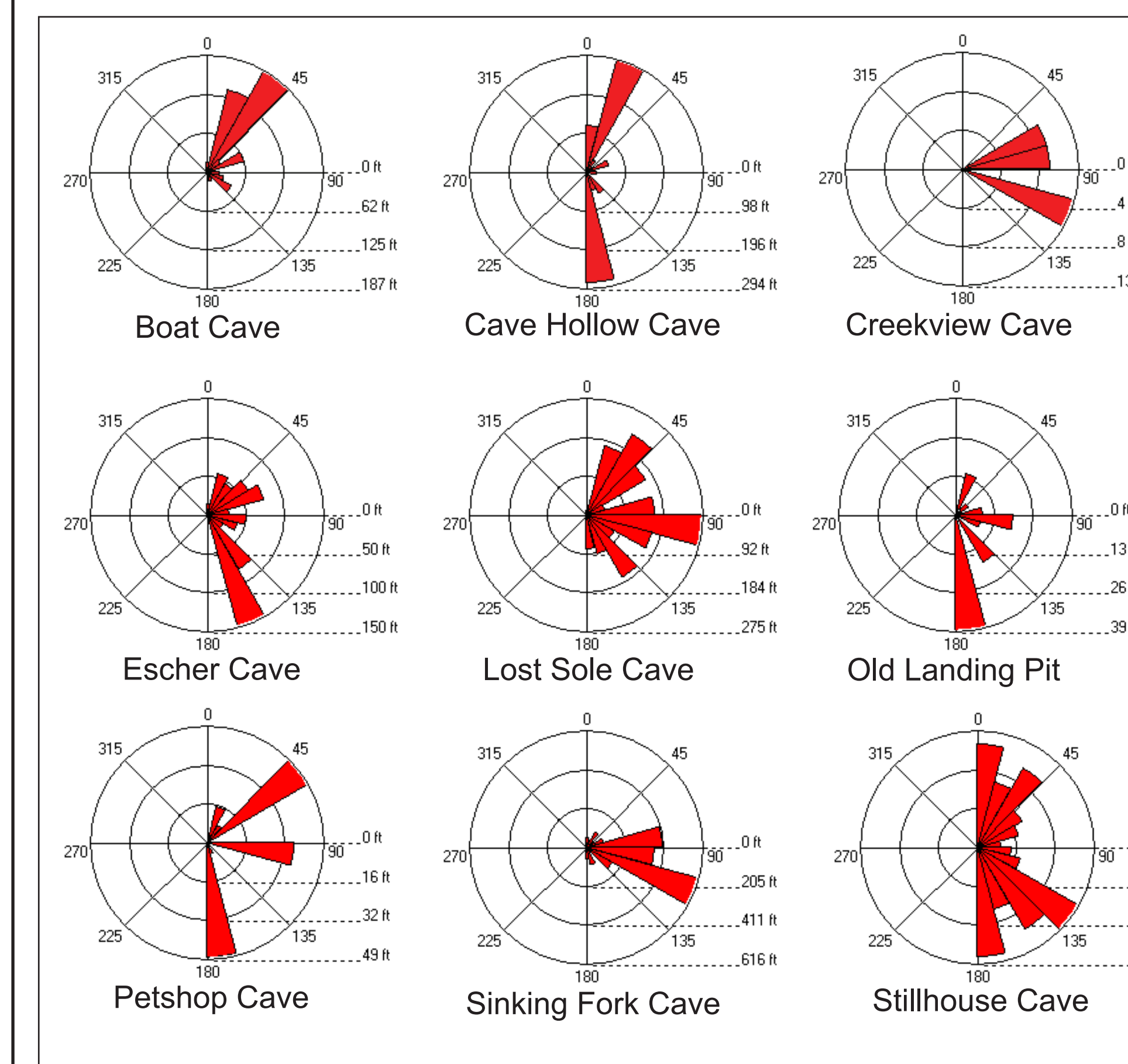


Figure 4 (above). Rose diagrams showing distribution of cave passage orientation.

Figure 5 (below). Table showing statistical analysis results.

	difference	lower bound	upper bound	p-value
Faults-Caves	3.944286	-3.21951	11.1080823	0.4895266
Joints-Caves	-5.816305	-14.48994	2.8573263	0.3112138
Trends-Caves	-9.870694	-20.31111	0.5697238	0.0716878
Joints-Faults	-9.760592	-17.11959	-2.4015976	0.0037001
Trends-Faults	-13.814980	-23.19183	-4.4381348	-0.0009006
Trends-Joints	-4.054388	-14.62970	6.5209200	0.7575326

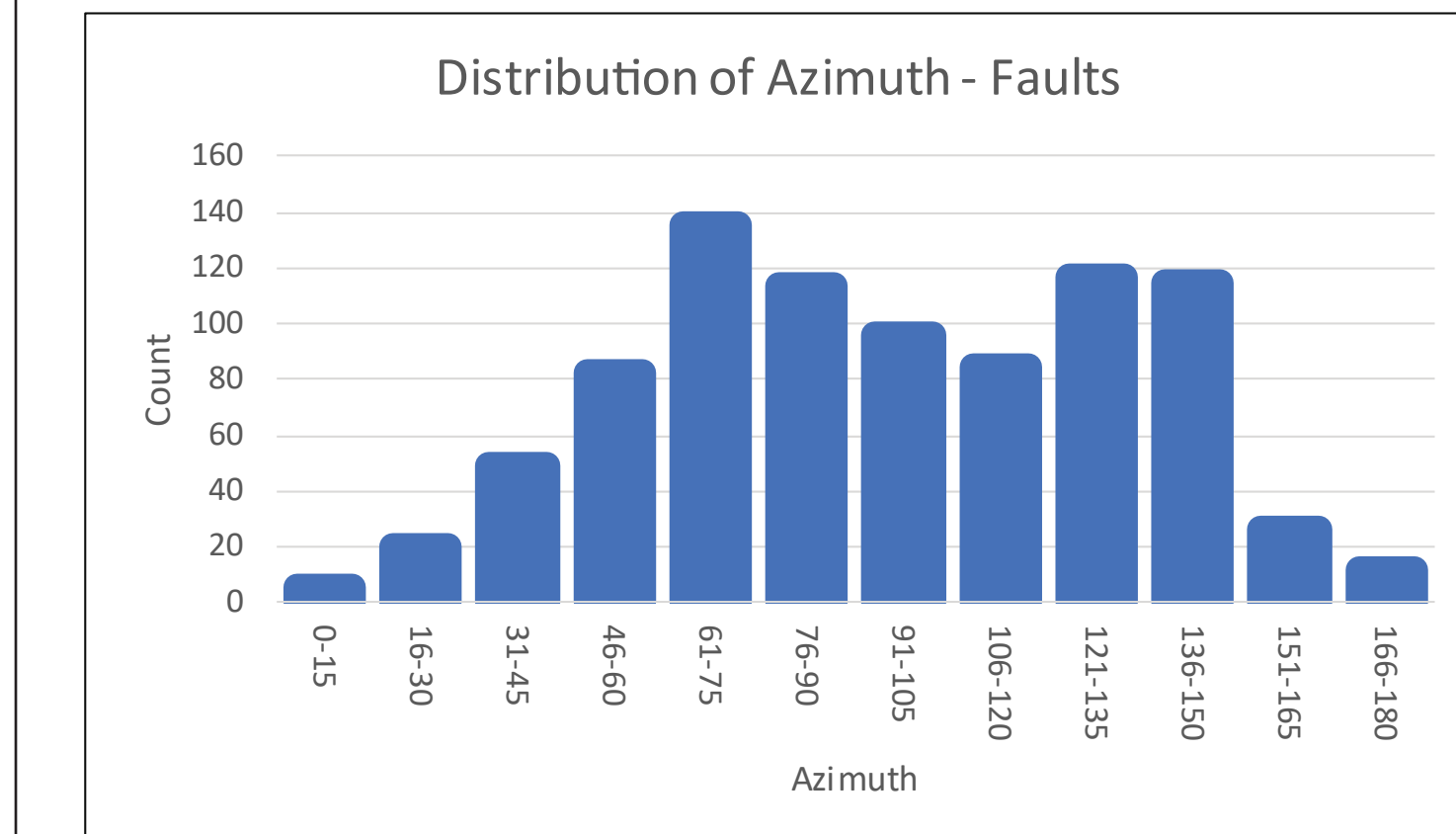
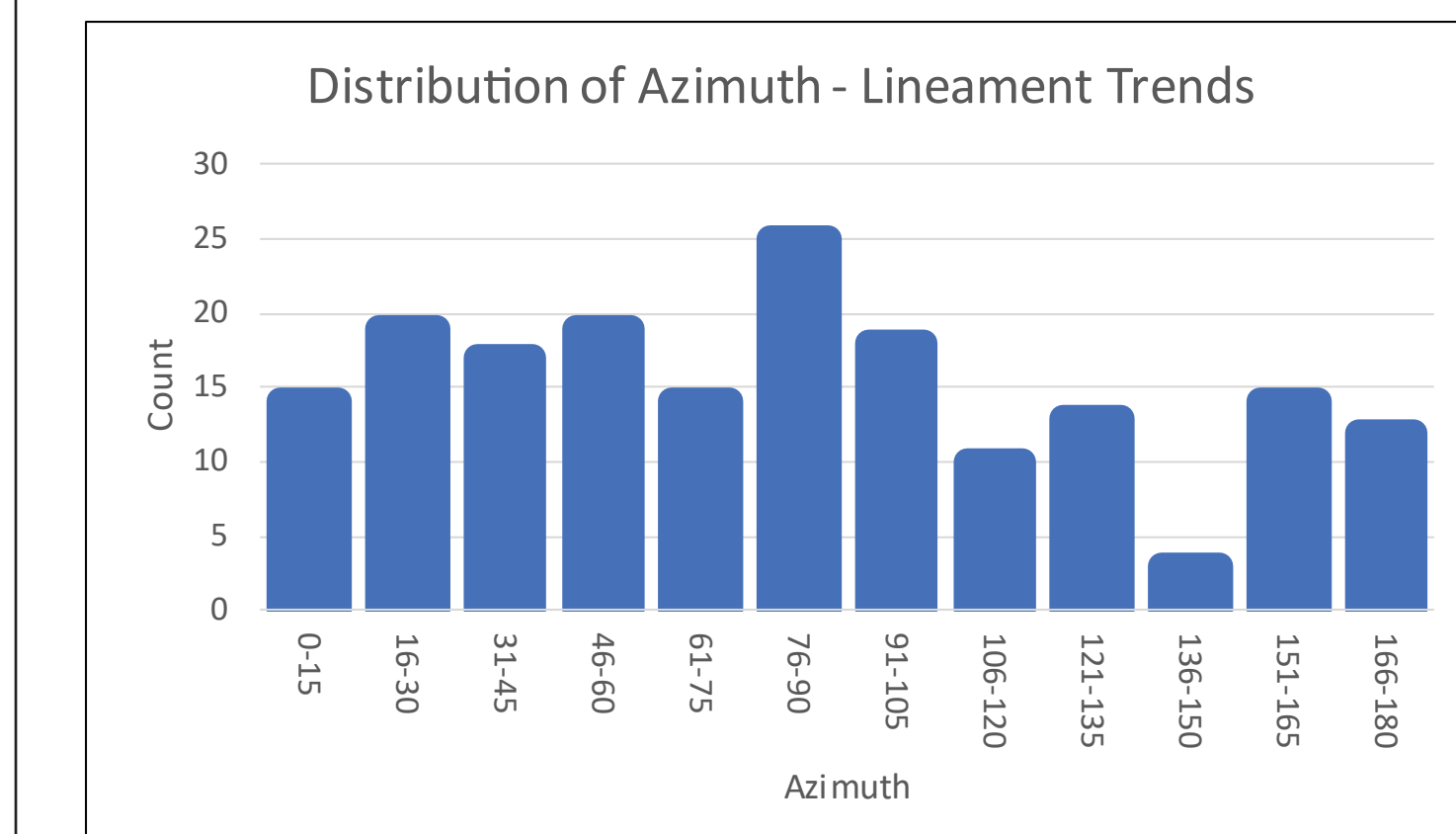
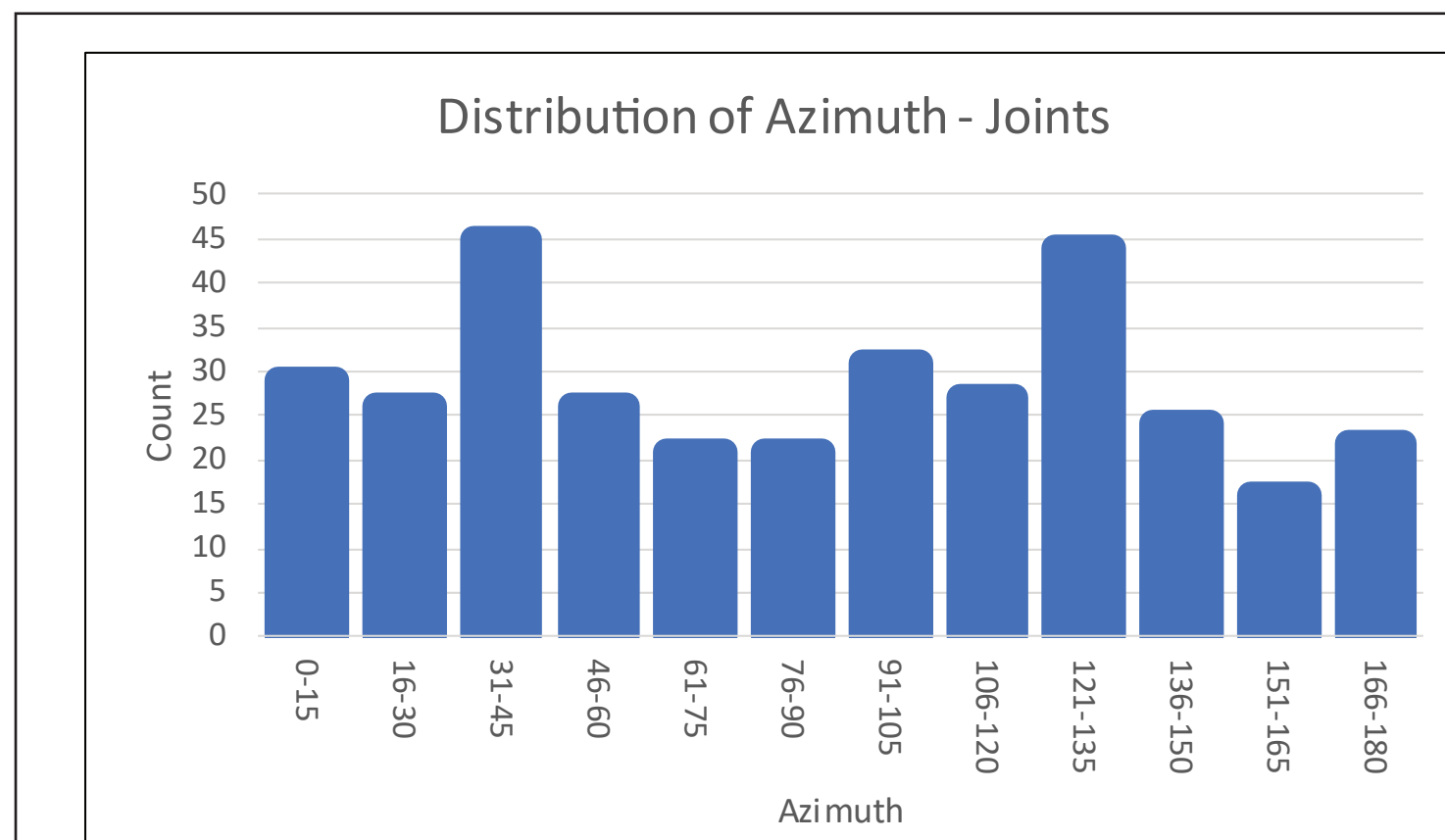


Figure 6. Histograms showing azimuth distribution for joints, lineament trends, and faults.

Discussion

Based on the results of the statistical analysis, it is reasonable to conclude that there is a correlation between structural features in RRG and the orientation of cave passages in Cave Hollow. Most of the caves studied have a significant amount of passageways oriented either NE, NW, or both. These findings are consistent with results presented by George, 1985. This publication also shows that the orientation trends in Cave Hollow are parallel to the NE-SW strike of the Pottsville Escarpment, due to fracturing from the upwarping of the Cincinnati Arch and the formation of the Appalachian Mountains.

Future research with this study could include further statistical analysis based on confidence ranking of the imagery-derived lineaments to see if higher confidence rankings are more likely to follow the trend. Future research could also include returning to the study area to confirm if the mapped lineaments are truly surficial structural geology features.

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