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Joint Patterns Along the Eastern Escarpment
of the Paunsaugunt Plateau in
Bryce Canyon National Park

by

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Introduction

The origin of the rock pinnacle landforms called "Hoodoos" for which Bryce Canyon National Park is famous, remains controversial, as do reasons for their apparent alignment and great abundance along the eastern escarpment of the Paunsaugunt Plateau in southern Utah. Current opinions about the control of hoodoo development in the area are based primarily on the

- 1) observation of apparent linearities in the areal distribution of hoodoos,
- 2) the assumption of positive angular relationships between hoodoo alignment and local or regional bedrock jointing patterns,
- 3) interpretation of hoodoo position along the Paunsaugunt Escarpment relative to bedrock structural and stratigraphic variation (Bezy 1980; Lindquist 1980, 1977; Evitt et al 1979; Brox 1961; Hager 1957).

The present study is restricted to an examination of the jointing exhibited in the sedimentary rocks cropping out along the escarpment of the Paunsaugunt Plateau in the northern portion of Bryce Canyon National Park. The objectives of this study are 1) to record the strike orientation of sufficient numbers of vertical joints to form a statistically sound data set, 2) to use this data set to define any discernable regional or local jointing patterns, and 3) to examine the relationships between jointing patterns and the larger structures (faults folds) reported in the region. The ultimate objective of this study is the projected use of the data in a comprehensive analysis of the morphogenetic relationships among jointing patterns, other gross structural features, lithological differences, hydrological variables and various surface characteristics on the erosional development of the Paunsaugunt escarpment within Park boundaries.

An intensive study of the joint pattern in the Bryce Canyon area was selected for three important reasons 1) previous investigations of the joint system are inadequate in extent and method to clearly establish either a positive or negative correlation between joints and hoodoo development, 2) analysis of joint patterns could clarify the existence and extent of structural features proposed as contributing to the unique patterns of scarp retreat and hoodoo development (Hager 1957), and 3) limitation of field observations to one class of data enabled extensive study of jointing along the escarpment within the time and personnel limitations imposed by the Field Camp schedule.

The report is the second of a series of investigations into the physical geography of Bryce Canyon National Park by members of the Summer Field Camp of the University of Arizona's Department of Geography and Regional Development. The previous report (Evitt et al. 1979) dealt with relationships between joint patterns and linear erosion features situated along the hoodoos in the Silent City segment of the escarpment. Field work for the present study was performed during May 1980 by the authors and six other members¹ of the field camp group under the direction of Dr. R. W. Reeves. We are indebted to Mr. John Bezy of the National Park Service for his introduction to Bryce Canyon, assistance in arranging accommodations and facilitating field work.

¹The authors would like to thank members of the 1980 Field Camp, Javier Armenta, Bill Cox, Andrea Hitzeman, Steve Vierck, Herb Weiss and Jill Wyatt for their aid in completing this project.

General Features

The general study area lies along the eastern "Pink Cliffs" escarpment of the Paunsaugunt Plateau within the boundaries of Bryce Canyon National Park (map 1). Streams dissecting the escarpment flow to the east into the Paria River and are thus part of the Colorado River drainage system. Of specific interest is the section of escarpment between Bryce Point and Boat Mesa (map 2). There, the upper drainage basins of Bryce and Campbell creeks cut into the escarpment to form eastward facing rock amphitheaters where hoodoos are particularly numerous and well developed.

The standard reference for the physical geography and geology of the region remains Gregory (1951), but more detailed descriptions of the immediate study area are given by Brox (1961) and Lindquist (1980, 1977).

Geology

The strata exposed along the escarpment are classified into three formations (Gregory, 1951). The upper 800-1000 feet of sediments make up the bulk of the Pink Cliffs and are called the Wasatch formation in Gregory (1951, pp. 44-52) and in most Park literature. The Wasatch formation in the Park consists of soft, limey, Eocene lake sediments and it is within the Wasatch formation that the hoodoos are developed. Underlying the Wasatch formation are the upper Cretaceous shales and sandstones of the Kaiparowitz formation and Wahweap sandstones.

The classification and equivalency of the Pink Cliffs Wasatch with type Wasatch formations outside southern Utah is controversial, and regional equivalents are most probably the Claron and Cedar Breaks formations (Doelling, 1975, p. 52 for discussion; Lindquist, 1980 p.32; also

Anderson et al, 1975 p. 10; and Robison, 1966 p. 28). For the purposes of the paper, however, Park precedent will be followed and the term Wasatch applied to the upper rock formation of the Pink Cliffs along the Paunsaugunt escarpment. Detailed lithological descriptions and selected sections of the Wasatch within the Park are given by Gregory (1951), Brox (1961), and Lindquist (1980).

Procedures

Three areas along the escarpment were chosen for survey during the 1980 field season. Criteria involved in site selection included presence of well developed hoodoos and ease of access to canyon walls and hoodoo faces from Park trails. The joint azimuth data from the 1979 study area was included in this study as a forth sampling area (map 2).

Area No. 1 is located to the north and below Bryce Point. The site extends in a northeasterly direction from the amphitheater called "Peekaboo Canyon" along the entire northwestern side of the ridge known as the "Alligator."

The main portion or No. 2 lies to the southeast and below Sunset Point. The trail extending south from Sunset Point forms the western boundry of area No. 2, which includes nearly all of the two ridges heading southeast and east-southeast from Sunset Point. A small portion of "Queen's Garden" northeast of Sunset Point is included in area No. 2.

Area No. 3 is a section of escarpment rim just northeast of the Park's North Campground and includes the northern half of the Campbell Creek amphitheater. An outlier of area No. 3 lies just off the Campbell Trail, which passes through the canyon between the rim area and the "Chinese Wall."

Area No. 4 is the 1979 Field Camp study site in the Bryce Creek amphitheater, the "Silent City area described by Evitt et al. (1979). Areas No. 4 and 2 are adjacent along the Sunset Point trail.

Joint measurements were taken directly from the rock face with Brunton pocket transits. Following the discussion of joint nomenclature in Hodgson (1961, p. 11-13), joints were defined for field measurement as fractures traversing rock stata but not accompanied by any discernable displacement of one face of the fracture relative to the other. All measured joints were assumed to be vertical, and only joint strike orientations were recorded.

During the two days of field work in areas nos. 1, 2, and 3 a sample of 1363 joint measurements was collected. Addition of the data from the 1979 study (no. 4) increased the total of joints measured to 1601. Data for each site and the combined total were grouped in 10° intervals, and percentage frequencies (within each group) for each 10° increment were calculated. These percentage frequency data were than displayed in three ways for analysis: 1) as 180° rose diagrams (fig. 1a,b 2) as 180° histograms with 30° running average curves (fig. 2), and 3) as 360° trend diagrams (fig. 3). In addition joint trend data was abstracted from the Brox (1961, fig. 22) and Lindquist (1980, fig. 32) studies and prepared in the above manner for comparison with our data.

Analysis

Inspection of the 180° rose diagram (fig. 1a,b) shows that within each area there is either one strong joint trend or several, and that some of these major trends are common among the various localities.

For instance, in all rose diagrams except for that of the Brox data, there are notable trends 1) to the northwest and 2) slightly to the east of north. Calculation of a 30° running average curve for each area (fig. 2) supports the observation that these are persistent strong joint trends along the escarpment.

Studies of jointing in the Colorado Plateau support a hypothesis that a system of major joint trends and lineations, produced by deep crustal stresses, overlies and complicates locally derived joint patterns throughout the Colorado Plateau region (Heylman 1970, Hodgson 1961, Kelly 1955). Removal of these Colorado Plateau regional joint orientations (fig. 4) from 360° star diagrams of study area joint orientations (fig. 3) leaves a simple pattern of residual joint trends (fig. 5) that are most likely related to the geologic structure of the Paunsaugunt region. With the larger regional joint pattern removed from consideration, dominant local joint orientation is shifted to northeasterly and east-west directions.

Joint patterns are produced in rock strata along lines of tensional and compressive stress induced in the rock by deformation and folding of the strata (Billings 1954, p. 168-170). In this manner, joint orientations are paired and the axis of the acute angle of each intersecting joint pair will parallel the axial trend of folding. Field studies (for instance, Harris et al., 1960) have shown that analysis of joint sets and joint set patterns can reveal regional and local fold structures not evident in outcrops.

Inspection of the residual joint orientation data from the study areas along the Paunsaugunt escarpment (fig. 5) shows in each area a joint pair of presumably local origin. The acute axial trend of these pairs are roughly parallel to the trend of the escarpment itself (map 3) and as such, not incompatible with any of the northeasterly trending anticlinal, synclinal or other gently arched structures posited by Gregory (1951, pp. 73-74); or Hager (1957, p. 2118).

Conclusions

In short, each study area produces a variety of joint azimuths, the number and orientation of which varied from area to area (fig. 1a,b; 2; 3). Major trends in each area are, however, dominant in the northwest quadrant and slightly to the east of north. These major trends are consistent with a pattern of joints and lineation trends common to the entire Colorado Plateau region and may be related to deep seated crustal stress field. Only minor joint trends in the northeast quadrant with each study area can be related to local structure (fig. 5; map).

In this paper the relationship between hoodoo alignment and joint trends is not explicitly examined. If indeed there is a positive relation between joint trends and hoodoo alignment it seems doubtful that minor trends derived from local structural variations would predominate over the much stronger regional trends.

It is to be understood that hoodoo alignments are, like joint orientation, not continuous long lineations but the aggregate of numerous short segments aligned in a variety of directions. Any statement on hoodoo alignment must be based on a body of data comparable to that of

this study of joint orientation to have a quantitative validity. Only then can the two sets of directions data be compared and the relation between structural linearities and erosional trends statistically determined. Such studies must also be integrated into further studies of geomorphic processes in Bryce Canyon National Park. Hoodoo formation and alignment cannot be a simple question of structural control but is inextricably linked to the general development of the entire escarpment along the eastern margin of the Paunsaugunt Plateau.