

Geology

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PRELIMINARY REPORT OF FIELD INVESTIGATIONS IN THE BRYCE CANYON

NATIONAL PARK AREA CONDUCTED DURING THE SUMMER OF 1974

SUBMITTED TO: CHARLES A. BUDGE, SUPERINTENDENT
BRYCE CANYON NATIONAL PARK

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INTRODUCTION

Considering the standing of Bryce Canyon National Park as one of the major National Parks, surprisingly little literature exists concerning the details of the geology of the Park. This investigator has searched the bibliographies and abstracts and found only a few articles relating to the Paunsaugunt area in general, one unpublished thesis, and papers partially related, such as ground water supply and soils and vegetation. Certainly the geology of Bryce should be explored and made available in studies of greater depth than those now available. This applies not only to the geomorphological aspects which have given rise to the unusual erosional forms, but also to the structure about which only some very general statements have been made and to the lithologic and stratigraphic character of the beds composing the Wasatch Formation on which the escarpment is formed.

The purpose of the research during this and succeeding summers is intended to study in detail the genesis of the unusual erosional forms of the Bryce Canyon escarpment and, so far as time permits, to detail the other related aspects of the geology of the escarpment area. Initial studies of slope movement, escarpment characteristics, jointing and its relation to wall trend, and structure were begun in preparation for more detailed studies in the following summers. Several sites were selected for these studies on the basis of their characteristics relating to hoodoo formation.

During these studies, faults were discovered in the Park, which to the authors knowledge, have not been previously reported. Although the faults are minor compared to the major bounding faults of the area (such as the Sevier and Paunsaugunt Faults) it is of significance to the Park due to the locations and resulting effect on landform development. Two of the faults constitute structural controls on the development of the Bryce Point area.

Similarly unreported are sets of conjugate joint planes with dips of approximately 35 to 40 degrees and strikes (and axes of intersection) ranging between NE and SE. Motion along some of these planes has produced a large

number of small thrust faults of varying displacements (largest measured had a vertical separation of 32 feet) and caused tilting of some of the walls. Cross-cutting relations among these joints, the vertical joints, and the faults indicate that this conjugate set (or sets) was formed at an early period, probably prior to faults described above and to most of the vertical joints.

OBSERVATIONS ON ESCARPMENT CHARACTERISTICS

The escarpment of the Park can be roughly divided into three segments on the basis of a set of interdependent characteristics involving degree of hoodoo development, lithologic and stratigraphic variability, stage of drainage development, and degree of exposure of the base of the Wasatch Formation. The concatenation of characteristics particular to each section produces a landscape which reflects the interaction of these characteristics and the geomorphic processes acting on it.

The northern segment extends from the Fairyland Canyon Trail northward to Utah State Road 12 to Tropic. This section has the following characteristics:

- 1) low density of erosional forms
- 2) landscape developed almost entirely on the Wasatch Formation with no downcutting penetrating to the underlying formation except for the extreme eastern margin near the Paunsaugunt Fault
- 3) less relief with smaller gully gradients and lengths near the rim
- 4) the plateau surface is topographically lower with fewer strong cap forming beds in the upper part of the section exposed (only two strong cap forming beds, one continuous, one probably discontinuous)
- 5) rim recesses formed in and tending to follow topographic lows on the plateau surface (shallow swales in the drainage pattern of the plateau surface)
- 6) ridge walls are the dominant hoodoo form
- 7) greater degree of normal badland topography.

The middle segment extends from the Fairyland Canyon Trail on the north to the southeast corner of the Bryce Point-Paria View peninsula and has the

following characteristics:

- 1) generally a high density of erosional forms along most of the rim
(although certain limited portions are almost devoid of the forms)
- 2) relief which extends throughout the Wasatch Formation with stream beds penetrating into the lower formations although the contact is generally covered with colluvial slopes or alluvium in the washes
- 3) long gullies with steep gradients extending through or nearly through the Wasatch Formation
- 4) a number of strong cap forming beds exposed throughout the section
- 5) only a few localized sections near the Paunsaugunt Fault or under the Brianhead cap where the escarpment has a vertical or near vertical face of any extent
- 6) rim recesses which do not as clearly follow topographic lows in the plateau surface with some recesses being structurally controlled
- 7) only small segments along the eastern margin near the Paunsaugunt Fault where the base of the Wasatch Formation is exposed and subject to undercutting.

The southern segment of the Park, continuing to Rainbow Point has the following characteristics:

- 1) numerous erosional forms restricted for the most part to the upper third with the lower two thirds generally forming a vertical or near vertical wall
- 2) strong relief and drainage pattern which a short distance from the escarpment is deeply cut into the underlying Cretaceous Kaiparowits and Straight Cliffs-Wahweap Formations with the base of the Wasatch Formation being exposed on the slopes
- 3) rapid weathering and undercutting at the base of the Wasatch Formation
- 4) strong, mostly massive, sandy limestone caprock over much of the rim
- 5) a number of cap forming beds in the upper third with the lower two thirds being more massive
- 6) rim recesses which again tend to follow topographic lows in the plateau surface
- 7) gullies which tend to follow narrow channels cut through the walls of the escarpment.

Much further work remains to be done on the details of each of these characteristics, the nature of the geomorphic processes at work, and the interaction of characteristic and process before the origin and form of the escarpment is fully understood.

SLOPE STUDIES

Of critical importance in the genesis of the erosional forms is the nature of the slopes in terms of the lithology and its weathering characteristics, the angle of the slopes, length of the gullies, and the mode and rate of the downslope movement of the mantle material, and the weathering and erosional processes resulting in the inter-gully forms. Studies were begun this summer (to be continued in following summers) to determine these characteristics and processes.

Several gullies were measured in the northern segment of the Park to obtain the longitudinal profile on the escarpment, with the associated degree of wall development also being noted. Gullies and stream beds in the central and southern segments will be measured next summer and the characteristics and degree of wall formation compared.

Movement on the slopes was also studied by setting up a grid of marked stones embedded in the surface of a slope which was then photographed at intervals throughout the summer to determine the nature and rate of the downslope movement on the slopes. This method was adopted as more or less a stopgap method after other planned methods proved unsatisfactory due to the unforeseen nature of the slope material and profile.

During the early part of the summer which was very dry (with no measureable rainfall for the preceeding 4 or 5 months), the slopes were mantled with hard, brittle, porous, calcareous clay clumps which formed a nearly continuous, rigid surface layer. The clay of the clumps was apparently derived from and graded into small clastic fragments of disintegrating bedrock and clasts contained in the clumps were derived from the harder, purer beds of limestones upslope. The covering of clumps graded into bedrock in distances varying from zero on bare disintegrating vertical surfaces to perhaps 4 or 5 inches on the softer beds. The rigidity of this cover and its attachment to bedrock was such that it

The slopes were observed during a number of thunderstorms with amounts of precipitation ranging from traces to almost an inch. With amounts of a few tenths or less, the porous nature of the surface allowed very little run-off and the surface was affected in only a very minor degree. It was only after a series of showers (3 in 4 days) of amounts 0.2", 0.3", and 0.4" that the surface began to show signs of dissolution of the clay clumps and the formation of rivulets on the slopes. There was only one major thunderstorm (0.9") in the study area during the entire summer and this had a very pronounced effect on the surfaces, producing a number of deep rills on the slopes, disintegrating the clump structure of the surface, and clearing the gully bottoms of accumulated debris down to bedrock. It was only during this thunderstorm that large quantities of debris was carried down the gullies and appreciable flow occurred in the washes. The same results were found along the Bryce Point Trail for a similar thunderstorm.

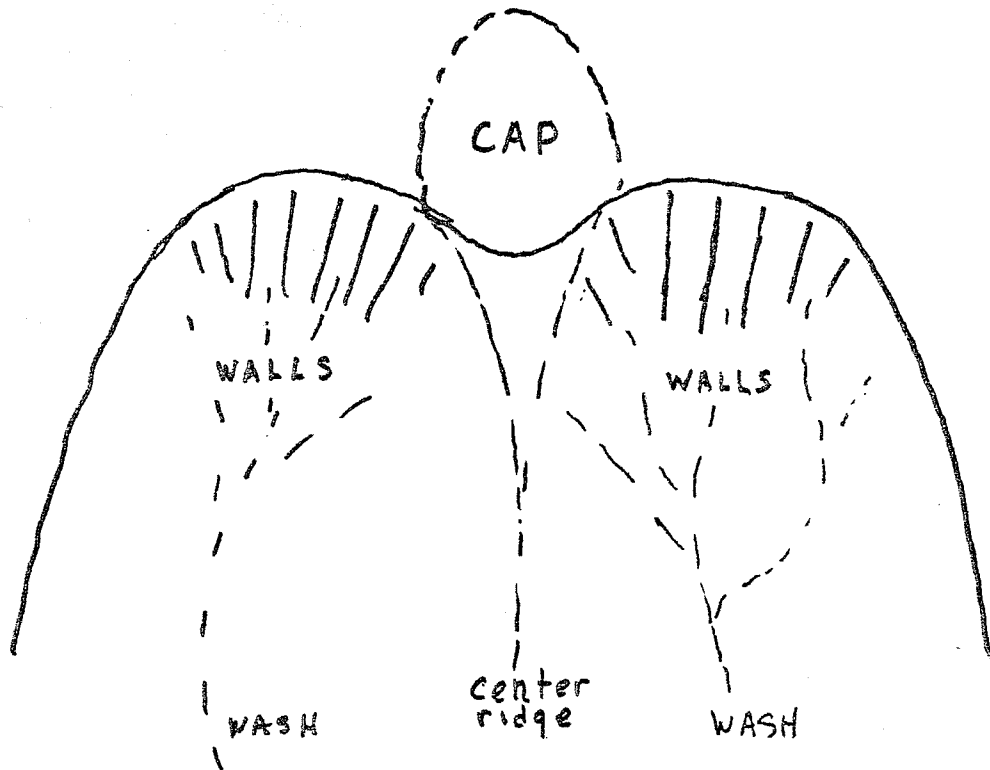
All the rills examined along the slopes were carved into the bedrock by the downslope motion of the clay-detritus mixture so that the cutting action of this mixture is a direct action on the bed rock. It was not until farther down in the gullies where the gradients were about 12 to 15 degrees that any significant amounts of alluvium began to appear in the gullies. It appears that most of the transport and carving occurs most intensively during the heavy rainstorms when accumulating material in the gullies and on the slopes moves down through these bedrock channels.

In discussions with Park personnel, it also appears that much downslope movement occurs during the melting of heavy snow cover when the slopes are probably thoroughly wetted and bear the overburden of snow.

OBSERVATIONS OF HOODOO OUTCROPS ON THE RIDGES WEST OF THE EAST FORK OF THE SEVIER RIVER

The area west of the East Fork of the Sevier River is composed of a series of east-west tributary valleys and intervening ridges. Many of these ridges (particularly in the study area) are capped ^{by} either stretches or isolated areas of a dense, hard, relatively pure limestone producing rather flat ridge crests. Along a number of ridges, particularly those north of King, Badger, Skunk, and Blubber Creeks, there are isolated outcrops of hoodoo formations found (with one exception) on the south sides of the ridges.

These outcrops extend from the ridge crests through most of the Wasatch Formation terminating in washes not far above the valley floors. In all cases, the outcrops were capped with the dense limestone bed mentioned above and had (with one exception) a distinct form consisting of a central ridge extending from the cap with basins on either side as diagrammed below and shown in Photo 1.



The slopes immediately under the caps were either vertical or near vertical and decreased away from the caps and at lower elevations. Wall development was not uniform in the basins with best development occurring in the recesses on either side of the cap as shown in the above diagram. Slopes along the basin walls had continuously decreasing slope values from the cap to the outer part of the basins. In the regions of best wall development slopes generally ranged from about 38 to 45 degrees. The heads of the gullies which cut the beds into walls were forming not on the cap but mostly in the bed below the cap. This bed (approximately 50 feet thick) was much softer than the overlying cap and had a large clay fraction. Much of the material flowing through the gullies was derived from the soil and saprolite from the slopes into which the basin walls were cutting. Below this bed there was a series of alternating soft and hard beds in which the best formed walls were

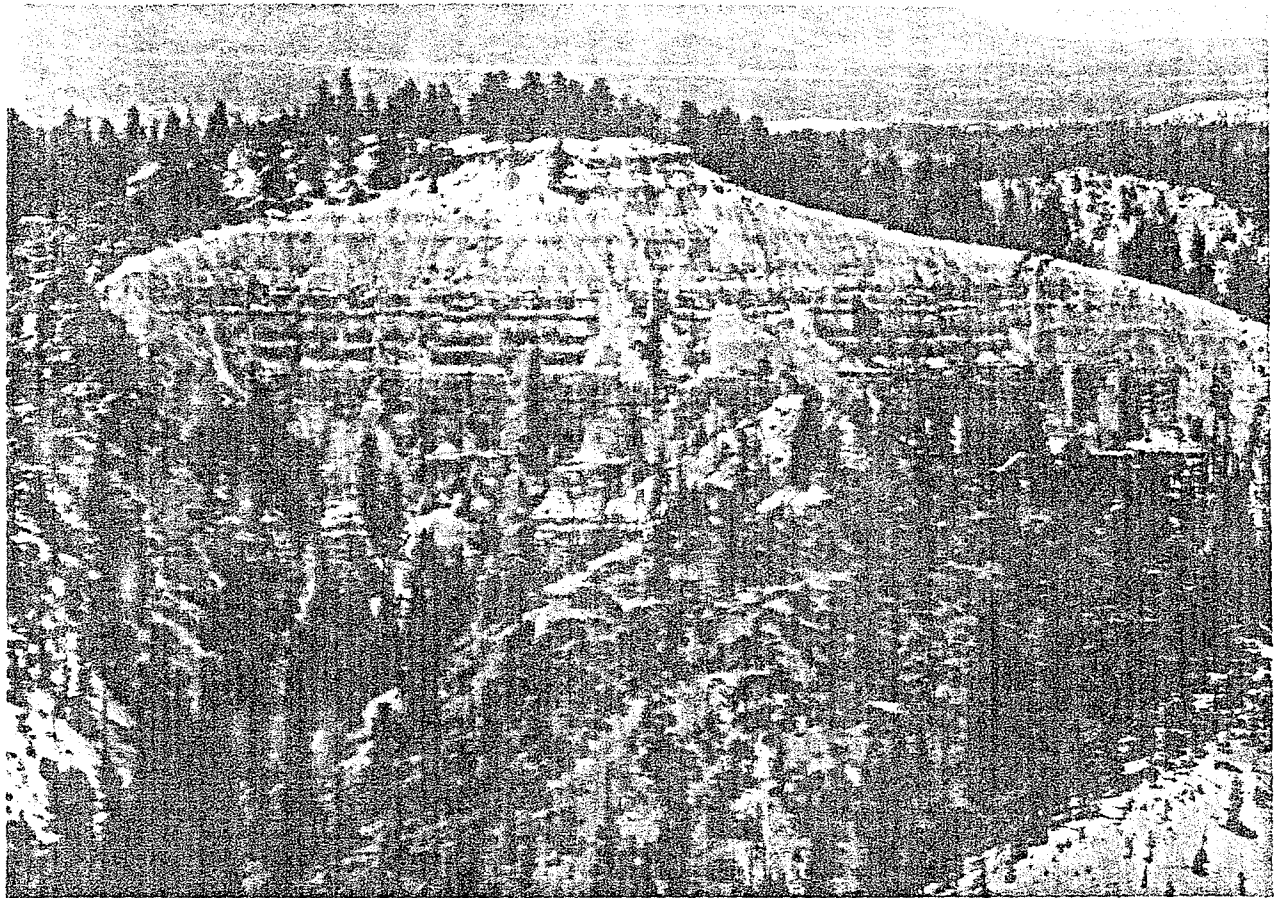


Photo 1. View to the north of the eastern most hoodoo outcrop
on the north side of Badger Creek.

found. In this interval five other beds and corresponding levels of wall tops were apparent. The sixth level was also a hard, dense limestone similar to the caprock at the top. Below this level the walls were more massive and mesa-like with more massive bedding although there were two more lower beds, more diffuse and discontinuous, which formed the last two levels of wall tops.

This study area seemed to indicate a definite relation between outcrop formation and micro-climatic factors (and consequent vegetal cover). The south facing slopes of the ridges in many places had only a sparse cover of vegetation consisting mainly of bristlecone and pinyon pine with very little ground cover while slopes facing in other directions were generally covered with ponderosa forest with a patchy or continuous ground cover of manzanita or grasses. The south facing slopes were covered with a veneer of small clasts derived from the upslope beds with little or no soil development and very little gullying of any significance.

These outcrops on the ridges were investigated for possible study areas since they were of limited extent, providing a more compact study area with well defined characteristics. The eastern most outcrop on the ridge north of Badger Creek was selected for study and mapping of the basin, wall directions, and a few joints was accomplished this summer. Further studies of the joint system, relations between joints and wall trends, and determination of the stratigraphic section are planned for next summer.

WALL CLASSIFICATION SCHEME

Erosional forms in the Park are found both on the main escarpment and farther out on the ridges both extending from the escarpment and those formed between lines in the drainage pattern. The best developed forms are mostly found along the main escarpment, particularly in the Silent City area, the Bryce Point area, and surrounding Boat Mesa. Invariably, the forms are developed on slopes or ridge crests with the exception of the residual forms which appear to have been formed at a much earlier time. However, slightly different conditions and processes at work on these slopes appear to produce forms which are capable of categorization into a small number of classes based, for the most part, on mode of origin.

- 1) Walls on the main escarpment and ridges which appear to result mainly from active downcutting in the gullies, possibly along favorably oriented joints.
- 2) Secondary walls formed not directly on the rim or ridges, but on the walls of class 1. These secondary walls appear to have formed by weathering back along joints in the main walls or by secondary gullying at an earlier stage of development.
- 3) Ridge walls which are formed on and follow the crests of ridges lower in the drainage basins and separated from the main escarpment. These are particularly prevalent in the northern segment of the Park and appear to be the result of the exposure of one of the harder beds along the ridge crest combined with rapid weathering and downslope movement along the slopes. A possibility also exists that the caprock common to these ridge walls is a discontinuous stringer type formation since this caprock tends to be a sandy or conglomeratic limestone.
- 4) Clump or cluster type forms which do not have the distinctive slab form common to so many walls along the main escarpment, but are more rounded or irregular in shape. These forms are mainly found on the slopes of the lower ridges and those of lower slope values and probably reflect slight variations in lithologic characteristics within a given caprock bed exposed to weathering along the slopes. The Red Canyon area on the west side of the Paunsaugunt Plateau along Utah State Road 12 shows this type of development to a greater degree than the escarpment of the Park area.
- 5) Residual walls at lower elevations on lesser slopes whose mode of origin is uncertain.
- 6) Possible intermediate forms.

ASPECTS OF THE STRUCTURE

FAULTING IN THE MAIN AMPHITHEATER SECTION OF THE PARK

Although much of the faulting in the Paunsaugunt Plateau area has been reported by Gregory (1951), there is no mention of any other faults than the Paunsaugunt and some cross faults near the northern boundary of the Park that lie within the Park boundary. One report has stated that the faulting is restricted to these faults. This investigator has found that this is not the case, and has found four near vertical faults and numerous thrust faults. These faults, to the investigators knowledge, have not been reported previously and represent a new finding concerning the geology of the Park. These faults are of minor displacement compared to the major faults such as the Paunsaugunt, but are important to the Park for the effect which they have had on landform development within the main amphitheater of the Park. Three near vertical faults are located in the Bryce Canyon-Bryce Point area and two of these, bounding Bryce Point on the east and west sides, constitute important structural controls on the development of Bryce Point.

In this report names will be proposed for these faults in accordance with Park features and for Park interpretive purposes although it is hoped they will be generally accepted.

The Bryce Point Fault (proposed name) lies just east of Bryce Point and where exposed has a dip of approximately 62° ($N103^{\circ}E$) and a strike of approximately $N13^{\circ}E$. The eastern block, the upthrown side with a vertical separation of 90 feet at the northern outcrop, has also been tilted with a dip of approximately 4 to 5 degrees to the northwest. These relations indicate (along with slickenside information) that the fault is a reverse, dip-slip fault with a rotational component. However, due to the location of the outcrop (Photo 2) in the walls of the tilted block, there is some question as to the true dip value due to the possibility of shear gliding (Kehle, 1970) down the upthrown side producing a smaller measured dip. The northern outcrop of this fault can be found just west of the tunnel along the Bryce Point Trail where the bed acting as caprock over the tunnel shows a downward drag folding and is broken by a series of small faults. Along these small faults

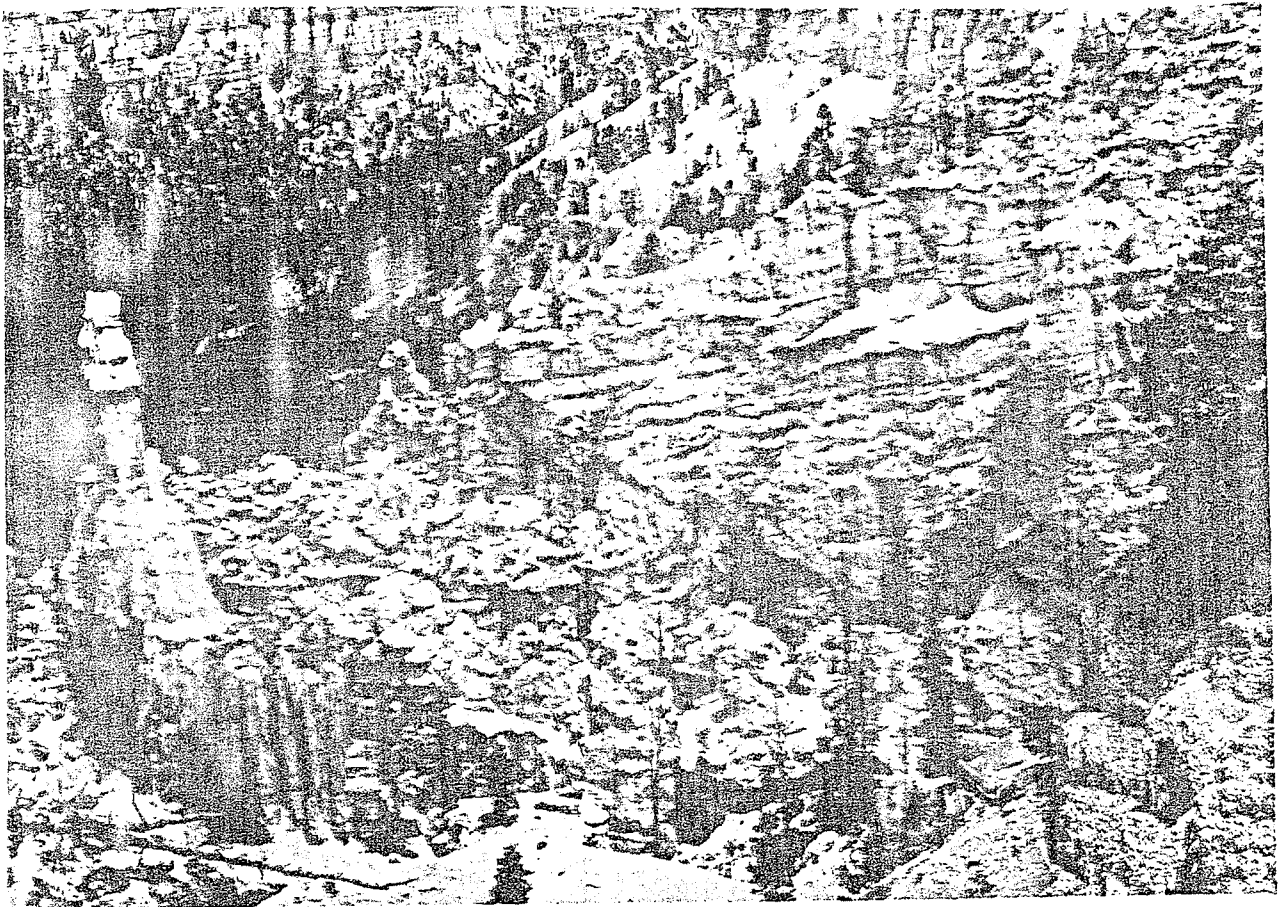


Photo 2. Trace of the Bryce Point Fault. The fault surface can be seen dipping to the right in the walls in the center of the picture. The right or upthrown side has a dip of 5° to the NW. View is to the NE from the Bryce Point Trail.

there are narrow zones of breccia and gouge. This bed terminates along the gully crossing the trail at this point and is then found on the west side of the gully at about 90 feet lower elevation. Photo 3 shows this area and the relations of the beds. The northward continuation of the fault trace becomes more apparent where it passes through a series of walls (where the dip and strike were measured) which cross the fault at nearly right angles. Some drag folding occurs in these walls in the footwall block and some outcrops seem to indicate some distributive faulting. The zone of brecciation is rather narrow, generally a few inches or less, although in some limited areas it extends one to two feet from the fault surface. Along much of the exposure in the walls there is a wedge or slice which also outcrops in the walls giving an erroneous impression of a 45° dip. After passing through the walls, the trace of the fault then passes northward into the canyon to the NNE and is lost under the colluvium and alluvium of the canyon. From here the trace becomes uncertain and repeated searching has failed to produce any indication of the fault passing into or through the central ridge leading to Bristlecone Point. It is tentatively proposed that the fault terminates near its intersection with another fault which has its trace to the NW up Bryce Canyon.

In the eastern most recess on the south side of the peninsula, the fault outcrops again with the same or slightly larger displacement (uncertain measurement of 100 feet). Due to the great difficulty of access, the fault trace or surface could not be examined on the ground, but could be identified by several displaced marker beds. The fault surface could not be observed directly to obtain dip, strike, or direction of net slip, but from the height and separation of the walls on both sides of the fault, it can be concluded that the fault surface must be near vertical. The eastern block continues to be tilted up on the southeast with a 4° dip. The displacement is obvious when viewed from levels approximating those of the base of the Wasatch Formation or upper level of the walls (Photos 4 and 5). Although a thickness of approximately 100 feet of the upper stratigraphic section found on the western block is missing from the eastern block, the upward displacement and tilting has given it essentially the same elevation as the highest point west of the fault.

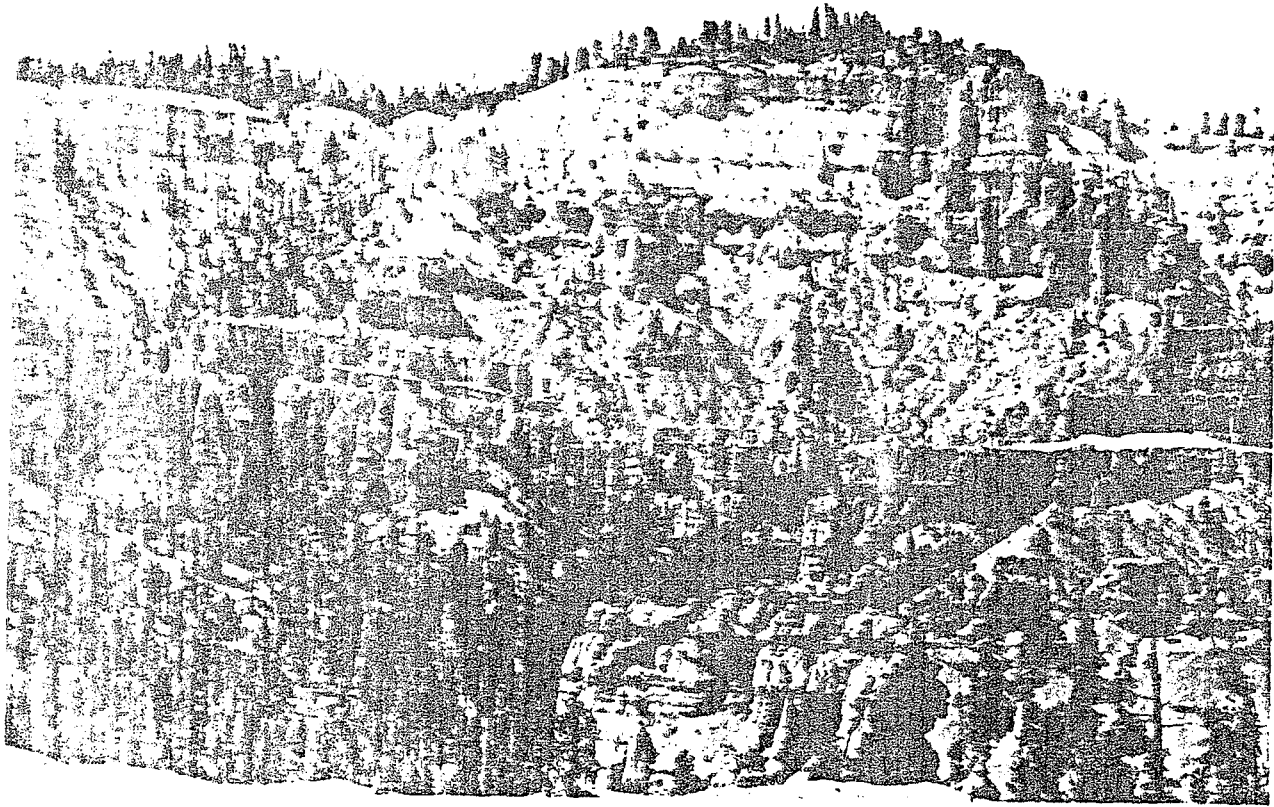


Photo 3. View south to Bryce Point and the Bryce Point Fault. Arrows identify a given bed and its displacement along the fault.

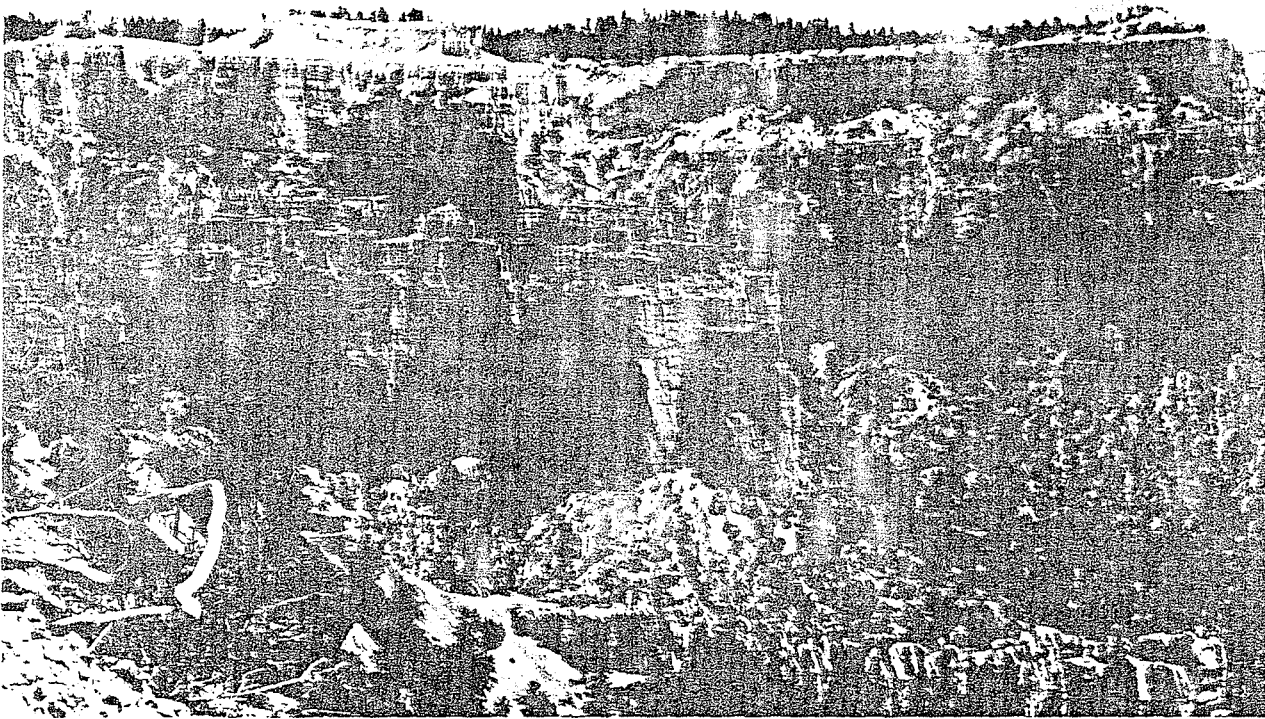


Photo 5. Southern recess from the level of the upper level walls.
View is to the NNE.

There are a number of interesting points concerning the faulting in this recess. Two faults, the Bryce Point and Peekaboo Faults have a juncture near the rim of the recess. Difficulty of access precluded observation of the precise relations of this juncture and further work needs to be done in this recess.

The most unusual feature of this recess, however, is the set of tilted walls on the western side of the fault (Photos 6 and 7). These walls have been tilted by the upward drag folding on the downthrown side. The upper portions of these walls appear to have formed with the walls in a vertical position with only the lower portions affected by erosion of the walls in a non-vertical position. This would indicate that the faulting, or at least the last movement, occurred after formation of the recess and the walls and is of fairly recent occurrence.

From the recess the fault trace passes across Yellow Creek and through a saddle of the ridge extending ESE and the SSE from the peninsula south of Paria View. The Under the Rim Trail crosses the saddle at this point. On the western side of the saddle (the downthrown side) there is a ridge formed on the Wasatch Formation with its base 30 to 40 feet below the crest of the saddle which contains no Wasatch Formation and is formed on the Cretaceous Kaiparowits Formation. The vertical displacement at this location could not be definitely determined due to the lack of identifiable outcrops on both sides.

Southward from the saddle the fault trace becomes more conjectural with only one definitive fault outcropping of extremely limited extent which provided no further information concerning dip or displacement. The fault, however, appears to join with the Paunsaugunt Fault and probably represents a splinter fault off it.

The Peekaboo Fault (proposed name), located in the main recess and gully west of Bryce Point, has an approximately vertical fault surface and a vertical separation of 42 feet (Photo 8). The fault surface could not be found due to the cover of colluvium in the gully. To the north the fault appears to die out quickly and no further evidence of the fault could be

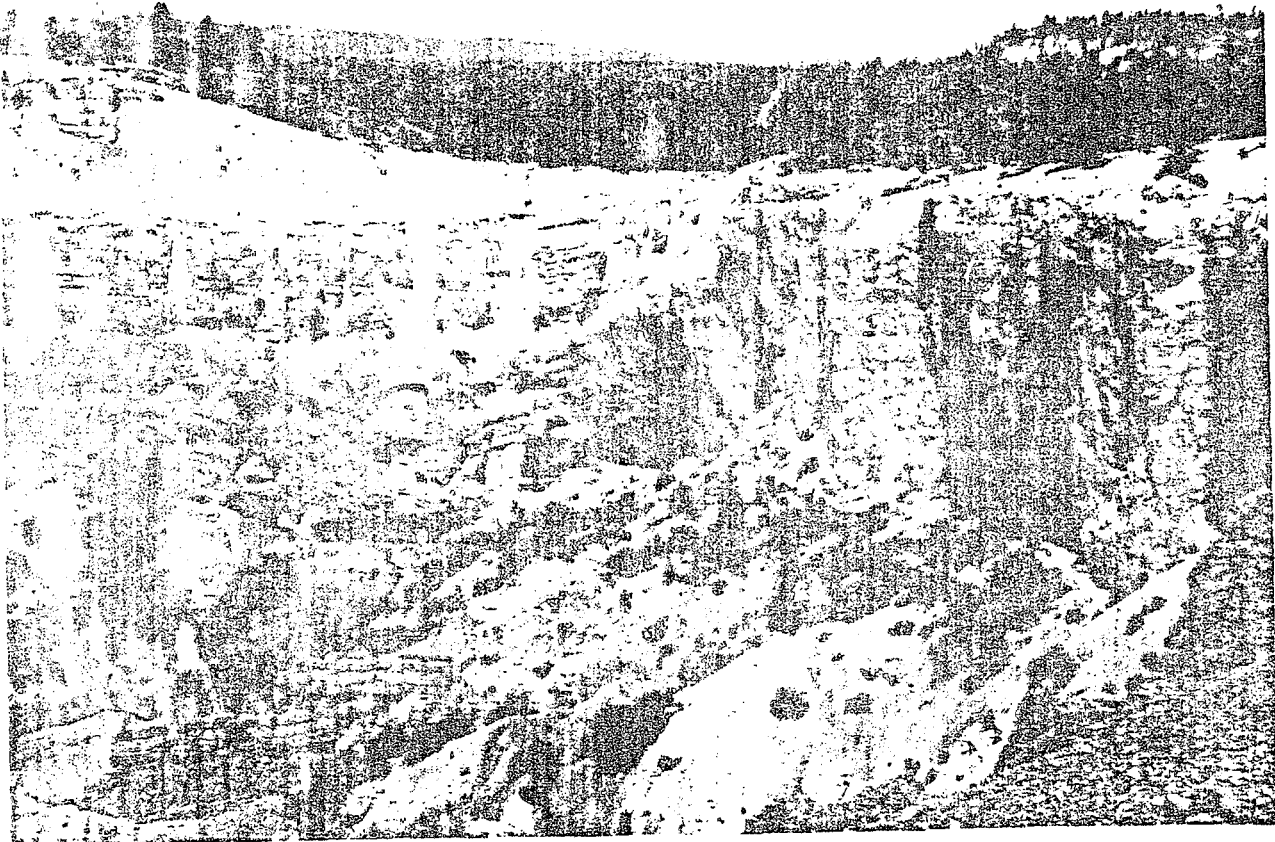


Photo 6. View to the NW of the walls in the southern recess which have been tilted by drag folding along the fault.

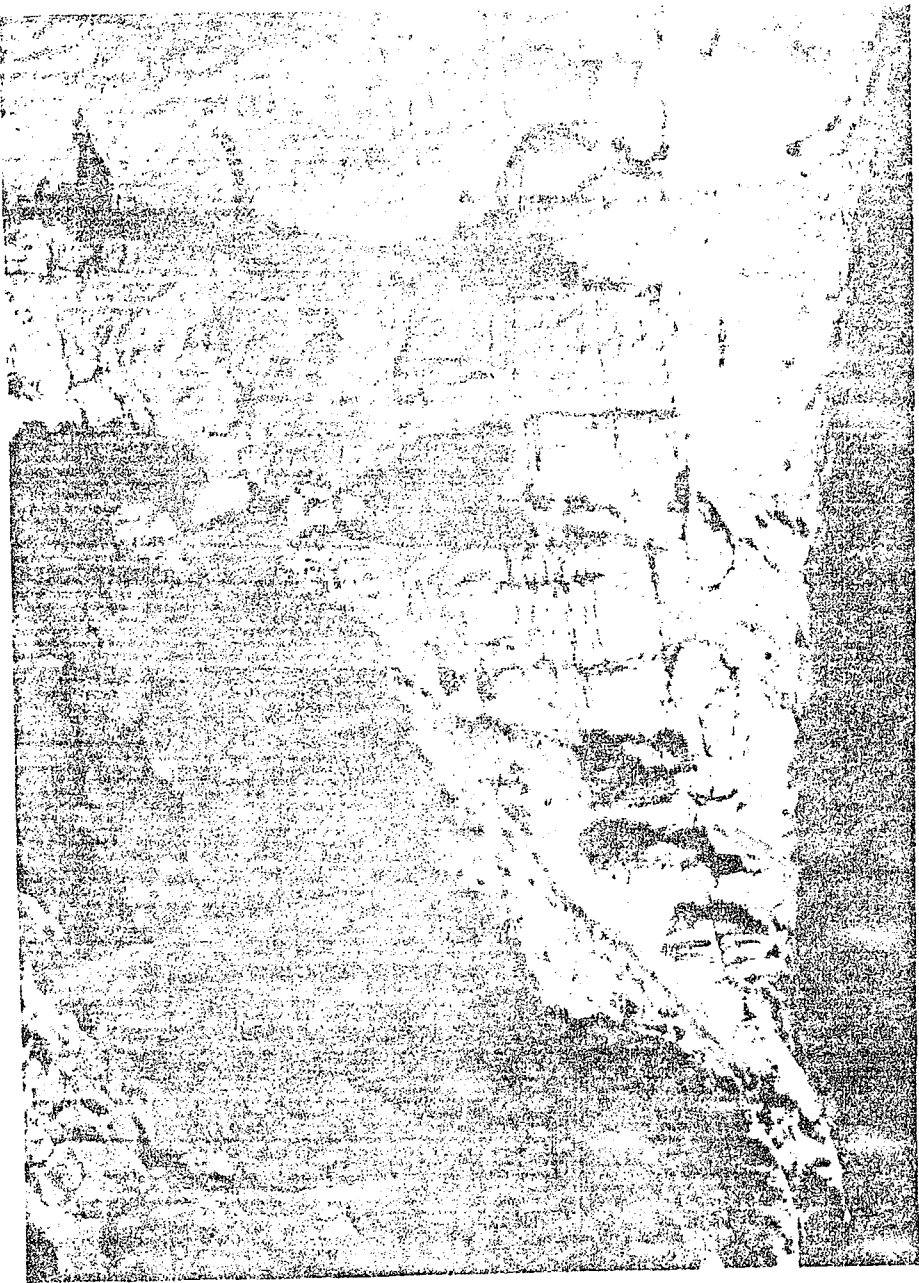


Photo 7. Close-up of the tilted walls. The upper half of the walls appear to have formed while in a vertical position while only the lower portions appear to be beveled by erosion in a tilted position.

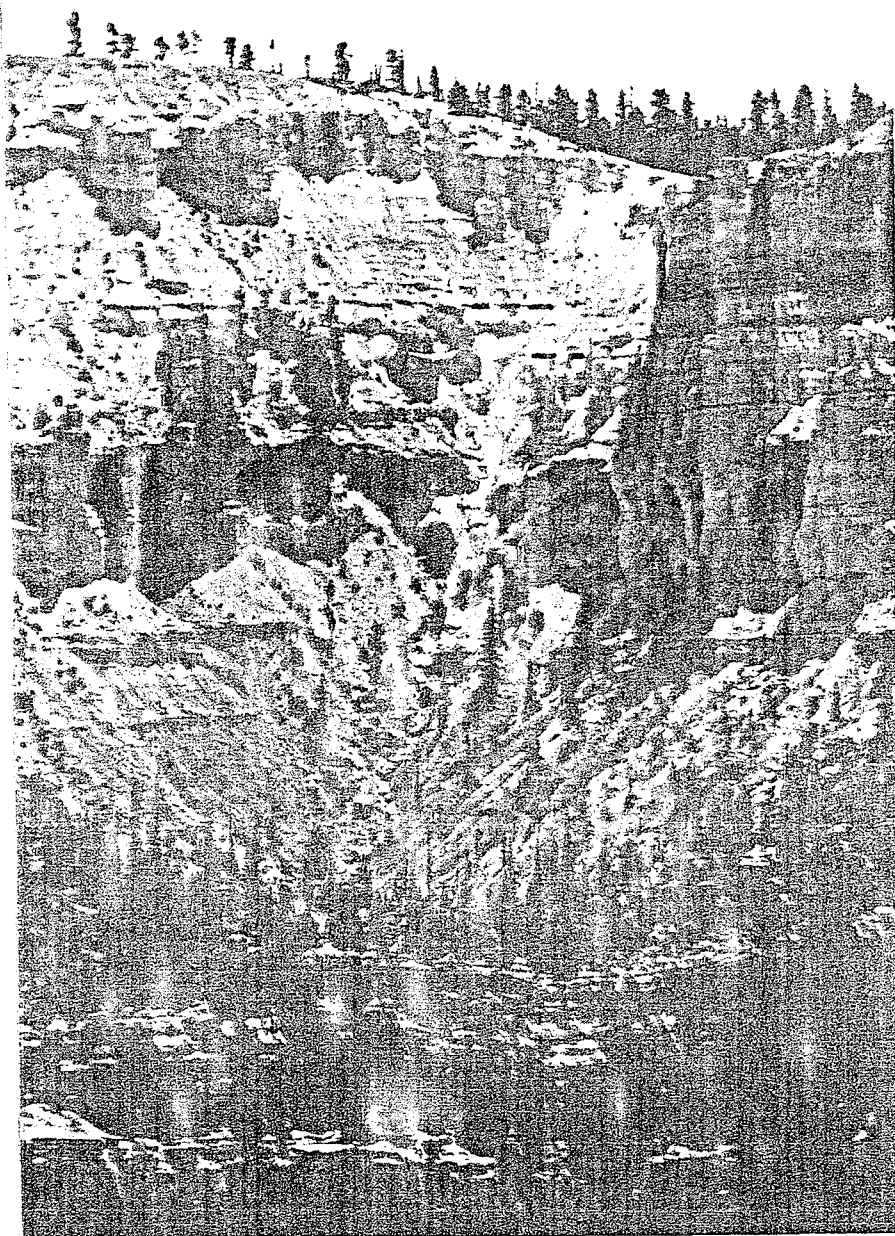
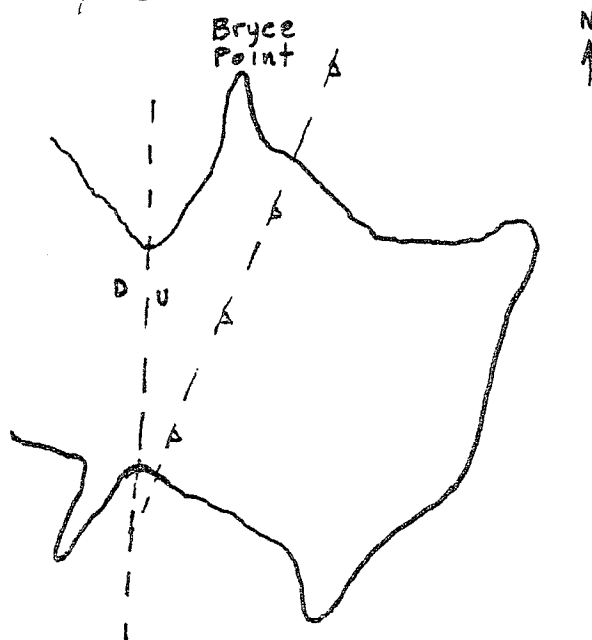


Photo 8. Fault in the recess on the west side of Bryce Point. A bed has been marked to indicate the displacement. View is to the south from Sunset Point..

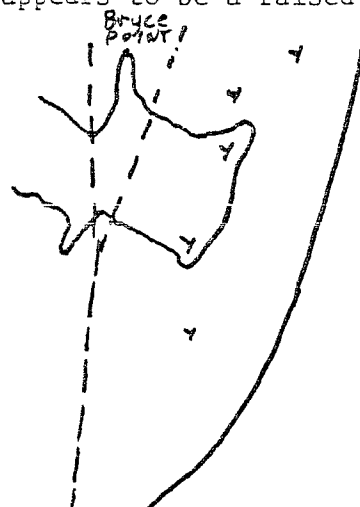
found in the walls or ridges along its projected trace. This fault also appears to cross to the same recess as the Bryce Point Fault since only the one exit point could be found on the south side where faulting had occurred.

Thus, Bryce Point appears to be a wedge between two converging and joining faults as shown in the diagram below.



The wedge containing Bryce Point is tilted up on the south end with dips of 5 degrees (N 0°) measured at an outcrop in the Bryce Point parking area and a dip of 8 degrees (N 0°) at an outcrop in the road cut just below the Parking area.

On a somewhat larger scale, the entire eastern block between the Bryce Point and Paunsaugunt faults appears to be a raised, tilted block as shown in the diagram below.



The Kaiparowits and Straight Cliffs-Wahweap Formations contained in the block to the east and southeast of this area also dip in the same direction as the overlying Wasatch Formation.

The third fault of the Bryce Canyon area, the Bryce Canyon Fault (proposed name), outcrops on the ridge extending NNE into Bryce Canyon from the NE corner of the Bryce Point peninsula. The north side is the down side and the fault surface appears to be vertical, with a vertical separation of approximately 47 feet and a strike of $N45^{\circ}W$ at this outcrop. The fault trace is rapidly lost to the northwest under the colluvium of the slope, but farther to the northwest on a ridge along this line two neighboring pinacles are displaced by 20 feet with the correct sense. Another displacement occurs in a gully leading to the rim, and although no definitive outcrops could be found on which the displacement could be measured, it appears to be smaller yet, approximately 4 to 6 feet.

The fourth fault is found to the north of the main amphitheater in the Boat Mesa-Fairyland Canyon area where its trace is well exposed. The Fairyland Fault (proposed name) cuts through the northwest end of Boat Mesa and to the north of the Mesa produces a noticeable offset in a bed which serves as caprock on many of the walls along the rim. Although there are few outcrops of the fault surface, the trace indicates an almost vertical fault with the west side being the upthrown side. The fault has a strike of $N 10^{\circ}E$ and a vertical separation of approximately 20 feet. The fault trace to the north can be followed across saddles in the ridges extending eastward from the scarp until it enters the rim where the trace becomes lost on the surface of the plateau. On the south side of Boat Mesa a small outcrop of the fault can be found just below the caprock of the Mesa where a small drag fold is exposed. The trace then crosses between two walls which are obviously displaced. On the western wall a small slice is found at a lower stratigraphic position than it would normally occupy. The trace can then be followed down a gully for some distance until it passes across Campbell Creek into the ridges to the south where it is lost. No indication of the trace could be found crossing the ridge leading to Bristlecone Point.

The age of the Fairyland Fault can be rather precisely determined relative to the age of the rock units of the cap. The fault cuts the stratigraphic

section up to the cap of Tertiary Conglomerate but does not cut this cap. On the north side of the Mesa, the up side protrudes into the lower part of the cap and is covered by drape folding until the upper part of the cap again becomes level and continuous. The cap, however, although not displaced, appears to be disturbed and a shallow swale across the Mesa is a topographic expression of the fault.

Further field work is needed on these faults in order to more precisely determine their characteristics, extents, and effects. The author believes that other faults are likely to be found in the area, particularly on the west side of the Sinking Ship and perhaps up some of the other canyons. The south end of the Park from Sheep Creek south was not investigated but certainly should be.

Numerous small thrust faults have also been found in the area and the author examined only a few of these in any detail. The thrusts appear to have formed along the numerous conjugate joint sets which appear throughout the section. Several were noticed cutting beds lower in the section while higher beds were continuous and not cut by the thrust. Apparently an interval of erosion had occurred after the thrust during which the beds were beveled, with deposition resuming thereafter. Two thrusts measured had vertical separations of 32 feet and 18 feet.

Time limited any detailed mapping and study of these thrusts, but they should be studied further for information which they might yield concerning the depositional period and its sequel.

In addition to the described faulting, a number of limited outcrops of strike slip faulting were also noticed but no measurements were made on these faults.

FOLDING

Usually the Bryce Canyon Park area is described as a series of beds with a gentle regional NE dip with some minor folds or warps produced by the faulting along the Paunsaugunt Fault. While this is not incorrect, it certainly leaves much to be desired as a working description of the Park. Hager (1957) has described an anticline whose axis roughly parallels to the east the

southern rim of the Park. The axis then penetrates the rim just to the west of Paria View where the northward continuation is no longer indicated. It is unclear as to whether there is a continuation or a dying out of the anticlinal structure. If the axis is projected through the Bryce Point-Paria View peninsula it enters the main amphitheater section of the Park to the east of the rim where the structure or dips, rather than being anticlinal, are synclinal. Hager's anticlinal axis, if it is meant to continue to the north, appears to be too far to the east and should approximately fall along the rim or just west of it. If this is the case, then the main amphitheater is formed on the eastern limb of the anticline with warping and drag folding along the eastern margin producing the synclinal character of the amphitheater.

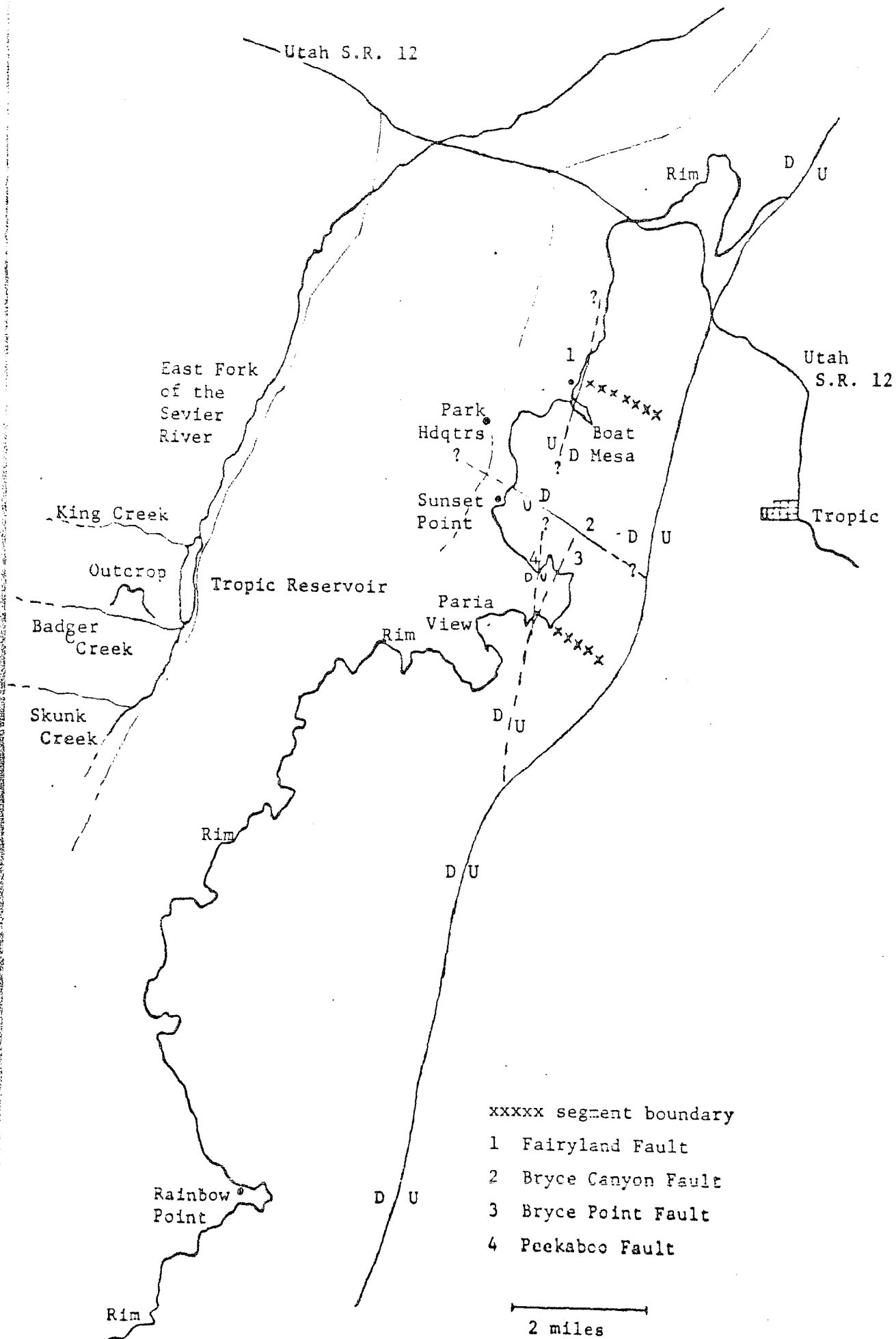
Thus, one of the major structural features which may possibly be an important control for the joint pattern and erosion in the amphitheater is not sufficiently well documented.

CONCLUSIONS

The base of information concerning the geology of the Bryce Canyon National Park area is surprisingly small. None of the various aspects including structure, stratigraphy, history, erosional processes, or even escarpment characteristics seem to have been studied with any degree of either comprehensiveness or detail. In-depth studies of these aspects are crucial for an understanding of the genesis of the hoodoo forms and the development of the particular escarpment characteristics. The studies initiated this summer will serve, first, to describe the characteristics of these areas of hoodoo formation and, secondly, to determine the processes which lead to their formation.

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MAP OF THE BRYCE CANYON NATIONAL PARK AREA

