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Climatic Change Considered as the Major Factor in the Abandonment of the Grand Canyon Region

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CLIMATIC CHANGE CONSIDERED AS THE MAJOR FACTOR IN THE ABANDONMENT OF THE GRAND CANYON REGION

by

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INTRODUCTION

Grand Canyon National Park comprises 1009 square miles of contrasting life zones and landscapes, with elevations ranging from 2500 feet at the Colorado River to more than 9000 feet on the North Rim. This area includes 117 miles of the Canyon, part of the Kaibab Plateau known as the North Rim and part of the Coconino Plateau or South Rim. Both formations are included in the Colorado Plateau (See Figures 1 and 2).

Archaeological evidence indicates that prehistoric agriculturalists - the Cohonina peoples and later the Anasazi - resided in the area from circa A.D. 700 until A.D. 1200. Over 600 sites have been identified within the boundaries of Grand Canyon National Park, and many more have been found in the vast areas comprising the Grand Canyon National Monument, the Kaibab National Forest, and the Coconino Forest which surround it. Futhermore, locations of these sites indicate occupation of all life zones from the Colorado River to the North and South Rims.

In general, these sites are small and consist of no more than one or two rooms. A few multi-room pueblos do occur on the North Rim, on presently inaccessible flat-topped formations in the Canyon, Unkar Delta on a terraced wash adjacent to the Colorado River, and Tusayan on the South Rim. Stylistically these sites show strong affiliations with the east - the Kayenta Region. This so-called

Kaibab phase of the Kayenta Branch of the Anasazi Tradition occurs in an area that is now considered to have been marginal for an agricultural way of life.

Both Canyon and Plateau were almost completely abandoned by the beginning of the thirteenth century A.D. and recolonized only in the late nineteenth century when the physical environment became an attraction to sightseers. The one group which has remained in the area to the present time is the Havasupai. These people occupy a remote side canyon in the northwestern section of this area and make their agriculturally based livelihood by diverting the year round water supply of Cataract Creek. In addition, the narrowness and height of the Canyon walls on either side of the creek help to conserve the moisture in the air and in the ground. Because of this permanent water supply, the situation of the Havasupai is unique (See Figure 3).

Utilization of this area between the thirteenth and twentieth centuries was scant and of transitory nature. Both prehistoric and post-Columbian traders passed through and, in more recent times, Anglo-American prospectors have traversed the area. Always considered a barrier to European exploration, the Grand Canyon region was generally avoided by the Spanish in the sixteenth, seventeenth, and eighteenth centuries and by the Americans in the nineteenth century.

Today permanent residence in the Grand Canyon area is

restricted to a small enclave on the South Rim (Grand Canyon Village), comprising Grand Canyon National Park concessionaires and National Park Service employees. A few ranchers raise beef cattle in the outlying areas. They are all heavily dependent on resources that are hauled in to them from outside the area. Undoubtedly, modern American technical and agricultural expertise allows people of today greater opportunities to exploit the land than the prehistoric agriculturalists of 800 years ago. Modern man, however, has never found this to be a very productive area for other than tourist enterprizes.

THE PROBLEM

The problem I pose is this: Why are numerous sites of prehistoric agriculturalists followed by abandonment and failure to recolonize the land from the thirteenth century to the present?

Lack of water is apparently the major deterrent to settlement of the Plateau. It is neither available in the form of springs nor surface waters for drinking or as available moisture in the soil which is necessary for the growing of crops.

It was early recognized that the area is essentially useless because of the lack of a reliable supply of water. According to Hughes (1967) the almost total lack of permanent surface water is the most pressing practical problem

in the development of the area. In a Forest Service report of 1918 Grand Canyon Village was recognized as primarily existing to accomodate tourists, as there was really no other reason for a settlement so far from a reliable source of water. Questions of water sources, supply and seasonal change is of the utmost importance in the lives of these contemporary Southwesterners. To make life (without any serious thought of agriculture) possible in this region in modern times water has been acquired in the following ways:

1. Beginning in 1901 and continuing until 1969 trains hauled containers of water to Grand Canyon Village from distances of 80 - 120 miles.
2. In 1932 a pipeline was constructed to carry water from permanent springs at Indian Gardens in the Inner Canyon to the South Rim by means of a steam-driven pump.
3. A pipeline was constructed in the late 1960's to bring water from Roaring Springs below the North Rim to the South Rim.
4. The few pastoralists in the area have large "tanks" bulldozed in the earth to catch rainwater for their cattle to drink. Sealent must be applied to the bottoms and sides of these "tanks" to prevent rapid loss through the ground.

Just outside the Park boundary on Route 64 a real-estate office sells half-acre home sites. More than 3000 have been sold since the office first opened in the early 60's but just three of these sites are presently being occupied. Other potential residents are waiting for a better and presumably less expensive solution to the water problem than long distance truck hauling.

Many Grand Canyon villagers attempt to grow gardens and lawns but nearly all are doomed to failure even with daily doses of reclaimed water. In the spring and summer of 1970, I was employed as a Fire Control Aide in Hopi Fire Tower on the South Rim and had the opportunity to plant a garden beside my cabin at the base of the tower. I planted corn and squash seeds in hills in the manner practiced on the Hopi Reservation 150 miles or so to the east. I also planted some seeds in two abandoned buckets (in order to be able to bring them indoors if a late spring frost threatened). I watered this garden nearly everyday but with the exception of those seeds which were planted in buckets very little ever came up. These grew fairly well. Anticipating the rainy season beginning in mid-July I planted more seeds. On most days thunder showers occurred in the early afternoon, but the ground would return to its dry sandy state within an hour. As before, nothing came up.

Part of my duties at the fire tower included noon weather observations. If it was raining at noon the relative humidity

reading would be, of course 100%. Within half an hour the reading would return to 10-20%. Relative humidity is directly related to foliage type and ground cover. Fairly heavy August rain sink rapidly into the earth unimpeded, and this situation makes moisture from rainfall essentially unavailable for growing crops.

THE HYPOTHESIS

In light of my own observations I would suggest a change must have taken place between the prehistoric occupation of the area and the present time. I think it reasonable to hypothesize that this change occurred in the climate, accompanied by a change in the character of the ground cover rendering the soil too permeable for moisture retention.

Evidence recovered in the course of archaeological investigations in the area has also generated notions of climatic change: Bryan (1941) feels that an erosion cycle exists that is similar to one beginning in the middle of the twelfth century, and that present climatic conditions are therefore somewhat the same as those during the period just prior to the thirteenth century abandonment of the region. Wheat (1955) and Reed (1950) maintain that increasing aridity has made sedentary agricultural exploitation of the land impossible during present times, although it was possible in the past.

In summary, the evidence available to me indicates that

primary resource potential of the Grand Canyon area prior to the thirteenth century was greater than that of today; hence, accounting for the abandonment of the area at that time and the subsequent failure to recolonize it. Further, I suggest a climatic change as the most probable explanation for these phenomena. This paper will be devoted to exploring this possibility and its expected effects on the peoples of the late twelfth century as revealed through their cultural remains.

The first section will include a general survey of the geography of the Grand Canyon area. Later sections will deal with certain pertinent geographic details as they arise in succeeding discussions. Related to this and following it will be a survey of the literature regarding climate and climatological changes that have taken place in the last 1000 years. Research based on dendrochronology and palynology will be examined.

This section will be followed by brief discussion of the Anasazi tradition in Arizona - its development, spread and intensification. Evidence of man in the Grand Canyon region will be reviewed from the earliest sites through Pueblo III times. Thereafter, the South Rim site of Tusayan will be described and discussed in some detail, with special attention focused on site location, agricultural potentialities of this locality, and access to critical life support resources. This discussion will be based on a survey of the

literature as well as personal observations of the area.

Finally the phenomenon of abandonment and various theories concerning it will be examined to ascertain those arguments which represent the most reasonable alternatives to my contention that climatic change is the major factor inducing abandonment by the Anasazi in the thirteenth century.

GEOGRAPHY AND GEOLOGY

Local elevations range from 2500 feet above sea level at the Colorado River to 9200 feet on the North Rim, resulting in great extremes in topography and environment. The Colorado Plateau slopes up from south to north, with drainage toward the Canyon from the North Rim and away from it on the South Rim (See Figure 2). The Canyon and plateau have eroded accordingly and the Canyon South of the river is steep-walled with short dry side canyons. North of the river water and silt have eroded side canyons that are low and wide and characterized by springfed streams that seasonally flow into the Colorado River. The south side of the river from Lava Canyon to Unkar Delta has no running streams, and only sandy knolls separate beaches from the cliffs behind them. It is not surprising that most aboriginal occupation occurred north of the river.

Both the North and South Rims are formed of Kaibab limestone in which no springs occur. Kaibab limestone is

highly permeable and most water soaks through it quickly rather than passing along drainages. Water is to be found only in rare intermittent rock tanks or pools and these tend to be very small. The only permanent above ground drainage on the Colorado Plateau is Cataract Creek, located on the western side of the plateau in the side canyon of the Havasupai.

Soil is thin and poor. It is orange-yellow in color and gritty, with small pebbles throughout. Plants are mainly of the cactus-succulent varieties and very widely spaced, leaving much of the earth bare. As a result the windstorms of spring and early summer tend to pick up the soil to some extent.

In 1066 or 1067 Sunset Crater, a volcano near the San Francisco Peaks and the present town of Flagstaff, erupted. The ash from this eruption spread over an area of 800 square miles between the San Francisco Peaks and the Little Colorado drainage, forming a moisture-conserving mulch over the land. According to Colton (1933; 1949), Reed (1944), and Plog and Martin (1973), much of the Anasazi population increase observable from late Pueblo II to early Pueblo III times was related to this phenomenon. As the greater agricultural potential of this ash-covered land became known peoples moved into the area and the population swelled. The ash cover apparently made conditions for dry-farming and springs possible where they were not possible before and are not possible now. The region between the San Francisco Peaks and the Little Colorado is presently without any apparent water supplies.

Although there was no direct effect of this ashfall on any of the Grand Canyon area (the prevailing winds from the southwest caused it to pass to the east), certainly a wider social and exchange milieu was created as a result of increased populations to the east and south.

According to Colton (1932), southwesterly winds blew the black sand from the area and into drainages where it washed away. By A.D. 1200 most people had left the ash-fall area and by A.D. 1300 it was entirely abandoned.

CLIMATE

According to Schwartz (1971), neither the South Rim nor the Inner Canyon have sufficient rainfall during the growing season to raise maize without irrigation. And, as previously mentioned, moisture from precipitation is rapidly lost, primarily through evaporation at the lower elevations and seepage through the highly permeable Kaibab limestone and soil surface at higher elevations. Therefore, flowing drainage is not presently available to divert for irrigation.

The average annual precipitation on the South Rim is 15.5 inches, occurring mainly in the form of winter snows during December, January and February and in often violent convection storms from late July until the beginning of October. Yearly precipitation averages 6 inches in the 2500-3000 foot elevations of the Inner Canyon and 28.5 inches in the 7800-9200 foot elevations on the North Rim.

Temperatures vary from - 25° to 91° on the North Rim and the average growing season (from frost to frost) is 93 days - from about June 14th to September 15th. South Rim temperatures vary from - 22° to 98° with a growing season averaging 141 days. Average temperatures at Inner Canyon elevations vary from 19.4° in January to 106.5° in June. Summers within the Canyon are extremely hot and dry. There are on the average 200 frost free days each year (Schwartz, et. al.: 1971).

There apparently have been vast changes in this southwestern environment in fairly recent times. According to Schwartz's (1955) analysis of early Spanish records, there were grassy meadows, green valleys, and clear running streams in the Little Colorado area just to the east of Grand Canyon. This is a very different picture from today's dry, brown, arroyo-cut land.

Reed (1944) and Wheat (1955) believe that the Southwest in general has been and is still undergoing a long term of gradually increasing aridity. They note a progressive drying up of the climate following the last glacio-pluvial period. Evidence supporting this are palynological indications of a gradual retreat of the yellow pine forests, along with other floral and faunal changes.

A gradual change, however, could not totally account for the radically different Southwest of today from that which the Spanish recorded. A number of periods of deposition

and erosion which reflect probable climatic changes have been proposed by Bryan (1941), Gregory, and Hack (cited in Schwartz 1955). According to Bryan, today's type of erosion has occurred at least three times before. This is revealed in the palynological record by changes in the relative occurrence of cheno-am and compositae pollens. Cheno-am pollen (derived from chenopods and amaranths) is recovered from environmental situations that involve a dissected land surface, low water table, saline soil, and summer rainfall. Compositae, on the other hand, is dominant during conditions of higher undissected floodplains, higher water table, non-saline soil, and bi-seasonal precipitation. Two of these periods of deposition and erosion, the Tsegi and the Naha, have occurred within the time frame (ca. A.D. 1 to present) with which this paper is concerned.

Although the definite causes of these cycles is not clearly understood at the present time, Bryan postulates that the balance between protective ground cover and erosive sources is very delicate and that onset of these cycles is brought on by changes in the amount of seasonal distribution of precipitation. Therefore, during periods of deposition valley bottoms would be green and secured by ground cover. Top soil and organic debris deposited in the valleys via drainages would remain. Moisture would remain more readily available in the soil due to the impeding ground cover and

resultant soil composition. Possibilities of floodwater farming and irrigation would exist. Periods of erosion would lower the water table through arroyo cutting and therefore drain both the water and the silt from the valleys. Ground cover would decrease and soil permeability would increase. Therefore, during the depositional phase of the Tsegi cycle generally moister conditions would have made farming much more practicable.

These conditions continued during the Basketmaker era of the Anasazi, through Pueblo II times and into the Pueblo III period. Perhaps this is reflected in the fact that during the same time period Anasazi culture spread geographically, became more elaborate (resulting in more material remains), and also became locally specialized. During terminal Pueblo III the post-Tsegi epicycle of erosion occurred, occupying a time span between A.D. 1200-1350. The Canyon and both the North and South Rims were abandoned at the onset of this erosional cycle.

Deposition began again during the Naha cycle beginning about A.D. 1350 and continuing until 1700 when another epicycle of erosion began that continues to the present time. The landscape reported by the Spanish could well have been the result of this Naha depositional cycle.

As mentioned above cycles of erosion and deposition are thought to be the result of the interaction between changing rainfall patterns and the inability of the ground

cover to adapt to these new conditions. And, according to Reed (1944), the dendrochronological record does show several "droughts" followed by stormy periods. Gladwin (1946) points out that rings vary more due to changes in winter precipitation than changes in summer rainfall. Therefore the droughts indicated by Reed refer to a lack of winter precipitation.

Schulman (cited in Schwartz 1957) notes droughts occurring in the dendrochronological record in A.D. 715, 1100, and 1585, followed by stormy periods. The drought occurring in A.D. 1100 is the one of primary interest here. Immediately after A.D. 1100 there occurs a higher percentage of small rings than at any other time. This evidence suggests that there was a decrease in the amount of moisture effective in producing tree-rings, implying that precipitation came mainly in the summer months. Reed (1944) further notes in dendrochronological record that there was a stormy period following this drought, suggesting the return of winter dominant precipitation in the latter half of the 12th century. The erosion cycle beginning just prior to A.D. 1200 may have been triggered by this stormy period.

Schwartz (1971) suggests that agricultural developments do not reflect the amount of available precipitation as much as the time of year during which it occurs. Based on palynological evidence he records a gradual accelerating trend to a summer rainfall pattern, reaching its greatest

expression by A.D. 1100. From A.D. 1150 on there is a gradual return to winter dominant precipitation, and by A.D. 1200 it is the general pattern. The pollen samples involved were taken from the proximity of the archaeological sites at Unkar Delta on the Colorado River and also from the Tusayan site on the South Rim. Both sets of samples support this contention. Therefore, the palynological evidence supports the dendrochronological evidence regarding the shift from summer to winter precipitation and the ensuing stormy period.

Predominant winter precipitation allows extension of forest areas which are ecologically less varied and (biologically) less productive. The Inner Canyon showed the greatest biomass between A.D. 1000 and 1300 in the fossil pollen record-almost five times greater than that of the present time. Today, as is the case prior to A.D. 1100, summer and winter precipitation are about equally divided in a biseasonal pattern (Schwartz et. al. 1971). Schwartz feels that summer dominant rainfall increases agricultural possibilities and, indeed, it seems reasonable to suppose that rainfall during the growing season is of great importance. Euler (1967: 69), however, feels that the reverse is true, noting that:

> ...successful maize agriculture depends in large part upon soil storage of water...(and that) a change from winter to summer precipitation could well have made farming impossible...

On either rim, however, the very permeable nature of Kaibab limestone does not allow for appreciable soil storage

of water. The presence of ground cover would alter that situation to some degree, but I feel that the most agriculturally effective moisture is that which falls as rain during the growing season in the Grand Canyon area.

THE ANASAZI IN ARIZONA

By A.D. 1, the Anasazi were beginning to appear in the northern portions of the Southwest near the Four Corners Area where Colorado, Utah, New Mexico, and Arizona come together. Material remains found at the sites of the Anasazi at this time include fine baskets and sandals but no pottery - thus they have been termed Basketmakers and developmentally classified as Basketmaker I, II and III. Remains of maize and squash found at sites of this time period indicate that agriculture was already a part of their subsistence base. However, agri-products were supplemented by game brought down with spears, atlatls, rabbit sticks, nets, and snares. The sites in question are found in caves and rock shelters.

About A.D. 500 beans and cotton were introduced and new varieties of maize were developed. Fired pottery, cotton cloth, and the bow and arrow were added to the material culture assemblage. Circular pit houses and surface storage rooms appear.

According to Martin and Plog (1973) the heartier Harinoso de Ocho variety of maize was introduced from the south in about A.D. 700 and crossbred with existing varieties,

producing a new variety with a smaller number of rows and a flintier texture. This variety was more adaptable to some of the marginal areas of the state than other varieties and today flintier corn can still be found in the northern half of Arizona.

By A.D. 1050, the Anasazi had developed into the Classic Tradition of the Pueblo Expression, reaching its zenith first in the east in the Chaco Canyon area of northwest New Mexico and somewhat later in northern Arizona. These people lived in above ground rooms of masonry. Later these rooms became contiguous, eventually developing into multi-story apartment complexes in some areas. Pottery flourished and diversified into black on white ware, black on red, and polychromes. Jewelry appeared: turquoise mosaics, beads, pendants, and shell bracelets.

Pueblo II occupied the timespan between A.D. 900-1100, and a distinguishing feature of this period was the widespread distribution of small villages. This unit or single clan houses were built above ground of stone masonry and feature four to ten adjoining single story rooms.

The period of classic development is designated as Pueblo III in the Pecos Classification System. This period occupied the time between A.D. 1100-1300. Scattered settlements developed into towns through aggregation and large centers with multi-story pueblo apartment buildings appeared. Three great centers of Pueblo development peaked at Chaco

Canyon, Mesa Verde, and Kayenta. Arts flourished and there was intensive local specialization.

The Kayenta Regional Tradition occupied essentially the Colorado Plateau of northeastern Arizona and southern Utah. Included in this tradition are the Pueblo sites of the Grand Canyon area. The Kayenta region generally is a land of high mesas, canyons, limited rainfall, hot summers and cold winters. Aggregation did not begin in the Kayenta area until about A.D. 1150. Settlements were less dense and those that survived increased in size.

The succeeding Pueblo IV period was one of decline and, in many cases, depopulation and/or abandonment. More will be said about this in following sections.

GRAND CANYON OCCUPATION

The earliest evidence of man in the Grand Canyon area is in the form of split-willow figurines which have been found in caves in the Inner Canyon and the recesses of Canyon walls on both sides of the river. Carbon 14 dating places them between 2200 and 1100 B.C. These are apparently associated with the Desert Culture which was widespread over western North America from ca. 7000 to 2000 B.C. The fact that these figurines were found on both sides of the river suggests that it was not an uncrossable barrier. There is no other evidence of man in the area until A.D. 700.

The main period of prehistoric occupation occurred

between A.D. 700 and A.D. 1200 by the agriculturally based Cohonina, followed by the Anasazi. The Cohonina people appear to have come from the south and west and settled on a range of the Coconino Plateau that includes the South Rim. According to Euler (1967), the Cohonina disappear from the archaeological record by A.D. 1150 for reasons not yet clearly understood. Schwartz (1955) is certain that they settled in Cataract Canyon and became the modern Havasupai. The Pueblo people from the Kayenta region of the Anasazi Expression also appear in the Grand Canyon area about A.D. 700, but from the opposite direction. They first settled on the North Rim.

Although the Colorado River apparently acted as a barrier for a time (Wheat 1955), evidence exists for contact between the two groups eventually flourishing. A Cohonina site designated as Grand Canyon 505 was excavated by Joe Ben and Pat Wheat in 1954. G.C. 505 is located 200 meters west of the Tusayan ruin and consists of two pit houses, a group of storage pits, and four small above ground storage rooms. It was occupied from A.D. 700-900 and yielded 28% Anasazi wares and Pueblo I manos and metates.

By A.D. 900, Pueblo people had reached the South Rim. About A.D. 1000, another wave of Pueblo immigrants entered the Canyon region from the northeast and by A.D. 1050, Pueblo sites are found throughout the area - from rim to river.

Most Pueblo sites in the Grand Canyon area are of one

room or, occasionally, two adjoining rooms. A few are multi-room complexes. (See Figure 4) A 14 room pueblo was excavated by Schwartz in 1969 at Sky Island, a flat-topped formation projecting from the Canyon floor near the North Rim. Another multi-room site was excavated at Walhalla Glades on the North Rim the following season. In 1967 and 1968, Schwartz excavated several multi-room structures in the Inner Canyon along the Colorado River at Unkar Delta. Schwartz (1965: 293) suggests that the latter was an area of high population density for the land available and that:

> It is possible that this site was a center, that its large habitation site and kivas were not just related to presence of farmland but that the site served a wider area for a ceremonial or trade center.

Archaeological surveys along the Colorado River from Nankoweap to Unkar were conducted by Schwartz in 1965 and Taylor and Euler in 1966. Several other Pueblo III sites were discovered. Grand Canyon 548 consists of 8 rooms of storage and living units and is located at the Tanner Delta on the south side of the river, 100 meters east of the delta and 3 meters above its flood plain. Site C: 13: 2, a single, large masonry room 3.6 meters long, is located on a high sandstone ridge on the south side of the river. Across the river from the Unkar settlements, this site furnishes a lookout in all directions. Euler and Taylor (1966) surmise that it is associated with a cross-canyon trail from rim to rim through the Unkar Villages.

TUSAYAN

Tusayan is a small multi-room pueblo ruin located in a present pinon-juniper woodland on the South Rim about three miles west of Desert View, one mile south of Lipan Point and about ½ mile from the nearest Canyon edge. It is in the Upper Sonoral Life Zone at an elevation of 6800 feet.[1] In the Arizona Site Classification System its location is recorded as East DE-9.75 (Martin and Plog 1973) (See Figure 5). With its 8 or 9 contiguous living rooms, Tusayan is the largest site found on the South Rim.

A certain amount of confusion is caused by the fact that "Tusayan" not only designates this site but is also the name applied to an entire pueblo province which does not even include it. Hence, Tusayan ceramic wares are named for the province occupying the region of Black Mesa rather than the archaeological site. Twenty miles away from the site a small modern village is also named Tusayan.

Tusayan was excavated in 1930 by Dr. Emil Haury and Harold S. Gladwin under the auspices of the now defunct Gila Pueblo (Haury 1931). Tusayan is a broad "U"-shaped pueblo structure with two associated kivas (See Figure 6). It

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[1]Dortignac (1960) has concluded on the basis of his research that the pinon-juniper woodland type of vegetational cover is characterized by higher temperatures, higher wind movement, low relative humidity, and much higher evaporation rates than other forest types.

consists of 5 or 6 contiguous first story living rooms with a partial second story postulated from the amount of rock debris found heaped on the standing remains at the time of excavation. Connected to the central portion are wings on the east and west that are composed of what are considered by Gladwin to have been storage rooms on the basis that they are too small to have been living quarters (Gladwin 1946). They resemble present pueblo practices for storage. Prehistoric occupation of this site has been estimated at 25-35 individuals.

Two kivas are present but Haury does not feel that they represent two clans. Evidence instead suggests that one succeeded the other in use. One kiva is located at the juncture between the central living block and the west wing of storage rooms. The second kiva is situated about 15 feet from the free tip of the east wing of storage rooms. Construction is a rough, unshaped limestone boulder set in clay mortar. Vertical surfaces were heavily plastered.

The original letter designations of the kiva assigned by Haury reflecting the order in which he excavated them have been maintained in Figure 6. According to Haury, Kiva B precedes Kiva A in time of construction. Kiva B, it will be noticed, forms part of the contiguous structure while Kiva A does not. Kiva B apparently burned during occupation and Kiva A was built in and on the softer, more easily worked midden to replace Kiva B. An interesting point about Kiva A

is the fact that a metate was found partially imbedded on end in the floor, and was apparently used as a deflector between the vent and the fire pit. Haury feels that the comparatively poor construction of Kiva A indicates carelessness and haste on the part of the builders. Kiva A also burned, and a layer of trash overlying charred roof beams indicate that it happened sometime before abandonment. Apparently no attempt was made to replace this structure.

Haury feels that the nondescript character of the structures at this site indicate a lack of care in construction. He further describes the site as materially impoverished even though it was undisturbed at the time of excavation (Haury 1977: personal communication). Only a few sherds were found, no whole pottery, and two metates, including the one mentioned above.

Based on dendro-dates derived from six specimens of pinon charcoal recovered from the floors of the burnt kivas, Tusayan was occupied from ca. A.D. 1170 to 1205 (Haury 1931). For several reasons, however, these dates are thought to be unreliable. Haury himself suggests that pottery and architecture appear to be of styles at Pueblo III sites of a slightly earlier time period. Schwartz (1970 a.) notes that Black Mesa Black on White sherds such as those found at Tusayan appear in the Southwest Ceramic Series during the period A.D. 875-1130.

Gladwin subsequently re-examined the charcoal specimens and came up with a date of ca. A.D. 1054 to 1073 and pronounced the site as Pueblo II developing into Pueblo III. He suggested that Tusayan was peopled by refugees from Medicine Valley 50 miles to the south who were supposedly fleeing the cinder showers from the A.D. 1066 or 1067 eruption of Sunset Crater. (Gladwin 1946 a.)

Perhaps part of the dating problem stems from the fact that dendrochronology was then in its infancy and the charcoal specimens were very small and poorly preserved. Unfortunately there can be no retesting of these specimens as they were lost when archaeological material stored at Gila Pueblo was moved to the University of Arizona.

Whatever the actual dating may be, Tusayan is ceramically and architecturally well within the Pueblo III period and reflects associations to the northeast Marsh Pass area of the Kayenta Anasazi (Euler 1976; Haury 1977: personal communication). Sites of this time period in the Grand Canyon area are assigned to the Kaibab phase of the Kayenta Anasazi.

Tusayan was settled subsequent to the North Rim and Unkar settlements and may have been settled as a result of population pressures arising in those areas. Chronologically, the North Rim was settled first, followed by the sites at Unkar and finally by Tusayan. Population pressure of two types can be postulated - that from normal growth and/or external pressure exerted by nomadic Athabaskans on Kayenta frontiers to the north and east (Wheat 1955).

The fact that Cohonina site G.C. 505 was located only 200 meters from Tusayan suggests that this area had its attractions. Euler (1967) feels that Tusayan is situated for best access to rim-to-river trails. He notes a strong correlation between site locations and routes of access to the Inner Canyon. Wheat (1955) also notes that a possible chert quarrying site existed at a nearby limestone ridge.

A dominant factor must have been the agricultural possibilities of this area. Less than 100 yards to the east of Tusayan lies Coconino Wash which continues for several miles to the south and east as the major drainage of the area. (See Figure 5) The 100-300 foot broad, flat character of the wash suggests that a wide drainage existed sometime in the past. Today, however, a deep and narrow arroyo cuts into it and pinon-juniper vegetation has moved down and claimed the wash.

Haury (1977) feels that site placement is strongly linked to the agricultural possibilities of this wash. Ron Everhart, Grand Canyon National Park Service Archaeologist (1977), believes that the amount of earth in Coconino Wash suggests that a checkdam may have been constructed here by the Tusayan and perhaps the earlier Cohonina agriculturalists. Taylor (1958) has made the observation that, if the Tusayan group came from the river and/or the North Rim, they were well aware of terracing and wing dams, both of which are in evidence at North Rim sites and at Unkar.

While the narrow arroyo cutting into Coconino Wash and

the vegetation returning to its floodplain demonstrate erosion and a lowering of the water table, conditions may have been very different in the past. During a period of deposition it would have been much more promising agriculturally. Intact ground cover would have maintained the floodplain without the arroyo-cutting which lowers the water table and removes the top soil by carrying water and silt away at its lower level drainage.

In the similarly dry environment of the Hopi Reservation to the east, 3-4 acres per person over the age of two is cultivated today (Martin and Plog 1973). Coconino Wash would certainly have provided adequate cultivated area to support the people of Tusayan.

Another possible location for fields is on the Colorado River at the base of the Tanner rim-to-river trail. Although this would have required that Tusayan farmers commute twelve rugged miles to their fields, Haury (1977) notes that some modern Hopis are known to run 10 miles from their village to their fields and 10 miles back on a daily basis. Of course, this interpretation presupposes that the short narrow drainages available on the south side of the river at that point would provide adequate water supply in the hotter, more arid environment of the Inner Canyon.

Occupation of Tusayan may have been seasonal. Due to the impoverished nature of the site, Haury believes that it was occupied mainly during the summer, with winters spent in the

warmer elevations within the Canyon (Haury 1977). The Grand Canyon Natural History Association (1936) supports this idea and mentions the severe winters at the South Rim. Euler (1967) and Schwartz (1955) suggest the reverse seasonal occupation pattern. They note that the Havasupai, prior to their restriction to the canyon bottom in 1895 by the U.S. Government, occupied Cataract Canyon in the summer and the surrounding plateau region in the winter. Schwartz (1955: 224) advances three reasons for this arrangement: First, food to supplement the stored agricultural harvest could not be obtained within the canyon. Second, there were no firewood sources within the canyon. And third, humidity from Cataract Creek intensified the effects of the cold weather. The plateau, on the other hand, offers forage, hunting, and abundant firewood. Trees offer protection from the wind and the colder but dryer, air is better tolerated. An additional point is that the shade that is provided by the canyon walls until late in the morning and beginning early in the afternoon would be particularly unwelcome during the already short winter days.

Euler (1967) points out that the lower reaches of the Canyon would be better suited for agriculture because of the longer growing season. This is perhaps true, but even though the growing season is longer it is certainly much drier. It is possible also that frost free seasons on the rim may have been longer in the past. During a cycle of

deposition, for instance, ground cover and foliage would serve not only to retain moisture in the soil but also in the air, creating a higher relative humidity than that of today. Moisture in the air tends to hold atmospheric heat better than drier conditions. Vascillations between night and day temperatures may not have been so great as now, and late and early frosts not so prevalent.

The large building previously described as site C: 13: 2 may have been a seasonally occupied lookout constructed for the use of the Tusayan farmers. Euler (1966) believes that its high position on the sandstone ridge, with the wide view it offers in all directions, indicates its use as a lookout. River terraces and nearby dunes might have provided arable land. Even so, water would have had to be carried to the crops because of the limited Inner Canyon rainfall and the relative lack of drainage for the diversion of water on the south side of the river. Forde (cited in Schwartz 1965) notes that transporting water to plants in jugs is within the Pueblo tradition. Ollas, water proof baskets, and tumplines for easier carrying were also part of the Pueblo material culture.

Collins (1914) describes Pueblo maize as a type that is able to produce fair crops in areas were insufficient water would cause other varieties to fail. Hopi maize owes its success to the fact that it alone has the ability to force a sprout to the surface after being planted 12 to 18

inches deep. The sprouting part, the mesocotyl, grows to 4 inches in other maize varieties but in the maize raised by the Hopi it grows to a length of 12 inches. Another factor in its success is its ability to develop a single long root that rapidly descends to find moisture during the critical seedling stage.

Sources of water are important for other than agricultural reasons. More primary means of water consumption involve cooking and drinking, and Pueblo living required water for other purposes as well. In building construction, water was needed for both the mortar joining the limestone masonry and for the plaster that was used in surfacing the walls. Water is also need to soak fibres during the process of making baskets and for the manufacturing of pottery.

Presently there exist only two permanent sources of water within a 15 mile radius of Tusayan. Cottonwood Spring, originating from the Muav Limestone below Grandview Point on the rim-to-canyon Grandview Trail, produces an estimated 5 gallons per minute (Metzger 1961), and the Colorado River, 8 to 12 miles from Tusayan via the steep, switchbacked Hance, Grandview and Tanner Trails. The topography of the Canyon makes access to these sources difficult and time-consuming. However, this does not mean that these sources were not used to obtain domestic and drinking water.

Seasonal sources of water include rainfall and meltwater from winter snow and ice. Perhaps some of the latter

was stored in large ollas as they were emptied of stored food in the winter. Occasional seasonal springs occur in the Hermit Shale formation which underlies the Kaibab Limestone. Exposed only beneath the rim of the Canyon, this formation erodes through chemical action between rock and water into small potholes which collect precipitation.

Environmental stresses, such as a lack of easily obtainable free-running water, call for adaptive reaction. Kirmiz (1962) has observed among the Bedouin people of a hot, dry desert climate, that lean eating and little drinking go together and that, up to a point, a lack of adequate provisions in the environment can be accomodated. It is necessary to be careful about generalizing our own culturally based water needs to peoples of the past. Haury (1977: personal communication) has observed that present-day residents of Walpi, one of the Hopi Mesas, have to import water for domestic use from Polacca at $3.00 for a 55 gallon barrel. Consumption is less than one gallon per day per person.

Animal resources in the pinon-juniper forest zone included mule deer, antelope, mountain lions, bobcats, coyotes, jack rabbits, cottontail rabbits, porcupine, raccoons, ringtail cats, rock squirrels, foxes, woodrats, lizards, snakes, mice, and birds. By contrast there is a paucity of fauna in the Inner Canyon - occasional bighorn sheep, woodrats, mice, lizards, snakes, and birds. Schwartz et. al. (1971) identified suckers and catfish in the river along

Unkar Delta, but there is no evidence to suggest that they formed part of the Pueblo diet.

Edible plants of the plateau include prickly pear, yucca, mescal, cat claw, agave, whipple cholla, and pinon nuts. Schwartz (1955) mentions that the latter was one of the fall staples of the Havasupai. Pinons, however, only produce cones and nuts during seasons preceded by adequate winter precipitation. The winter of 1976-77, for example, lacked adequate precipitation to produce these pinon nuts that year. None of the above plants, other than the pinon, occur in any abundance. At the present time few gatherable foodstuffs grow below the rim. Those that do include mesquite (producing a sort of beans), prickly pear, and algae on streamside rocks. This disparity between non-agricultural resources in the Canyon and on the rim suggests the possibility of intense trading relationships between peoples of the rim and river. Tusayan may have needed agricultural products while those at Unkar needed game and its products and perhaps other wild foods and fibers for weaving. Taylor (1958) suggests that small granary-like structures Deer Creek Ruin, in the absence of any nearby arable land, might have been used to store imported foodstuffs from the rim.

ABANDONMENT

Anasazi populations increased between A.D. 850-1100 and peaked just before the first wave of abandonment beginning

ca. A.D. 1200. A general decline and movement from the great houses in the Anasazi area began about A.D. 1200. According to Martin and Plog (1973), Hopi villages, Kinishba, and Grasshopper grew with some of the immigration caused by this northern abandonment. The Anasazi area shrank from the whole northern fourth of Arizona to a small territory in the vicinity of the modern Hopi villages. Schwartz notes that depopulation appears to have coincided with the first period (ca. 1200) of abandonment of the northern Southwest (Schwartz 1965).

Both rims and river of the Grand Canyon area were abandoned by A.D. 1200, with the exception of Havasupai. Schwartz regards the fact that abandonment of rims and river was simultaneous as evidence of an intimate social and economic relationship between the residents of these areas (Schwartz 1971 b.).

Several reasons have been advanced for abandonment. One of the most popular notions is that pressure from Athabaskan nomads eventually reached the threshold of Pueblo ability to deal with it and the population was decimated and/or moved on. There is no direct evidence that such a thing took place in the Grand Canyon area, with the possible exception of burial 46 excavated at North Rim site G.C.: 212 which had a projectile point embedded in the shoulder (Schwartz 1970 b.).

Martin and Plog (1973) note that differences between languages of Apache and Navajo and that spoken in the North-

west Athabaskan language source area indicate that Apache groups began their move to the Southwest at about A.D. 825 and that the Navajo began about A.D. 1100. Therefore, these groups may have been making their presence felt in the Anasazi area at about the time of the early phase of abandonment ca. A.D. 1200. No direct evidence of Athabaskans predates A.D. 1390-1500 but nomadic peoples leave few traces. Gunnerson makes a good case for Athabaskan arrival in Pueblo areas for the first time around A.D. 1525. She mentions that Castaneda, one of Coronado's party in 1541 was told by the Pueblos that the newcomers had arrived rather suddenly from the Plains sixteen years earlier. Archaeological evidence recovered by Kidder indicates an abrupt increase in Plains artifacts about 1550 (Gunnerson 1956).

A further argument for raiders bringing about the abandonment of the Canyon is the fact that all movements seem to have been to the south, east, or west and never to the north. Lindsay (cited in Martin and Plog 1973) hypothesizes that many Pueblo III sites are located where there is a good view of the surrounding area, with the implication being that there was a need to be watchful. Several small masonry structures are located below the rim in the canyon wall and on sections of cliff that project out from the main rim. These pueblo structures appear fort-like in character. Euler (1966), however, notes that these sites are virtually cul-de-sacs cut off from all food and water and could not have been defended.

Lack of violence does not rule out the possibility of nomadic pressure. Basso notes the Cibeque Apache raiding pattern on the Spanish in the eighteenth century. The latter were considered economic resources that were valuable in producing grain and livestock that could be raided. It was advantageous to the raiders that such resources remain functioning. Property destruction and mass killing did not accompany these raiding activities (Basso 1970).

Another possible archaeologically undetectable result of Athabaskans in the area could have been the introduction of new diseases causing decimation of the Pueblo people in somewhat the same way that many native American populations suffered from European diseases with which they had no previous experience. Presumably Athabaskan populations of the Northwest had been separated from Anasazi populations for millenia - perhaps long enough and far enough away to have developed differing resistances to disease.

Colton suggests "bad sanitation" as a factor in population decrease and describes health problems that could result from a change from single unit structures to contiguous masonry pueblos which occurred about A.D. 1100. He notes a Pueblo population increase from about 3000 in A.D. 600 to some 23,000 by A.D. 1100, dropping dramatically to about 1900 in A.D. 1890. Excreta of the Pueblo families of today are deposited just outside the crowded living quarters but within the Pueblo plaza compound. Drinking

water collected from puddles and potholes is then contaminated. Hopi infant mortality from infantile dysentary is very great immediately after the summer rainy seasons. Until the early 1900's this disease killed many infants in civilized cities. Therefore, without adequate sanitation measures country life is healthier than city life. Navajos tend to live apart from one another in single family dwellings and perhaps because of this residential pattern morbidity of Navajo infants is much lower than that of the Pueblos (Colton 1936).

The Grand Canyon area is considered to have been marginal for the agriculturally based Pueblo people and Schwartz notes that few beads and pendants were found in Grand Canyon excavations and little to indicate that the people had surplus time and energy beyond that needed for necessities to expend on decorative items (Schwartz 1970a.). Paucity of remains at Tusayan also might be interpreted to support this position.

An already marginal existence can become impossible if conditions for agriculture become even worse. Climatic changes previously noted indicate that this must have happened. According to studies of fossil pollen in the area, abandonment occurred shortly after a change from summer dominant to winter dominant precipitation. Added to this is the erosion cycle that began in the latter half of the twelfth century following a stormy period that ensued after the winter droughts occurring around A.D. 1100. An erosional cycle would serve to lower the water table due to arroyo

drainage and the lack of summer precipitation would compound the problems of an agricultural people. There is evidence of a possible decline at the Tusayan site beginning with the nondescript character of the ruin in general. Kiva A, built to replace Kiva B that burned, reflects even shoddier construction and one of the two metates found at the site was in use there as a deflector. Occupation continued for a time after Kiva A burned but apparently no attempt was made to replace it.

Greater competition for dwindling resources may have led to intra- and inter-Pueblo strife. There is no direct evidence for this sort of thing actually occurring, but Martin and Plog (1973) do cite a skeletal population recovered from Polacca Wash near the Hopi villages in 1970 that includes thirty individuals of varying sex and age that were mutilated, dismembered, and probably cannibalized about A.D. 1600. So the Pueblo people did fight among themselves.

According to Wheat (1955) North Rim sites show increasing influence of Pueblo people from nearby areas in Utah from A.D. 900 on. This, along with natural increase in the already established number of sites, would have combined to exert ever greater pressure on the resources of the area. Zubrow's concept of carrying capacity as a dynamic equilibrium system is of interest here. In the optimal resource zone population will grow by natural increase or immigration until the carrying capacity of that area is

reached (or until pressures on the resources begin to make themselves felt). When this occurs daughter populations bud off and occupy the next marginal resource zone where the process repeats itself, but in a shorter time due to the lower quality of the resources in the marginal area. Daughter populations move into increasingly marginal areas. A negative change in the resources will speed this process of out-migration (Zubrow 1971).

Others mention local problems of the area such as depletion of soil, game, and firewood as causes in bringing on the abandonment of the Grand Canyon area.

It is reasonable to suppose that difficulties of several kinds caused depopulation and abandonment. Many of them may have resulted from or compounded the problems brought about by the change in climate and the accompanying change in water resources and ground cover.

Certain of the above pressures result in stress and, as Alland (1966) has noted, stress bears on morbidity in terms of lessened resistance to agents of infection. Alland (1966: 45) further states that "the negative effects of stress may well act as an adjustive mechanism to decrease population when a level of adaptive saturation is achieved."

SUMMARY AND CONCLUSIONS

One of the most pressing problems in the historic settlement of the Grand Canyon area has been the lack of agricultural potential of the Colorado Plateau and the absence

of reliable water supplies. Yet over 600 prehistoric sites of agriculturally based peoples have been found within the Grand Canyon National Park. Therefore, either a change in the capacity of the people to adapt to conditions in the area has occurred or a change in the environment, itself, has taken place since the area was abandoned at the turn of the thirteenth century.

The Grand Canyon environment is one of extremes. Elevations range from 2500' at the Colorado River to 9200' on the North Rim. Due to insufficient rainfall and the permeability of the Kaibab limestone capping the plateau of both rims, the area must always have been marginal for agriculture at best. Plateau drainage from north to south assured that the North Rim and northern side of the river had better water supplies than those on the south.

There are several indications that the geographic and climatic environment of today in the Grand Canyon area is different than that which existed during the prehistoric occupation. Climatic changes discussed above have included increasing aridity since Pleistocene times, changes from summer to winter dominant rainfall patterns, droughts followed by stormy periods, and cycles of deposition and erosion. The erosion epicycle present today is perhaps further augmented by recent loss of ground cover due to over-grazing of cattle earlier in the twentieth century.

Archaeological evidence indicates that Cohonina people moved into the Grand Canyon area from the south about A.D.

700 and Kayenta Anasazi began moving into the area from the north at about the same time. Both groups were agriculturalists. Except for a possible enclave of Cohonina in Cataract Canyon they are absent from the record after A.D. 1150. By A.D. 1050 Anasazi sites occupied both North and South Rims and the Inner Canyon near the Colorado River. By A.D. 1200 the entire area was abandoned.

Tusayan, a small site of the Pueblo III period, is the largest on the South Rim and was occupied for a period of twenty to twenty-five years in the late twelfth century. It had a population of twenty-five to thirty-five people who had an agricultural subsistence base.

Site placement of Tusayan may be related to the agricultural possibilities of Coconino Wash, proximity to rim-to-river trails, and/or population pressures on North Rim and Unkar sites. Pueblo III sites contemporaneous with Tusayan are located on both sides of the river in the Inner Canyon and on the North Rim. The fact that abandonment of these sites was simultaneous has caused speculation about the existence of a strong socio-economic relationship between these peoples. Animals and harvestable natural plant resources occur much more abundantly on the rim than in the canyon and could have provided a basis for trade.

As mentioned earlier, Coconino Wash near Tusayan is thought to be the site of agricultural activities. This wide drainage is presently cut by a deep, narrow arroyo. There exists the possibility of riverside crops as well.

Water needs other than for agriculture include masonry, cooking, drinking, basketry, and pottery. The nearest permanent source of water to Tusayan is Cottonwood Spring and the Colorado River, about seven and eight miles away respectively. Seasonal sources of water include rainfall, melts (and possibly storage in ollas), intermittent pot holes, tanks, puddles, and seasonal springs which may have occurred in years of adequate winter precipitation in the Hermit Shale formation accessible from rim-to-river trails.

Anasazi populations increased between A.D. 850 and 1100 and peaked just before the first wave of abandonment beginning ca. A.D. 1200.

Several reasons have been advanced for abandonment - pressure from enemy raider, disease resulting from pueblo living condition, internal strife, population pressure, and climatic changes and their effects. There is little evidence to support either strife or enemy pressure, but palynological and dendrochronological data do support the occurrence of possibly deleterious climatic fluctuations. It is probable that several factors were involved in the abandonment of the Grand Canyon area but the following lines of evidence suggests that climatic change was the prime factor: First, there is the fact of the abandonment and the subsequent failure to recolonize the area. Secondly, the only group remaining in the area were the Havasupai. Their's was a unique situation, for the permanent waters of Havasu Creek would have been easily diverted for irrigation. Thirdly, domestic crops

can not be grown in the area at the present time. Finally, palynological and dendrochronological evidence along with historic observations of the Spanish support the occurrence of a deleterious climatic change.

The contention that the Grand Canyon area was marginal for prehistoric agriculture is supported by the archaeological recovery of very few decorative items, and a decline is suggested by the nature of the Tusayan construction and other aspects of the site.

Stress resulting from the above causes many have further reduced the adaptable effectiveness of the people.

Therefore, it would seem that these peoples, already living under marginal conditions for their agricultural way of life, were beset by changes in resources that eventually made it impossible to persist as agriculturalists in the Grand Canyon area. The fact that only the Havasupai with their permanent source of water remained suggest that people were responding to insufficient water resources when they abandoned the area at the end of the twelfth century, and that historic settlers were responding to that same inadequate water supply when they subsequently failed to resettle the Grand Canyon area.

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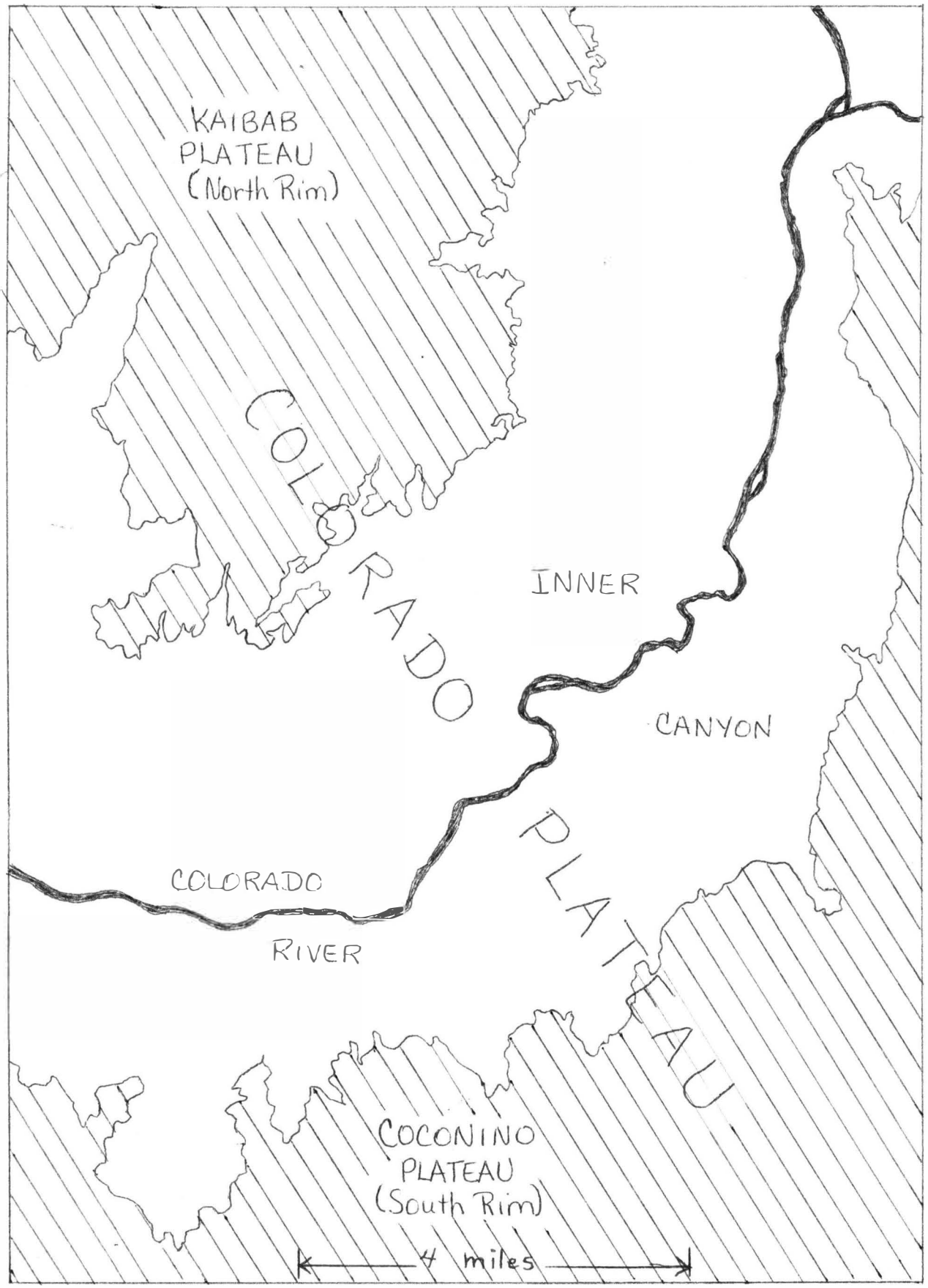

Figure 1 -- The Colorado Plateau

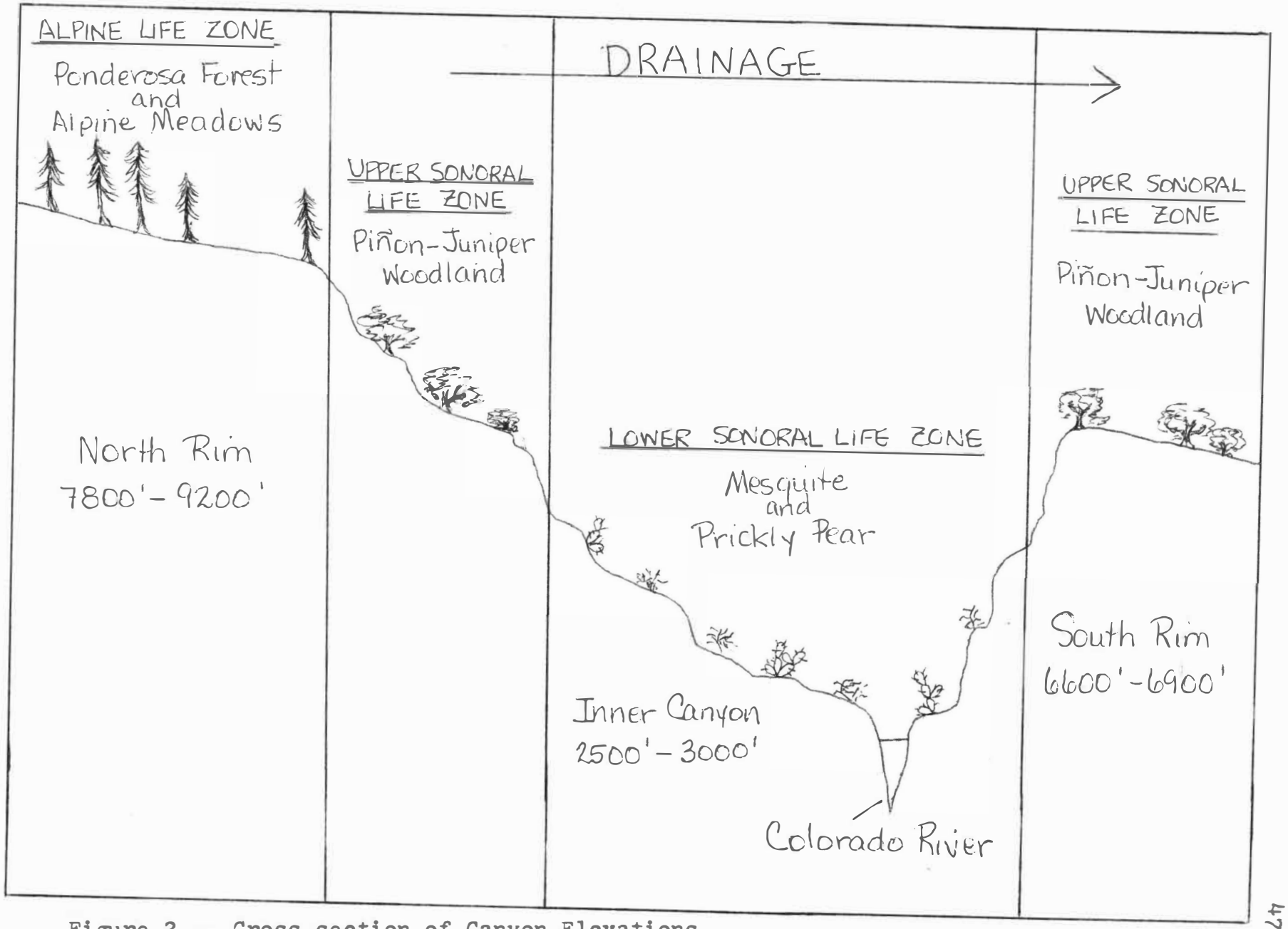

Figure 2 -- Cross-section of Canyon Elevations

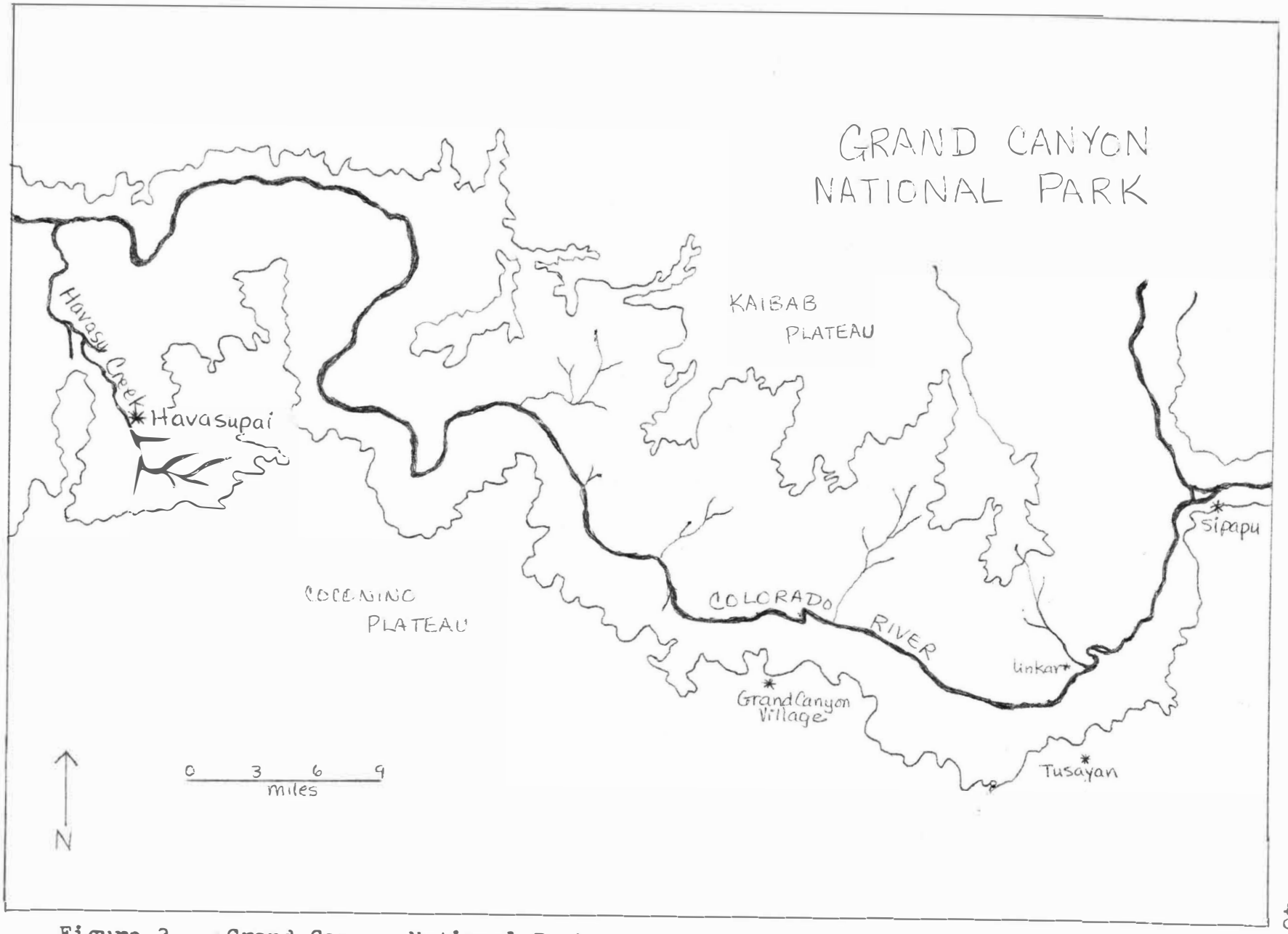

Figure 3 -- Grand Canyon National Park

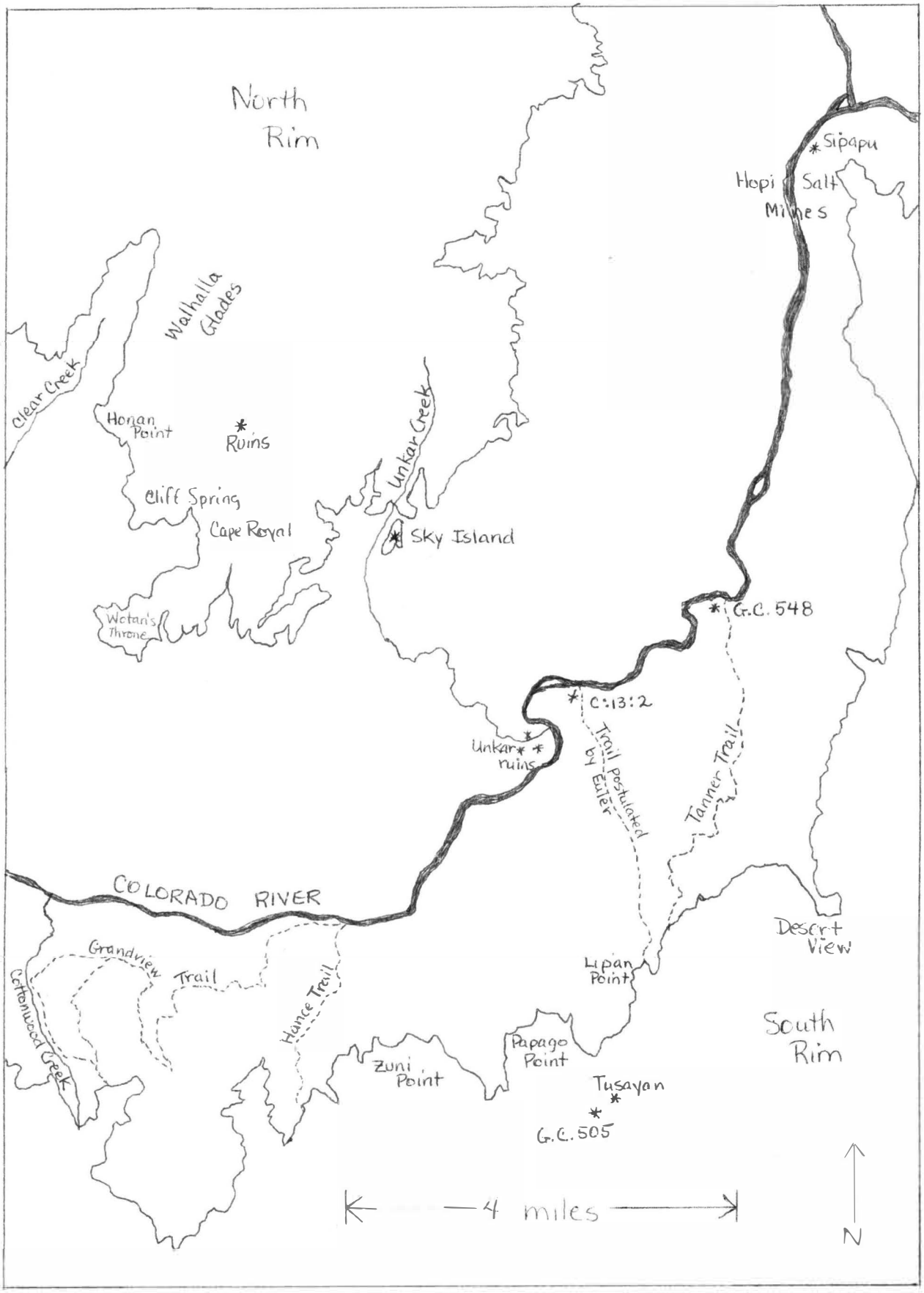

Figure 4 -- Sites near Tusayan

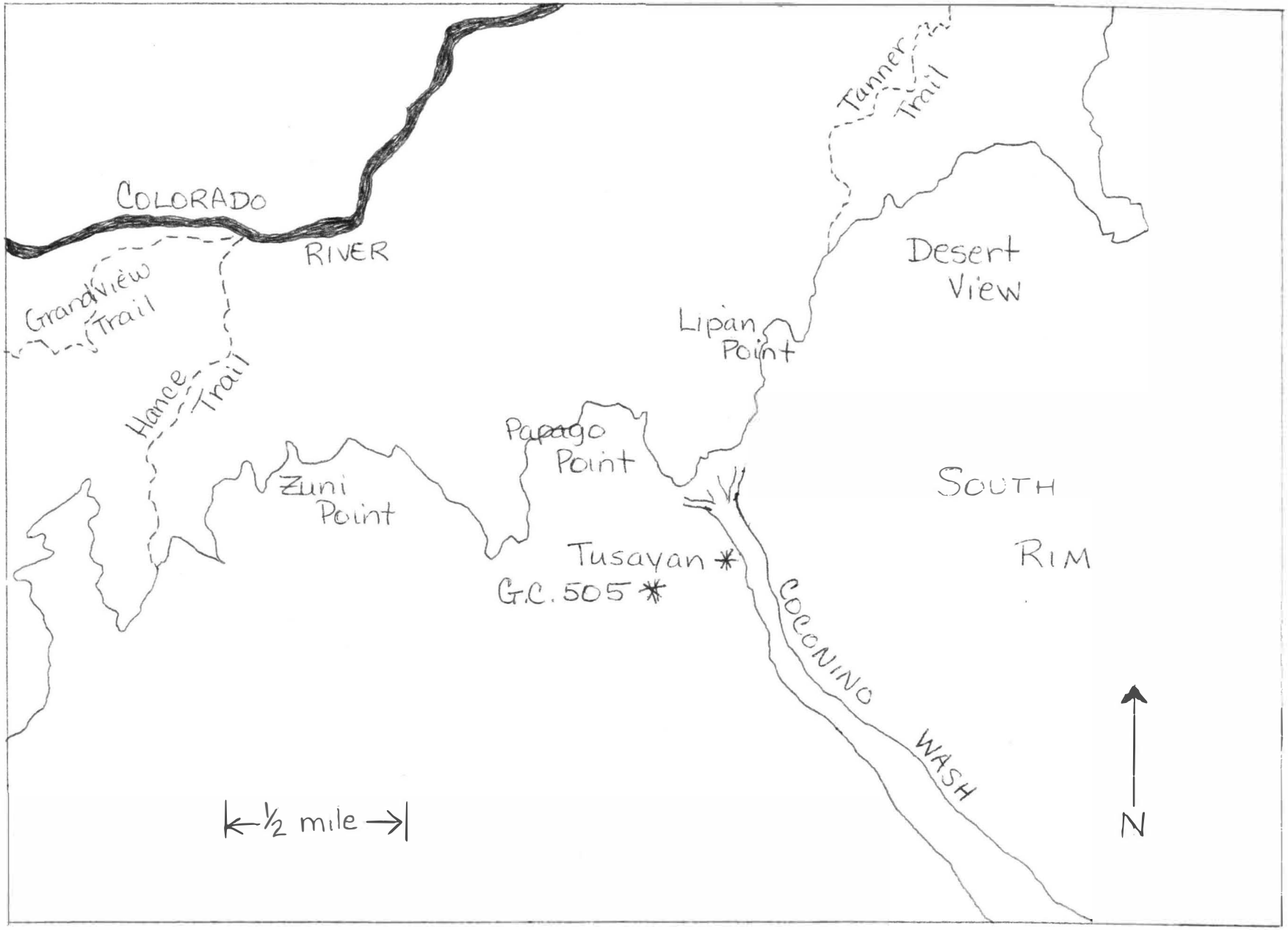

Figure 5 -- The Vicinity of Tusayan

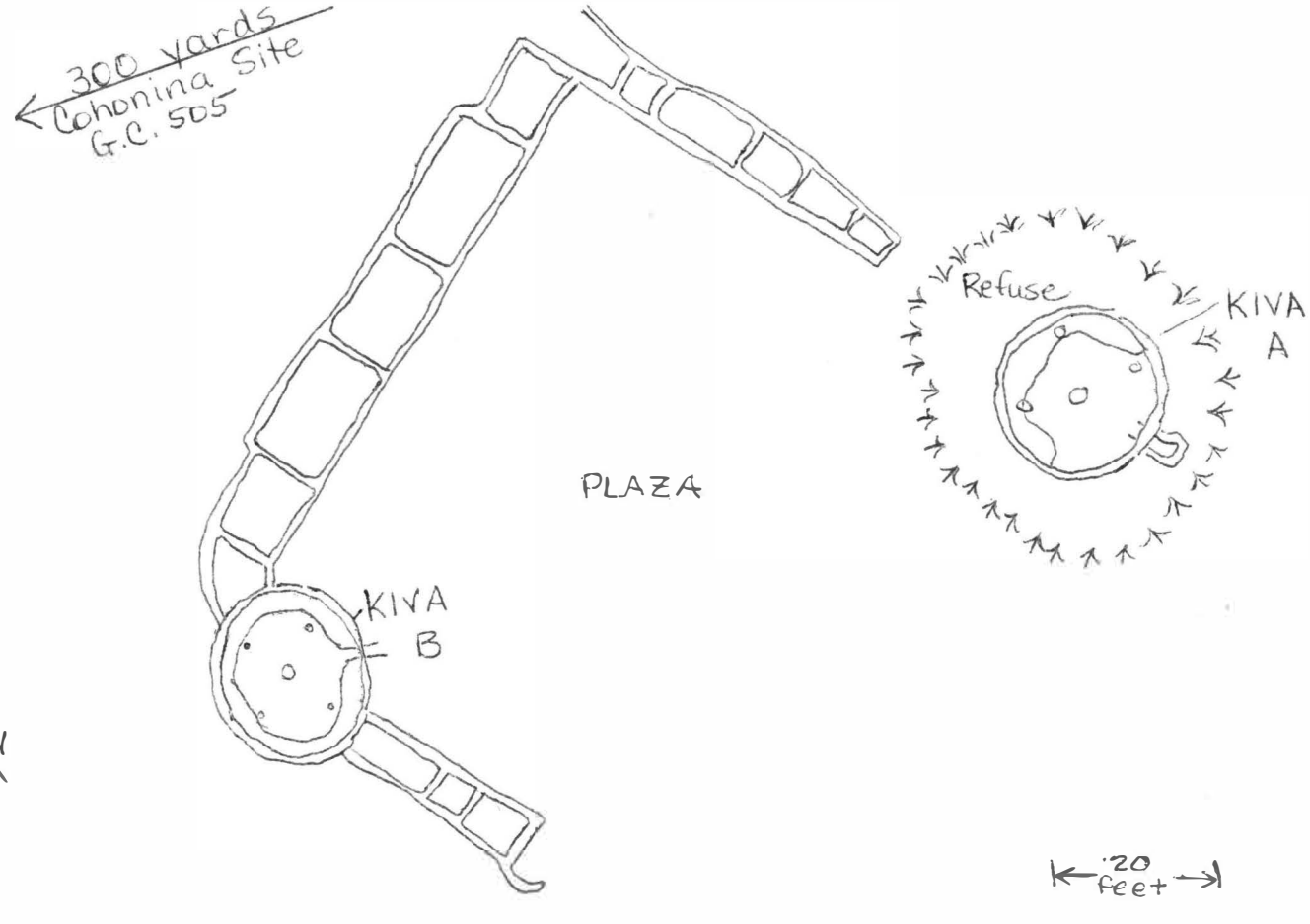

Figure 6 -- Tusayan Site Map