# GRAND CANYON Nature Notes

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# GRAND CANYON NATURE NOTES

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M. R. Tillotson,
Superintendent.

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Park Naturalist


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# FIELD STUDIES OF THE ARCHEAN IN GRAND CANYON


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THE OLDEST ROCKS of Arizona which form the precipitous walls of the inner or granite gorge of the Grand Canyon have never received the intensive study that has been given to their counterparts over the great northeastern plains of Canada, in the mountains of Scandinavia or on the rolling expanses of Finland. The metamorphosed rocks standing in places on end under the wedge of the Grand Canyon series of sediments (Algonkian) and elsewhere under the mantle of Paleozoic sediments are known as the Vishnu schist. To J. W. Powell[1] these were known as the "Grand Canyon schists" of tentative "Eozoic" age. C. D. Walcott[2] who proposed the term Vishnu from the occurrence beneath Vishnu temple in the Grand Canyon classified[3] them as "bedded, sedimentary, unconformable, pre-Unkar (Lower Grand Canyon series) strata".

The most complete available report has been given by Noble in "A Reconnaissance of the Archean Complex of the Granite Gorge, Grand Canyon, Arizona". In this study it is indicated that the schists represent an original sedimentary series, cut by intrusives, and subjected to regional metamorphism.

It is hoped in this sketch to present some evidence as to the nature of the schists based upon field studies in the


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1. The Geology of the Eastern Portion of the Uinta Mountains, p. 70 (1876)

2. Walcott, C. D., Am. Jour. Sci., 26:439 (1883)

3. Walcott, C. D., U.S.G.S. 14th Ann. Rept., p.506 (1894)

4. Noble, L. F., U.S.G.S. Prof. Paper 98-I (1916)

gorge during the fall of 1932. The research is made possible by the cooperation of the United States National Park Service and the support of the Carnegie Institution of Washington.

## OUTLINE OF ROCK RELATIONSHIPS

The Archean rocks of the Grand Canyon inner gorge stand in an almost vertical position, very rarely displaying any marked dip to the east or the west. They possess a regional strike of N 15-30° E. Igneous injections and schists are intimately intermingled. The sequence of deposition of the sediments is at present unknown. Cross-bedding in Lone Tree Canyon gives meagre indication that younger strata occur to the west. On the other hand, in the western part of the gorge a large body of gneiss is exposed for which Noble[1] suggests the interesting possibility of being the primordial basement upon which the Archean sediments were deposited.

The writers have as yet been unable to visit the critical areas and are thus not in a position to contribute to this fundamental problem of the Grand Canyon Archean. Study of these areas is contemplated in the near future.

## ROCK TYPES

### Introduction

Geologists classify all rocks into three great groups - the igneous,(those solidified directly from molten material); the sedimentary, (those deposited as fragmentary material by wind or water); and the metamorphic, (those whose original features have been changed by heat and pressure). Only the first and last types are found in the Archean of the Grand Canyon, and of these the metamorphic are probably the oldest, perhaps the most abundant and certainly the most varied, so they will be discussed first.

1. Noble, L. F., and Hunter, J. F., U.S.G.S. Prof Paper 98:112 (1916)



Figure 1. Looking south across the Colorado River from the mouth of Bright Angel Creek, showing the precipitous crags of Vishnu schist and associated granite sills forming the walls of the inner gorge. In the upper left is a capping of Algonkian strata.

Photo by U.S. National Park Service.

## Metamorphic Rocks

As is indicated in the brief definition above, metamorphic rocks have always had a "past history" -- they were not always as we see them today,and it is the unravelling of this past history that is one of the major problems of the present day study. It is plain, in the case of certain types, that they must have been originally of sedimentary nature;in other cases, it seems likely that igneous rocks have been their ancestors; in still other cases - and these are the majority-

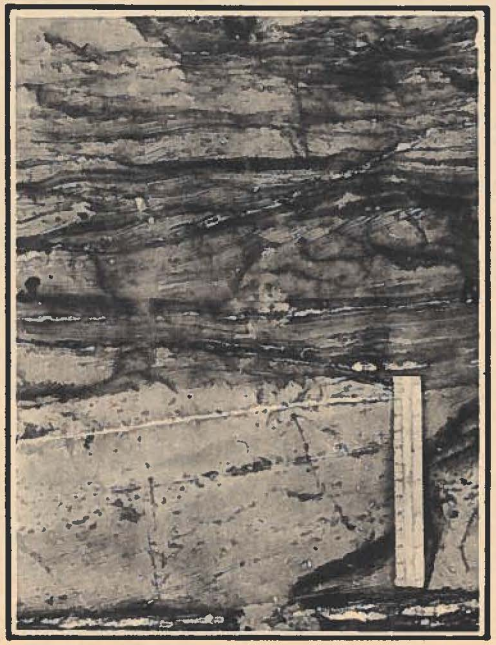

Figure 2. Cross-bedded mica schist in the bed of Lone Tree Canyon.





the original character must await chemical and microscopic study for its detection. Brief descriptions of some of the metamorphic types follow.

Quartz mica schist. This is one of the commonest types. It is usually light in color, finely foliated, and consists of closely interwoven bands of silvery white mica and quartz. In some cases, the ancestry of this type is uncertain; in others, there is no doubt of sedimentary origin. Thus in a notable exposure in Lone Tree Canyon, beds of quartz mica schist were found in which such an unmistakable sedimentary structure as cross-bedding was still preserved. (See fig. 2). Such rocks have been developed as the result of metamorphism of shaly sandstones, like those occurring in the Bright Angel formation.

Quartzite. This is a type not unlike the preceding, except that mica occurs in small to vanishing amounts. The high content of silica, and the rounded character of the quartz grains, which can be detected in some instances, are strong indications that this type was originally sedimentary. Lentils of quartzite are found in the schists of Lone Tree Canyon,and other occurrences have been noted in and near Pipe Canyon. The original rock in these cases may well have been a sandstone similar to the Tapeats sandstone.

Chlorite schist. This is a type in which the brittle, green, micaceous mineral, chlorite, is the chief constituent. Quartz and various other minerals may be present in greater or lesser amounts. This is a widely distributed type, and in most cases is of uncertain origin.

Amphibolite schist. The principal constituent of this type is a dark green to almost black amphibole, which may be either hornblende or actinolite. The structural relations as well as the texture (which is very dense) and mineralogy of this rock suggest that it may have originally been an igneous type, similar perhaps to a basaltic dike. These dike-like structures are found in Horn Canyon and Lone Tree Canyon.

Garnet schist. This is a distinctive type, characterized by small to large garnets (some are over an inch in diameter) which are irregularly distributed through the rock and stand out prominently by virtue of their bright red color and of their hardness, which is greater than that of the surrounding quartz and mica. The origin of this type is uncertain. Specimens are found in Pipe Canyon and Phantom Canyon.

Staurolite schist. This is a rare type, seen only in Lone Tree Canyon. The mineral staurolite, which stands out on the surface of the rock in dark, roughly elongated crystals or in interesting cruciform structures, gives it its name, although quartz and mica are abundant constituents. In a related variety, garnet is also present, thus forming a garnet-staurolite schist. Both types may have resulted from the metamorphism of sandy shales, such as are exemplified by beds in the Bright Angel or Supai formations.

Magnetite schist. Very dark colored schists, unusually hard and unusually heavy, were found in Pipe Canyon. The chief constituent is the iron oxide, magnetite. Their distinctive composition may be the result of the metamorphism of an Archean sedimentary iron formation, and immediately suggests the interesting possibility of correlating with the Archean iron formations of the Lake Superior region.

Lime-silicate rocks. In a few places, notably in lower Horn Canyon and upper Pipe Canyon, there are to be found rather coarsely crystalline rocks consisting of epidote, garnet and diopside, frequently accompanied by calcite and occasionally by black tourmaline. This is an assemblage typically due to the contact metamorphism of impure limestones or calcareous shales. It points rather clearly to a sedimentary origin for the rocks in question.

Gneiss. This type, which is distinguished from the schists by its much coarser foliation, is very abundant. The commoner types have about the same composition as granite, and are therefore called granite gneiss. This type grades insensibly into a rock best described as a gneissoid granite (i.e., a granite possessing some degree of parallelism of its minerals) which in turn can be traced, through almost imperceptible





changes, to a true granite.

Now this type of metamorphism, evidenced in the foliation of the granites, may have come about in several different ways. (A) It may be the result of the same tectonic forces which tilted up the sediments and largely accomplished their metamorphism. (B) It may have developed from the convection currents set up within the granite magma at the time of its intrusion (flow-banding). (C) It may have come about because of directed pressures operating on the viscous magma just before its crystallization (piezo-crystallization). (D) It may be due to relict structures persisting from earlier metamorphosed rocks which the granite has in large part assimilated or replaced. In the case of the first type cited, (A), it would indicate that the intrusion of the granite antedated the general folding, tilting and metamorphism. In the case of the last three it indicates that the intrusion was either concomitant with or followed the general metamorphism. It seems likely that examples of all types are present in the Grand Canyon. Thus, (A) is represented by a quartz-diorite gneiss found to the west of Horn Canyon. (B) and (C) may both be illustrated by some phases of the gneissic granite along Garden Creek; while (D) may be exemplified by portions of the granite body found along Phantom Creek.

Migmatite. Another kind of rock which represents a transitional type is one in which many thin, sheet-like intrusions of granite lie parallel to, and alternate with, layers of schist. Such a phenomenon is explained by the principle of "Lit-par-lit injection". It is beautifully illustrated by some exposures in Pipe Canyon, but is found in many other sections as well. Inasmuch as such a rock consists partly of schist (which may have been originally sedimentary material), and partly of granite, it is a mixed rock or migmatite.

## Igneous rocks.

The igneous rocks have already been partly discussed in connection with the gneisses. The principal types to be noted are the following:

Granite. This is a coarse-grained, usually light colored rock, sometimes showing a faint foliation in the parallelism of the flakes of black mica which are almost universally present. Hunter[1], who examined various specimens of these granites under the microscope, reported the presence of quartz, microcline, sodic plagioclase, biotite and a little orthoclase. The granites occur in bodies varying from small dikes an inch or less wide, to stock-like structures which represent tens of thousands of cubic yards of material. One of the best exposures of granite is in the lower part of Phantom Creek, not far above its junction with Bright Angel Creek. Because of its location, the suggestion is made that this rock be called the "Phantom Granite". Here, as well as at most other places where granite is well exposed, there appear to be two distinct types; a light gray to white granite, and a pink to red granite. Careful study, however, will usually reveal transitions between the two types, and it seems altogether likely that the pink and red granites have been developed by certain secondary changes ("deuteric alteration") operating on parts of the white granite, which therefore represents the original type.

The mode of emplacement of the granitic bodies is another of the problems for which solution is sought by this study. On the basis of present knowledge, the writers favor the idea of large-scale assimilation and replacement to explain the relation of the granites to surrounding rocks, rather than the simpler and somewhat better known idea of block-stoping, which, nevertheless, may have played its part.

Pegmatite. Many of the igneous intrusions display an unusually coarse texture - large crystals of quartz or feldspar or mica have been developed. Such rocks are known as pegmatites. In composition and general relationships they are closely connected with the granites, and may in many cases represent off-shooting dikes from the main granite bodies. Pegmatites are well and abundantly exposed along the lower part of Bright Angel Creek. These rocks represent the last phase of Archean igneous activity.

1. Noble and Hunter, op. cit.



Figure 3. A water-worn surface in the lower course of Pipe Creek showing crenulation of the schist and injected pegmatites. Photo U.S. Nat'l. Park Service.

## RESUMÉ OF ARCHEAN HISTORY IN THE GRAND CANYON

This resume makes no pretense to completeness or accuracy in detail, but it is believed to be justified by the comprehensive picture provided of the early, little known days of the earth.

The great series of Vishnu schists are the oldest known rocks of the Grand Canyon. So far as is known, they are not repeated by folding or faulting and consequently represent a very thick series of sediments deposited by an Archean sea. Whether or not the original granitic basement on which they were deposited is exposed in the western part of the inner gorge is merely a matter of surmise, as Noble has indicated. We cannot correlate the sediments with the Coutchiching or later Temiskaming series of the Canadian shield. Though proofs of discontinuities in sedimentation are lacking, the thickness of the section itself presumes a very long interval of time. It is probable that several epochs of Archean time were represented. (According to the best estimates, the Vishnu rocks are of an order of a billion years old.)

But the eons of time required for the accumulation of the sediments is a small part of the total Archean history. There came a period of mountain-making activity associated with regional metamorphism when the great series was turned up on end. Vertical pressures developed by the weight of overlying rocks and horizontal pressures developed by earth movements, together with great heat modified the original rocks, obliterating in large measure their original sedimentary features and recrystallizing their minerals.

Perhaps associated with the later phases of this activity, perhaps succeeding them, large amounts of granitic magma welled up into the crust, searching out fissures and impregnating the foliated rocks. This was a phenomenon of widespread occurrence throughout the whole region now occupied by the Grand Canyon. The pink granites of this intrusion are possibly to be correlated with the Laurentian granites of the Canadian shield which followed a similar epoch of mountain-making activity, the Laurentian Revolution. Little is known





of the lofty northerly trending mountain range which at this time must have dominated the landscape of Arizona and Utah.

The last great chapter of the Archean history of northern Arizona is not written in the constructive events of sedimentation or mountain formation but in the destructive activity of erosion (which carried the materials of the high-lying areas, little by little, to the streams and winds, thence to be distributed far away). In consequence of this process, continued over an extremely long period of geologic time, (known to geologists as the Ep-Archean interval), a broad, generally level land surface was developed over northern Arizona.

How long the wearing away of the land continued cannot be stated, but from the great thickness of rock removed, it must have been a very long time. The amount of the stripping may have been of the order of five miles. Some geologists believe that the time which elapsed during this interval of erosion may have been as long as all time since the beginning of the Cambrian, when the first layers of the Tapeats sandstone were laid down. If so, it would be several hundred million years in length. The interesting feature of this gap in sedimentation is that it is recognized everywhere on the earth where Archean rocks are exposed.

Eventually the sea again transgressed the land, reworking fragments of Archean schists and granites exposed on the surface and incorporating them in a basal conglomerate. A great thickness of sediments was deposited during this, the Algonkian Era, before mountain-making and erosion again occurred. The Algonkian beds lie on the truncated surface of the Archean schists near Bright Angel Creek and northeast of Grand View. The Algonkian beds themselves are bevelled and overlain by the great series of Paleozoic sediments forming the outer walls of the Grand Canyon.