A CAMBRIAN SLIDE BRECCIA, GRAND CANYON, ARIZONA.

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ABSTRACT. A coarse breccia consisting almost entirely of Algonkian Shinumo quartzite fragments is exposed at the base of the Cambrian Tapeats sandstone at one locality in the Grand Canyon. Various lines of evidence are cited to show that this breccia mass is a slide from a nearby Ep-Algonkian monadnock, the slopes of which had been undercut and oversteepened by marine erosion.

INTRODUCTION.

NUMEROUS breccias[1] have been attributed to an origin by sliding, but there are few in which the evidence for this is conclusive. The one described below, therefore has exceptional interest because its origin is clear.

The deposit is exposed on the west wall of Ninetyone Mile Canyon, which heads on the south flanks of Isis Temple almost due north of the Grand Canyon village in the Bright Angel quadrangle.[2]

Opportunity to make this study occurred during the Carnegie Institution-California Institute of Technology Grand Canyon Expedition of 1937, and the aid of these institutions is gratefully acknowledged. Leland Horberg has kindly suggested changes in the manuscript.

GEOLOGICAL SETTING.

The geological relations are shown in Text Fig. 1, and Plate I, Fig. 1. Archean igneous and metamorphic rocks are overlain unconformably by tilted Algonkian sedimentary beds, and both the Archean and Algonkian are truncated by the Ep-Algonkian erosion surface (Hinds, 1935, p. 7). This surface is buried beneath essentially horizontal Cambrian Tapeats sandstone, and the breccia lies at or a few feet above the base of the Tapeats. A few hundred feet north of the northern-

[1] Some students prefer to recognize only breccias of tectonic origin, others recognize both tectonic and sedimentary breccias. At present the latter view is the more widely accepted and is the one adopted here.

[2] Ninetyone Mile Canyon is not named on the Bright Angel quadrangle, but it is so named on the U. S. Geological Survey profile maps of the Colorado River, 1924, sheet C.

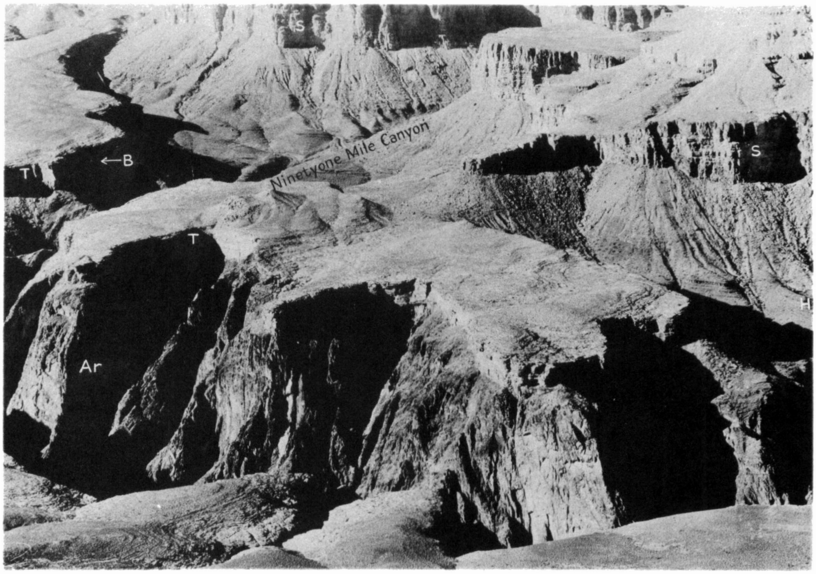

FIG. 1

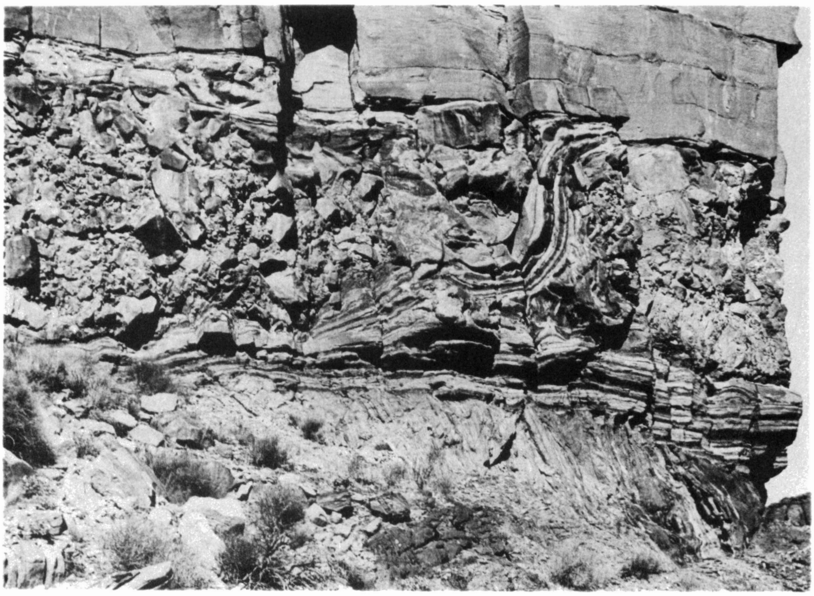

FIG. 2

FIG. 1. View northwest to head of Ninetyone Mile Canyon. B—slide breccia at base of Tapeats (T) which has been derived from the Shinumo quartzite (S). Ar—Archean, H—Hakatai. Section in text Fig. 1 cuts about through the T, B, and S near left edge. Inner gorge of Colorado River in foreground. Photograph by courtesy of U. S. Department of Interior.

FIG. 2. Slide breccia in basal Tapeats. Ninetyone Mile Canyon. Breccia bed is about 15 feet thick. Slide moved from right toward left.

most outcrop of the breccia is a fault wedge of Algonkian (Text Fig. 1) which survived the Ep-Algonkian erosion owing to its down-faulted position. The Shinumo beds of this wedge form an asymmetrical ridge-like monadnock or hogback, 700 to 800 feet above the level of the Ep-Algonkian surface. Part of the ridge is now clearly visible on the north side of the Grand Canyon near the south base of Cheops Pyramid and is easily recognized from observation points on the south rim (Plate I, Fig. 1). The dashed line in Text Fig. 1 represents approximately the outline of the monadnock before it was partly destroyed by modern erosion.

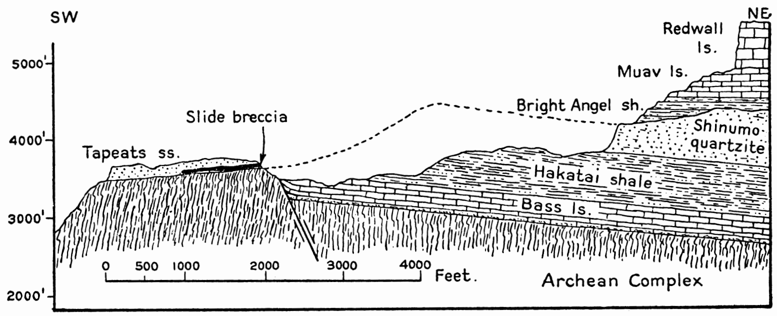

Fig. 1. Structure section across head of Ninetyone Mile Canyon. Dashed line represents restored outline of Ep-Algonkian monadnock from which slide breccia was derived. Bass, Hakatai, and Shinumo are Algonkian; and the Tapeats, Bright Angel, Muav, and Redwall are Paleozoic.

DESCRIPTION OF BRECCIA.

The breccia is 5 to 20 feet thick and rests upon two to five feet of basal sandstone beds, except locally where it appears to lie directly upon the Archean. It contains chiefly fragments of the Algonkian Shinumo quartzite and occasional fragments of the Archean complex and basal Tapeats set in a meager sandy matrix (Plate I, Fig. 2). The fragments are a fraction of an inch to ten feet in diameter and extremely angular except at the top where some are slightly rounded. They are jumbled together in a disorderly manner with no sorting or stratification. The matrix is a reddish-brown, ferruginous sand which comprises only a minor part of the deposit except near the top. The beds beneath the breccia are thin, alternating brown and white sandstones composed of material derived from the Shinumo quartzite and the underlying weathered Archean granite and schist. These beds have been severely deformed and locally incorporated in the breccia (Plate I, Fig. 2). In places they are dented by large fragments which rest upon them (Text Fig. 2) indicating that they were soft and unconsolidated when the fragments were deposited. Near the southern edge of the breccia a small fault in the underlying beds shows movement toward the southwest. Since this fault does not extend into the overlying beds, it is probably contemporaneous with the breccia. The upper surface of the breccia deposit is relatively smooth, and the overlying beds are typical Tapeats sandstone.

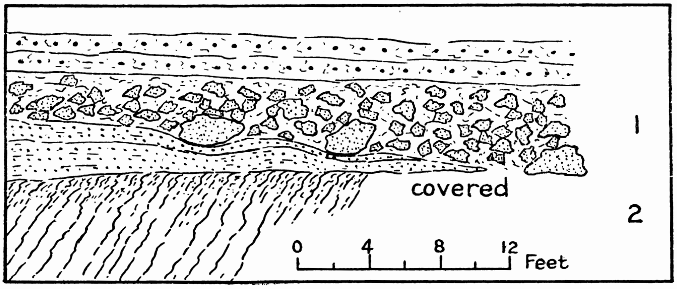

Fig. 2. Field sketch of basal Tapeats breccia. (1) Breccia bed, (2) Archean complex. Note depression of beds beneath large fragments.

The apparent competency of the deformed beds appears somewhat puzzling, for they must have been relatively soft and unconsolidated at the time the breccia was formed. However, the investigations of Cloos (1928) and Rettger (1935, p. 275-279, 286-288) on various types of deformation and Hubbert's (1937) discussion show that unconsolidated materials are reasonably competent if deformed under proper conditions. The deformation associated with the breccia occurred under such conditions that unconsolidated materials were folded and even faulted locally. A sudden, powerful force would give this type of deformation.

The breccia does not appear on the east wall of Ninetyone Mile Canyon nor on the walls of Trinity Creek[3] a mile to the west. The known areal extent is approximately one quarter of a mile north-south and one quarter to one half a mile east-west. A calculation based upon estimates of thickness and areal extent shows that approximately four million tons of rock are involved.

[3] Communication from Ian Campbell.

ORIGIN OF BRECCIA.

Outstanding features of the deposit are: (1) Size and angularity of fragments and the fact that most of them are composed of Shinumo quartzite. (2) Lack of sorting or stratification. (3) Deformation and incorporation of the underlying beds. (4) Limited areal extent. (5) Abrupt termination. (6) Proximity to an Ep-Algonkian monadnock of Shinumo quartzite. These features indicate sliding as the most likely mode of origin. This slide may have been entirely subaqueous, or it may have advanced into the water from a subaerial exposure. More important is the nature of the slope upon which it originated and the immediate cause of sliding.

The fault bounding the wedge of Algonkian rocks, a few hundred feet north of the breccia (Text Fig. 1), dips 65 degrees northeast, and a normal displacement along it produced a northeastward facing scarp prior to the Ep-Algonkian erosion. Reverse movements are known along many Algonkian faults in the Grand Canyon (Ransome, 1908, p. 669; Noble, 1914, p. 76-79; Maxson and Campbell, 1934, p. 301), and such a movement along this fault in early Tapeats time would have produced a southwestward facing scarp from which the slide might have come. The actual slide movement could have been started by an earthquake originating along the fault. This is a favorite hypothesis used to explain some slide breccias (McGregor, 1916; Bailey, Collet, and Field, 1928). However, intra-Tapeats or post-Tapeats movement on this fault is out of the question, for the basal Tapeats extends across it without displacement. These observations and conclusions confirm those of Ransome (1908, p. 668). Therefore, the possibility of sliding from a fault scarp is dismissed, and in its place the following sequence of events is pictured.

Extended erosion during the Ep-Algonkian interval produced a surface of low relief on which one of the higher eminences was a Shinumo hogback. This hogback was asymmetrical with its steeper face to the southwest, owing to the gentle northeastward dip of the Algonkian strata. Submergence beneath the Tapeats sea eventually brought the shoreline to the base of the hogback. The basal sandy beds beneath the breccia are the initial deposits of this sea. Beating of the waves against the flanks of the hogback undercut and oversteepened it until a great mass of Shinumo quartzite broke loose and slid down into the sea and at least 2,500 feet out over the relatively flat sea floor. In places the sliding mass has completely removed the initial Tapeats deposits and has picked up large fragments of the underlying Archean complex. Undoubtedly considerable coarse material which lay at the base of the monadnock was also gathered up and carried along. Locally parts of the initial Tapeats beds were severely deformed and incorporated in the slide, but elsewhere it was well enough lubricated to move over the bottom without greatly affecting them. The originally irregular upper surface of the mass was smoothed by waves and currents, some of the uppermost fragments were rounded, and fine material was worked into the top of the deposit. Continued subsidence increased the depth of water so that other beds were deposited upon the breccia completely burying it. Modern erosion has fortunately dissected the slide so that it is now wonderfully exposed at the base of the vertical cliff formed by the Tapeats sandstone.

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