ARTICLES

MEGABRECCIAS: EVIDENCE FOR CATASTROPHISM

Arthur V. Chadwick
Associate Professor of Biology
Loma Linda University

WHAT THIS ARTICLE IS ABOUT

Megabreccias are transported rock deposits in which some of the angular fragments exceed one meter in diameter. The forces needed to move such rock masses are extraordinary and imply catastrophic conditions. Dr. Chadwick considers three different conditions which may produce these megabreccias. 1) Turbidity currents which are rapidly deposited underwater mud flows; 2) debris flows which result in the transport of large blocks in a mud and clay matrix; and 3) slides and slumps when masses of loosened material move down a slope. Rock fragments and blocks several meters to several kilometers in size have been moved several hundred kilometers from their source. The data suggest that rapid depositional processes were involved in the formation of these megabreccias.

Many geologic phenomena of the past do not appear to be adequately accounted for in terms of the processes now occurring on the earth's surface. In some cases it is difficult to conceive of any mechanism capable of explaining them. Among these problem areas in geology the explanation of the origin, transportation and deposition of megabreccias has long rated a prominent place. An increasing number of geologists (the so-called "neocatastrophists") have recognized the need to consider forces of enormous magnitude not now operating to explain observations of the geologic record. One of these individuals, Derek Ager, has considered the catastrophic implications of megabreccias in his book *The Nature of the Stratigraphical Record*.[1] In this report we will take a more comprehensive view of megabreccias and attempt to bring the insights they provide to bear on the larger problem of understanding the past history of the earth.

Megabreccias are sedimentary deposits in which angular fragments of rock in excess of one meter in diameter occur as conspicuous components (Figure 1). Such a deposit may include many other clasts smaller than one meter, which may or may not be angular. This definition, modified from Cook et al.,[2] is purely descriptive and thus includes both subaerial (land) and subaqueous (underwater) deposits that have the above characteristics.

Subaerial events are generally more localized than similar processes occurring underwater. Both the size of clasts transported and the distances traversed are limited by the great difference in density between air and rock. In contrast to the more recent record, very few pre-Pleistocene megabreccias can be regarded as strictly subaerial.

FIGURE 1. Giant rip-up associated with megabreccia flow in basal Cambrian Tapeats Sandstone at Ninetyone Mile Canyon in the Grand Canyon of the Colorado. Weathered Precambrian Vishnu Schist is found below the Tapeats (lower part of the cliff). The Tapeats includes the massive sandstone found above.

By far the majority of megabreccias is considered to have a subaqueous origin. A rock equivalent to one cubic meter in volume may weigh three metric tons, and most megabreccia clasts are larger than this. Consequently, transportation of megabreccias to the site of deposition becomes a formidable consideration. Buoyancy supplied by clear water can reduce the weight by $^1/_3$ or more and can significantly decrease friction as well. As we shall see, under appropriate conditions buoyancy and other factors can be greatly modified by changes in the transporting medium so that rocks of truly enormous dimensions can be moved.

Three categories of subaqueous depositional processes that give rise to megabreccias will be considered: turbidity currents, debris flows, and slides and slumps. The latter two categories are not clearly differentiated from each other. In each case we will define the process, describe its operation, outline the extent of such deposits, and discuss their significance.

Turbidity currents. Turbidity currents occur when unconsolidated sediment becomes resuspended in water, forming a fluid of high density. Flow of such a suspension introduces turbulence which prevents the suspended material from settling out, thus perpetuating the density difference and prolonging the movement of the turbidity current. Such a current can flow downhill, on the level, or even uphill, if it has sufficient momentum. As the velocity is decreased in the region behind the moving front, material in suspension is deposited, beginning with the coarsest particles. The resulting deposit commonly exhibits normal grading with larger grains at the base and finer material at the top.

Turbidity currents of easily imaginable dimensions are capable of moving enormous clasts. Kuenen[3] has estimated that rocks weighing up to 100 metric tons can be moved in such flows. The initiation of a turbidity current flow probably occurs most commonly as the result of earthquakes, but other mechanisms are also involved.[4,5,6] Sediment capable of maintaining suspension of rock fragments of all dimensions generated in the original disturbance can be transported for great distances across minimal slopes.[3, 4,7]

Turbidites, the deposits left by turbidity currents, occasionally are reported to contain megabreccias. Clasts exceeding a meter in diameter are known from beds in Nevada,[8] Arabia,[9] New Hebrides,[10] and elsewhere.[7] Casshyap & Qidwai[11] report clasts exceeding four meters in a "diamictite" in India. The authors postulate glacial origin, but turbidity currents appear to be at least as likely a source. Rigby[12] reports clasts up to five meters in diameter in breccia beds interpreted as being deposited by turbidity currents.

There can be little question that turbidity currents capable of transporting large clasts represent catastrophic events. Earthquakes can trigger turbidity currents of large dimensions,[5] but it is more difficult to envision a process capable of simultaneously producing and transporting the brecciated clasts. We shall see in the following section that these problems become more complex as the clast sizes increase.

Debris flows. Debris flow is a term used by Cook et al.[2] to describe megabreccia deposits consisting of very large clasts that have been transported by a mass flow process, usually over a considerable distance. Debris flows, like turbidity currents, do not require a steep slope for movement, but unlike turbidity currents, debris flows are less fluid and flow more slowly. There does not appear to be any limit to the size of clasts that can be moved. The clasts are commonly exotic (blocks derived from a source different from that of the matrix) and are generally supported in a matrix of mud or clay.

For example, in Peru exotic blocks of up to 5000 metric tons (10-15 m in diameter) occur in Eocene strata far from the site of origin.[13] In Texas, slabs of exotic rock over 30 m long are found in Paleozoic mudstones, apparently derived from a source many kilometers distant.[14,15,16] In the Klamath Mountains of California clasts over 100 m in length occur at least 5 km from their source area.[17] Exotic boulders in Pennsylvanian strata of eastern Oklahoma exceed 100 m in length.[18,19, 20] Among these clasts are gigantic blocks of shale of similar length and possibly 20 m or more thick.[21] These rocks have been transported over 30 km. In early Tertiary strata of Venezuela exotic "boulders" of Mesozoic rocks over 100 m long and 30 m thick, which must have moved at least 40 km from a source area, occur in a submarine deposit. One slab of Cretaceous limestone in these strata is more than 1 km long and over 100 m thick.[22]

Newell[23] reports exotic blocks of reefoid limestone over 100 m long and perhaps 20 m thick in Mexico. Ordovician rocks in Newfoundland contain exotic clasts several hundred meters long.[24] In Miocene deposits on the island of Timor exotic blocks of Paleozoic and Mesozoic sediment up to 800 m in diameter are reported to have been transported tens of kilometers from the proposed source area.[25] Rigby[12] cites examples of clasts 300 m long and many other large blocks which have been transported several kilometers across very shallow slopes. In the Tertiary strata of Switzerland exotic blocks and “cliffs” up to 500 m long, some overturned, are known. A move of tens of kilometers is postulated for these blocks.[26] Mountjoy et al.[27] chronicle numerous other examples including clasts with dimensions of up to 1 km being moved for tens of kilometers.

Other examples could be added, but perhaps one more will suffice. Wilson[9] reports exotic blocks of Jurassic limestone in Cretaceous radiolarites in Arabia. The largest such block covers an area of 1600 km^2 and is 1000 m thick. This and other similar mountainous clasts are postulated to have moved a distance of many tens of kilometers to their present position!

Attempts have been made to develop a non-catastrophic explanation for the presence of exotic blocks in megabreccias. Some authorities have posited glacial transport. Others have concluded that the rocks slid to their present position from distant highlands.[19] Such attempts have generally failed to satisfy those who have carefully investigated the circumstances. For example, the “glacial” boulders are located in strata which otherwise represent a warm temperate climate;[19] the rocks which are presumed to have slid to their present positions give no indications of having done so. As far as I can ascertain, there is no recorded instance of a tailing disturbance such as would have been left in the wake of a rock moving across an unconsolidated surface. On the contrary, the only disturbed strata occur immediately below the clast,[12] indicating compaction below the clast following its movement (Figure 2). Since continuous, rapid movement would be required to prevent the clasts from settling during transit, these clasts must have been transported by some mechanism of mass flow. As Mountjoy et al.[27] have emphasized, no contemporary model for such a process exists. It is not only difficult to come up with a transport mechanism, but it is also difficult to imagine forces operative which would have produced clasts of this size.

The process of generation and deposition of these megabreccias represents catastrophes of extraordinary dimensions, as substantiated by both the clast size and by the requirement for rapid movement across gently dipping or flat terrain for many kilometers. Wilson,[9] assessing the magnitude of the problem, has called for consideration of “major disturbances originating outside the planetary system” which may have affected the speed of revolution of the earth and the earth’s revolution about the sun. All things considered, such a statement may not be too far from truth!

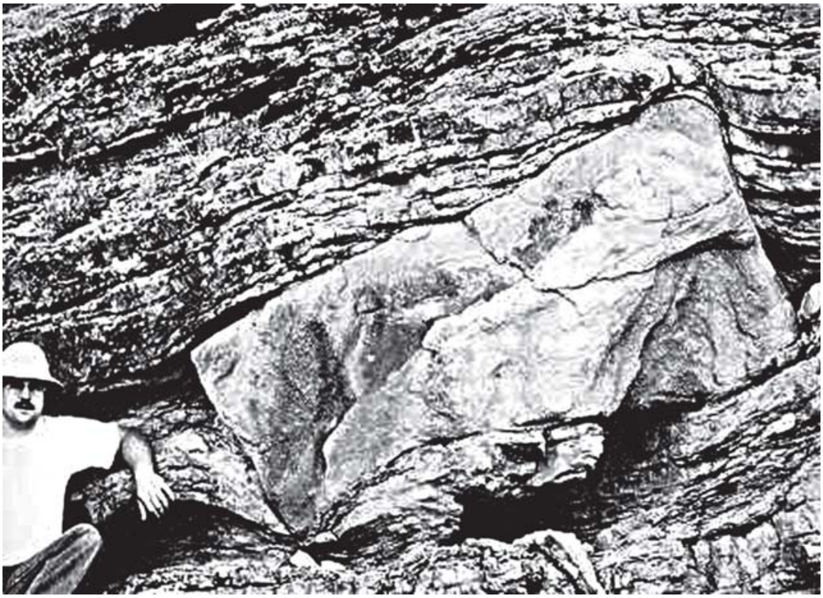

FIGURE 2. Exotic quartzite boulder compressing sand laminae in basal Bright Angel Shale overlying Tapeats Sandstone at Ninetyone Mile Canyon in the Grand Canyon of the Colorado.

Slides and slump deposits. If a mass of sediment is deposited on a sloping surface or is uplifted unevenly so that a slope is formed, the sediment will tend to move downslope. This tendency is counteracted by internal friction which is much greater in cemented or compacted sediment. Once movement is initiated, either by external or internal forces, the sediment will move downslope more or less as a body, forming a slide or slump deposit. Unconsolidated sediments will tend to form folds,[28,29,30] but when sediments differ in competence (resistance to flow or internal shear), the more competent members will tend to fragment and form a megabreccia within a matrix of the less competent members.

Slide deposits of immense dimensions with associated megabreccias are encountered in many parts of the world. The Tertiary strata of the Apennines in Italy contain megaclasts ranging up to many cubic kilometers. These blocks have in some cases traveled up to 100 kilometers from their source area. One slab of limestone, reported to be inverted, covers an area of over 200 km^2![31,32] Nearby in Greece are similar late Tertiary sediments containing blocks ranging from several hundred meters to several kilometers in length; again, many are overturned. These sediments are believed to have traveled 100 to perhaps 500 km from their sources to the point of deposition.[33] Farther east in Turkey late Cretaceous sediments contain blocks ranging up to “hill-sized” outcrops which presumably were derived from many kilometers to the north.[24] In the Appalachians of the eastern United States mountainous masses moved by “gravitational stresses” slid for up to 80 kilometers on a very gentle or flat surface.[35] Numerous other examples of gravity-induced slides and slumps are reported by other authors.[36,37]

A catastrophic interpretation for these deposits depends somewhat upon the time frame in which they are cast. If the movement of a mountainous clast over 100 kilometers occurs at the rate of a millimeter a year, it can hardly be considered a catastrophic event. If the clast moves the same distance in a matter of hours or days, it represents a catastrophe of earthshaking dimensions. How fast do slides move? The authors of most papers either do not directly confront this question, or merely assume very slow rates of movement.

The rate at which slides move depends in some degree upon the slope of the underlying surface. A number of authors have cited a figure of about 3º for the slope over which slide deposits traveled.[36,38] This figure is chosen because a lower slope probably would not support movement and a steeper slope would require that a source area many kilometers distant be several kilometers high. While one cannot be certain about the prevalent slope at the time of movement, it is safe to suggest that 3º is a minimal figure.

Several reports of recent offshore slumps and slides are available for comparison with the Tertiary deposits. One of these, the Grand Banks slump of 1929, is historical. In two examples the authors cite favorable comparisons between the recent slides and those from Tertiary strata mentioned above.[6,38] In each case the slides moved across slopes of approximately 3º for several kilometers, and the movement is either known[5] or inferred[6,38] to have been catastrophic. While we cannot be certain that this was the case in the fossil examples, under similar circumstances it is difficult to conceive of such movement as having been slow.

CONCLUSIONS

The presence of various kinds of megabreccias in the geologic column, showing in some cases the transport of extremely large clasts, indicates energy levels on a scale that staggers our imagination. Their common occurrence in major portions of the geologic column of some localities indicates significant catastrophic activity in the past not readily explainable in terms of contemporary processes.

ENDNOTES

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