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A brief review on breccia: it's contrasting origin and diagnostic signatures

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Abstract

A brief literature review on the breccias of contrasting origin, their diagnostic signatures along with related terminologies is presented here. The importance of individual breccia types and their geological implication has also been reviewed. The present study suggests that breccia is formed either by igneous, sedimentary and tectonic processes or a combination of these. This review is mainly focused on the most common seven sub-classes, (i.e., *volcanic*, *igneous-hydrothermal, chert*, *collapse*, *fault*, *impact* and *seismic)* and the specification of the processes involved in their formation, which subsequently brings more clarity in its classification and characterization.

Keywords: Breccia; Volcanic; Fragmentation; Tectonic; Ore deposits

1. Introduction

Breccia is a term generally used for an enigmatic rock group that consists of a variety of individual mineral grains or broken fragments of rocks, often very angular and cemented together by a fine grain matrix, and sometimes glassy matrix which may or may not be similar to the composition of rock fragments (Fisher, 1961; Schmid, 1981; Laznicka, 1988; Scholz, 1990; Knauth, 1994; White and Houghton, 2006). The breccias are observed under several kinds of geological settings, often associated with numerous ore types (e.g., endogenic, exogenic, supergene origin, subsurface or submarine environments) and found across the globe, which make them of general geological importance (Reimold, 1998). A cursory look at the old and the contemporary literature clearly indicates that the breccias have diverse origin and therefore they are defined by workers differently (Anderson, 1933; Macdonald, 1953; Laznicka, 1988; Lilletveit et al., 2002). Though, their classification into genetic or textural type has been attempted, the diagnostic signature of the individual breccia types and their genetic associations are not well-addressed (Laznicka, 1988; Reimold, 1998).

It is interesting to note that the breccias of various kinds have attracted the attention of geologists as well as geophysicists. Geologists working especially in the field of structural and ore geology get attracted towards breccias because of their tectonic and economic implications respectively (Laznicka, 1988; Jébrak, 1997). Evidence of any late shock event can be traced in a particular type of breccia (e.g., regolith breccia), which would eventually help in the study of planetary bodies like lunar highlands (Koeberl et al., 1991). The study of these breccias (meteorite or impact breccias) helps in understanding impact processes on planetary bodies, resulting structures and evolutionary history, which in turn enhance our understanding over early solar system processes of accretion, differentiation, and surface evolution (Bischoff and Stöffler, 1992). The study of breccias of a particular type is useful in understanding the depositional settings, tectonic events and geodynamic evolution of that particular region in a given geological time interval (Brown et al., 1983; Scholz, 1990; Mcgowran, 1989; Taylor and Pollard, 1993; Lyons et al., 2000). It is helpful in identifying the marker horizon in an unconformity zone or sometimes interpreted as a seismic marker and thereby resolving stratigraphic problems.

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It also provides inputs to geodynamic evolutionary history of a geological terrain or depositional settings of a particular area (Chatellier, 1988; Bhat et al., 2009; Kouhestani et al., 2011; Reimold, 1998; Reimold et al., 2012; Shukla and Sharma, 2017). It can also play a crucial role in understanding of the early solar system processes, as well as the primordial, chemical, and mineralogical characteristics of the accreted constituent bodies (Koeberl et al., 1991; Bischoff and Stöffler, 1992; Friedman, 1997).

Similarly, Geophysicists' perspective is to see statistical laws that govern brecciation mechanisms and their quantitative relationships with different measuring units (e.g., length, width and thickness) occurring in the fault zones (Scholz, 1990; Brown et al., 1983). Additionally, they also try to build models to understand the breccia fragmentation processes by applying theoretical, physical and statistical relationships between the particle size distribution and the energy input required for breccia formation (Jébrak, 1997; Mort and Woodcock, 2008).

Besides academic significance, the study of the breccias has important economic and societal implications such as exploration of hydrocarbons, uranium, gold-silver, sulfide and other ore deposits, and also serves as a potential aquifer in water deficit areas. The study of the breccias can be beneficial for addressing important future scientific issues related to geoenvironmental problems such as radon and gamma radiation, acid drainage and toxic metals in the immediate vicinity of mineralized breccia pipes and also issues related to planetary geology in exploring and characterizing extraterrestrial bodies.

Hitherto very few or no classification is available to group all the types of breccias according to their mode of origin, as majority of works have been dealt with only on individual aspect satisfying a particular set of condition and therefore no broad generalization has been made**.** In the classic work on Breccias and Fragmentites carried out by Laznicka (1988), he attempted to categorize all the coarse fragmental rocks according to their associations with metallic ore accumulations in different geological environments. Subsequently, Jébrak (1997) discussed eight main mechanisms of brecciation processes emphasizing more on tectonic pulverization, fluid-assisted brecciation and wear abrasion as the most common ones particularly existing extensively in vein-type ore deposits.

Despite having substantial data set over breccias, brecciation processes, its diagnostic signatures, and different modes of origin are not well understood and remain a subject of discussion. Therefore, the aim of this paper is to describe the breccias, their common modes of origin, associated diagnostic characters, and its related terminologies used in contemporary times. An attempt has also been made to provide a general classification of breccias based on modern understanding, which would eventually help particularly to those who are newly introduced to this complex group of rock. Additionally, several ore deposits including hydrocarbon reserves and geodynamically important features occur in association with breccias, which make this rock group economically as well as academically significant and need adequate attention.

There are the most seven common prefixes i.e., *volcanic*, *igneous-hydrothermal, chert*, *collapse*, *fault*, *impact* and *seismic*; which have consistently been used in the modern literature to describe various kinds of breccias. The brief description and diagnostic signatures of these litho units are discussed under three classes, namely Igneous Breccia, Sedimentary Breccia and Tectonic Breccia which have been dealt with here in some detail in the following sections.

2. Igneous breccia

Igneous breccias (or breccia of igneous origin) are the breccias in which igneous processes are involved in their genesis (Reynolds, 1928; Macdonald, 1953; Fisher, 1958). Igneous Breccias can also be termed as volcanic breccia or volcaniclastics. There are primarily two components in volcanic breccias, the one is mineral/rock fragments and the other component is the matrix in which the rock fragments are embedded. It is not necessary that the fragments of a volcanic breccia to be composed of volcanic material. A rock fragment of any origin may be incorporated within the brecciated regime, after being solidified; however, the matrix must be of volcanic origin that may be of tuffaceous matrix or vesicular and pumiceous matrix. Contrary to it, if the rock fragments are of volcanic origin these may be set in a nonvolcanic/sedimentary or volcanic matrix.

2.1. Volcanic-breccia (or volcaniclastics)

Volcanic-breccia is a rock composed predominantly of angular volcanic fragments (>2 mm in size) set in a subordinate matrix of any composition and texture or composed of mineral/rock fragments rather than volcanic set but in a volcanic matrix (Reynolds, 1928; Anderson, 1933; Macdonald, 1953; Fisher, 1958; 1960). It is further subdivided into *flow-breccia,* which is formed by the fragmentation of lava during its flow, and *tuff-breccia* (or *rhyolitic-breccia)* formed of fragmental products of explosive eruptions with abundant tuff matrix (Norton, 1917; Wentworth and Williams, 1932; Twenhofel, 1950). The occurrence of such type of tuff or rhyolitic-breccia were reported from the Jangalgali Formation sandwiched between the Neoproterozoic Sirban Limestone and Palaeogene Subathu Formation in Northwest Himalaya, India (Siddaiah and Shukla, 2012; Shukla and Sharma, 2017; Fig. 1), which has also been used as a marker horizon in differentiating the two geological formations mentioned above.

According to Fisher (1958) the size of fragments present in a breccia is an important parameter, which varies from 2 mm to >64 mm (Table 1)**.** Based on the grain size limits, he has grouped volcanic breccia into four classes. The grain/fragment size in class-1 ranges between 2 and 4 mm and termed as *Tuff*, in class-2 it is between 4 and 32 mm and called as *Lapilli* (or Lapilli tuff), in class-3 it is in the range of 32–64 mm and termed as *Pyroclastic breccia* and *Agglomerate*, and the fourth class has fragments of size >64 mm, which are referred as *Bombs* and *Blocks.* The basic difference between *bombs* and

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