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Original Article

Igneous breccia system of the Shand porphyry Cu-Mo deposit, Northern Mongolia

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ABSTRACT

The Shand Cu-Mo deposit is located in the Orkhon-Selenge depression, Northern Mongolia. It lies near the Erdenetiin Ovoo porphyry Cu-Mo deposit, which together define one of Northern Mongolian's most economically significant metallogenic belts. In the Shand Cu-Mo (Au?) deposit, several ore related breccia types are associated with the porphyritic granodiorite intrusions, and they contain pre-, syn- and post-mineralized porphyry stocks, magmatic-hydrothermal and intrusive breccia. There are genetically at least two type of hydrothermal breccias have recognized in Shand deposit, i.e. magmatic-hydrothermal breccia and intrusive breccia. Magmatic-hydrothermal breccia is presented spatially associated with intrusions but extending sub vertical which characterized by angular fragments/clasts supported or infilled by minerals commonly indicative of high temperature and salinity (e.g. tourmaline, feldspar), silicas, carbonates and sulphides (Cu, Mo, (Au)) matrix derived from hydrothermal fluids precipitation. May grade downwards into cupolas of intrusive with or without intrusive breccia and pegmatite where occur at approximately deep from 250-1300 m depth. Intrusive breccia is mostly occurred in contact between margin intrusions at shallow depth which is mainly composed by granodiorite porphyry, granodiorite and dacite. Our drillhole relogging and petrographical observations are granodiorite hosted breccia and granodiorite porphyry hosted breccia. Here, we present an integrated study involving detailed drillhole logging, and petrographical observations to elucidate the genetic relationship and evolution of the Shand deposit for magmatic-hydrothermal breccia and intrusive breccia. Also, we propose that the magmatic breccia types indicate emplacement of igneous rocks from initially dacitic magma composition.

Keywords: breccia types, magmatic-hydrothermal breccia, copper-molybdenum mineralization

INTRODUCTION

The northern Mongolia porphyry deposit province, one of the in Central Asia includes the Shand deposit of Erdenet mining district (Fig. 1A). The Erdenet mining district lies in the Orkhon-Selenge volcanic plutonic belt (Badarch et al., 2002; Gerel et al., 2005; Munkhtsengel et al., 2007) which overlaps the cratonic Tarvagatai terrane and the Orkhon-Selenge trough of Mossakovsky and Tomurtogoo, (1976). The characteristic features of the porphyry epithermal systems of the northern

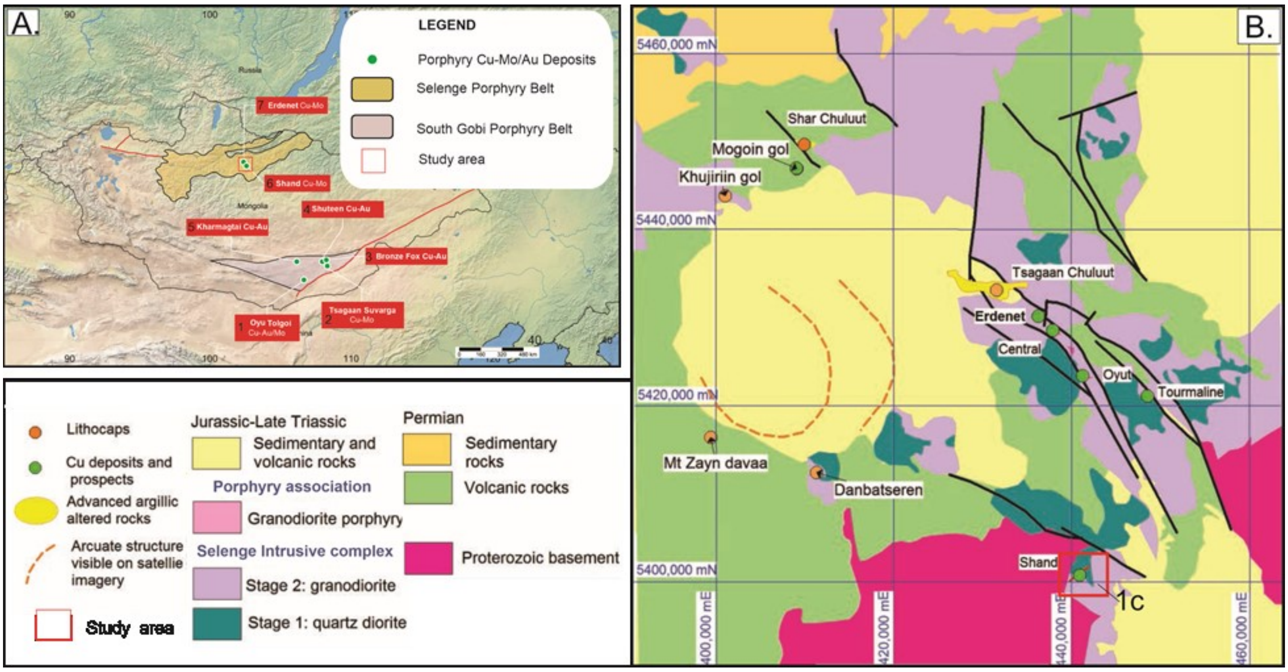

Fig. 1. A) Simplified location map of porphyry type deposits of Mongolia (7-8; Orkhon-Selenge porphyry belt (Seltmann et al., 2005)) ; 1-6 Gurvansaikhan Island arc). **B**) Simplified geology map of the Erdenet ore zone (modified Kavalieris et al., 2017)

Mongolian metallogenic province are related to the Tuva-Mongolian arc collage system that was formed during the evolution of the Paleo-Asian Ocean in the Paleozoic and the Mongol–Okhotsk Ocean in the early Mesozoic (Sotnikov et al., 1995; Gerel, 1998; Berzina et al., 2009; Gao et al., 2018). Geological setting, tectonics, and metallogenic features of Shand Cu-Mo porphyry deposit are similar to the Erdenet ore zone (Fig. 1B) (Gerel and Munkhtsengel, 2006; Seltmann et al., 2005) where the indicated resources are approximately 278.2 Mt of ore grading 0.33% copper and 334.1 Mt of ore grading 0.29% copper. Recently, Cu and Mo resources are increasing as additional exploration works in the Shand deposit. Mineralized breccias mainly occur in porphyry copper deposits in magmatic arcs (Corbett and Leach, 1998; Sillitoe, 2010). The igneous rocks in porphyry copper deposits range from volcanic rocks through hypabyssal intrusions, including porphyry dikes, breccias, and small stocks, to coarse grained plutons and batholiths (John et al., 2010; Ryan et al., 2010). The breccias form along wall rock contacts by emplacement of solidified intrusions (intrusion breccias), by forceful injection of fluids (magmatic or hydrous) that fracture, transport, and abrade wall rocks (intrusive breccias), and by planar fracturing of solidified intrusions and wall rocks (tectonic breccias) (John et al., 2010). Breccias can form throughout the evolution of a porphyry copper deposit, they are mainly permeable, and they can be mineralized in the breccia with vugs of millimeter to centimeter euhedral crystals of copper sulfide minerals, molybdenite, and other hypogene minerals, the coarsest grained hydrothermal minerals found in porphyry copper deposits (John et al., 2010).

We present an integrated study on the several breccia types of porphyry mineralization in the Shand Cu-Au deposit, based on field investigation, relogging core and petrographical observations.

GEOLOGY SETTINGS OF SHAND Cu-Mo DEPOSIT

The Shand Cu-Mo deposit area is located in the southeastern part of Erdenetiin-Ovoo ore mining, about 25 km southwest of Darkhan city and 330 km northwestern from Ulaanbaatar city (Fig 2A). The geological setting of deposit is covered by Quaternary sediments, red sediments of Neogene and overlying medium grained

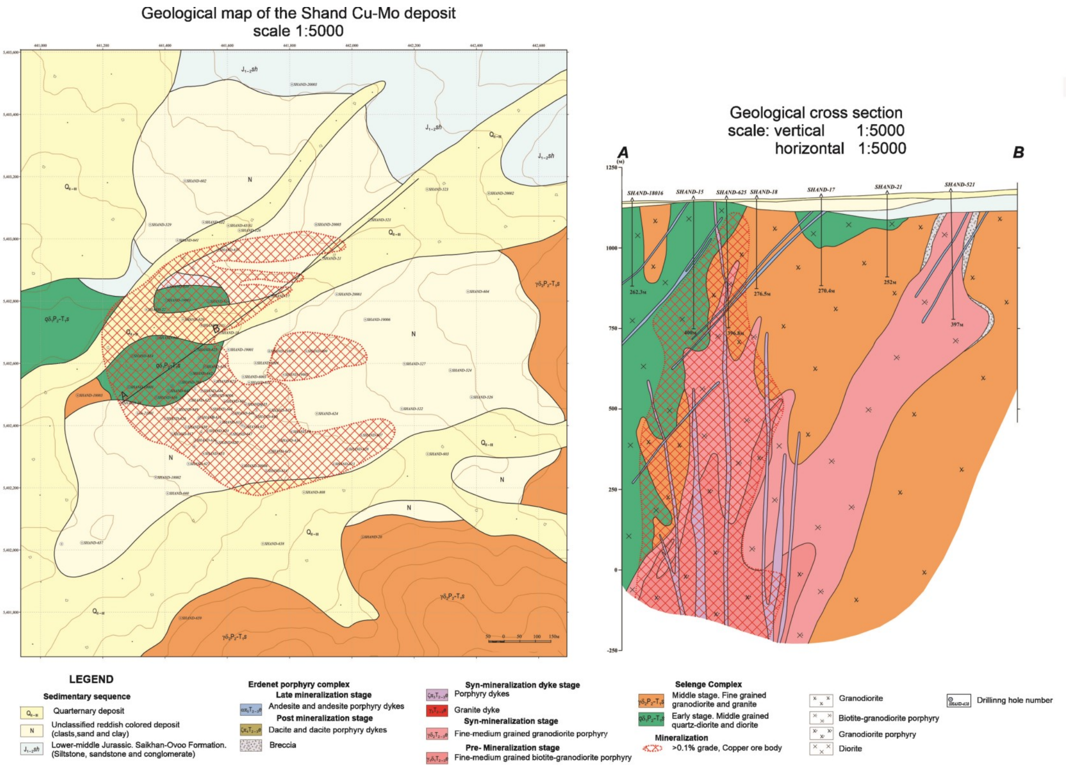

Fig 2. A) Geological settings of Shand Cu-Mo deposit, **B**) Geological cross section from A to B (modified after Sudalt Mana LLC, 2021).

sediments of Lower to Middle Saikhan-Ovoo Formation. In the southwestern part of Shand deposit, early phase diorite and quartz diorite of late Permian to Early Triassic Selenge Complex is intruded by later phase granodiorite. The mineralization of Shand Cu-Mo deposit is more related to the Erdenet porphyry complex which is composed pre, syn and post mineralization intrusions such as; biotite granodiorite porphyry (BGDP), granodiorite porphyry (GDP) and syn and late mineralization dykes (Fig. 2B). K-Ar ages dating of the granodiorite and granodiorite porphyry for the Erdenet complex indicate ages 235 between 239 Ma (JICA, 2003) in the Shand deposit, respectively.

In previous reports, the breccia types are illustrated through breccia pipe or eruption. Therefore, we interpret different breccia types, which occur in the upper levels of the intrusion in eastern part of the Shand deposit that are composed of clasts of granodiorite, granodiorite porphyry, dacite and hydrothermal breccia (Fig. 3A-C). Also, intrusive breccias are not dominated through deep ore zone and predominantly in upper levels. The alteration mineral assemblage is dominantly sericite-chlorite and potassic similar to the alteration of the porphyry copper-molybdenum deposit in the Erdenet ore zone.

In petrographical observations, some hydrothermal breccias are cemented by clay minerals, quartz and sulfides which contain titanomagnetite (0.02 mm), arsenopyrite and gold (0.002-0.004 mm) grains at a depth of 59 m, drillhole-624. The process of magmatic-hydrothermal breccia formation plays a significant role in gold and copper mineralization (Fig. 3D, E).

MATERIALS AND METHODS

Samples of the Shand Cu-Mo porphyry deposit were analyzed for petrography and interpreted for relogging of drill hole. In this study, rocks samples were collected systematically from both drilling and surface outcrops. Breccia type assemblages were identified from polarizing light microscope observation (6 samples). Seven selected drill hole rocks were presented for relogging observation approximately 8500 m. Petrographical analyses were carried out at Petrography laboratory of Institute of Geology,

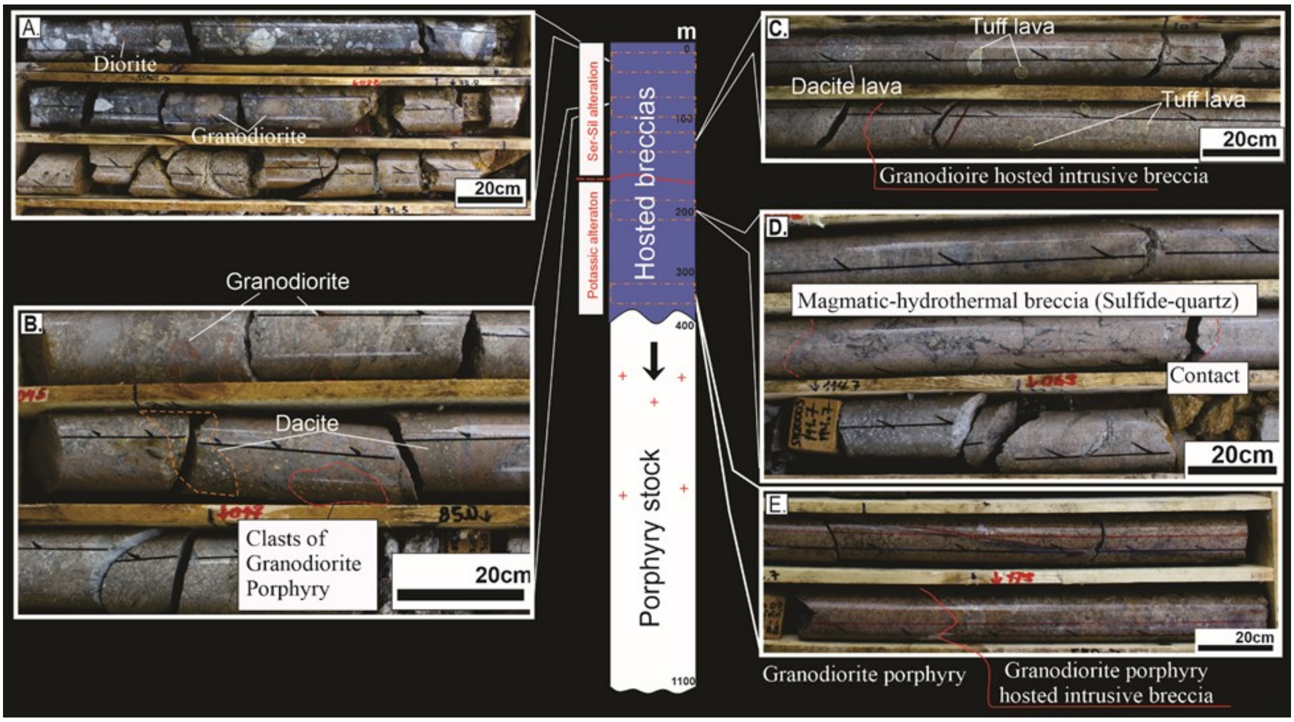

Fig. 3. Photos of drill hole of Shand deposit and lithology column; **A**) Contact of granodiorite and host rock, **B-C**) Granodiorite hosted breccia with clasts of dacite lava, **D-E**) Granodiorite porphyry hosted breccia, **F**) Lithology column of drill hole.

Mongolian Academy of Sciences (IGMAS) and relogging observations with Sudalt Mana LLC.

RESULTS

We interpreted relogging for selected seven drillhole cores in Shand deposit. This paper contains breccia types that how relate to magmatic stages and mineralization. The Shand deposit contains several different intrusive breccias and magmatic-hydrothermal breccias both mineralized and poorly mineralized those are occur approximately 60-70 m and 0.5-2 m thick, respectively. Breccia types are mainly emplaced in the eastern part of ore deposit which is dominantly composed of granodiorite and granodiorite porphyry at a depth of 100-250 m and rarely at 1000 m depth. On the basis of their appearance, mode of formation and petrology the studied breccia types may be classified as follows:

Intrusive breccia

Granodiorite hosted breccia. Intrusive breccia dominates commonly the top and margin of the granodiorite porphyry intrusion in the drillhole logged. This breccia is characterized by irregular, sub-rounded clasts from 0.1 to 10 cm in size. Commonly granodiorite hosted breccia is matrix supported with clasts and 45 to 55% void space prior to complete cementation by later matrix fill. Additionally, 45-55% of the clasts are granodiorite and dacite with the remainder being intrusive rocks of the Selenge Complex.

The granodiorite hosted breccia displays quartz-sericite and minor porphylitic alteration with minor mineralization characterized by (Fig. 4A) veins in small clasts with weakly disseminated pyrite and trace chalcopyrite noted in the igneous matrix (Fig. 4B).

Magmatic-hydrothermal breccia

Granodiorite porphyry hosted breccia. Granodiorite porphyry hosted breccia is located at the root part of the intrusive breccia (Fig. 4C) at 180 m and at more depth in drill holes. The breccia is characterized by irregular clasts, angular, from 0.5 to 4.5 cm. The breccia is clast dominated, with fragments constituting 90% of the rock volume, with a matrix of rock flour, gangue and sulfide minerals and rarely dacite lava (Fig. 5A, B). Clasts within the breccia are

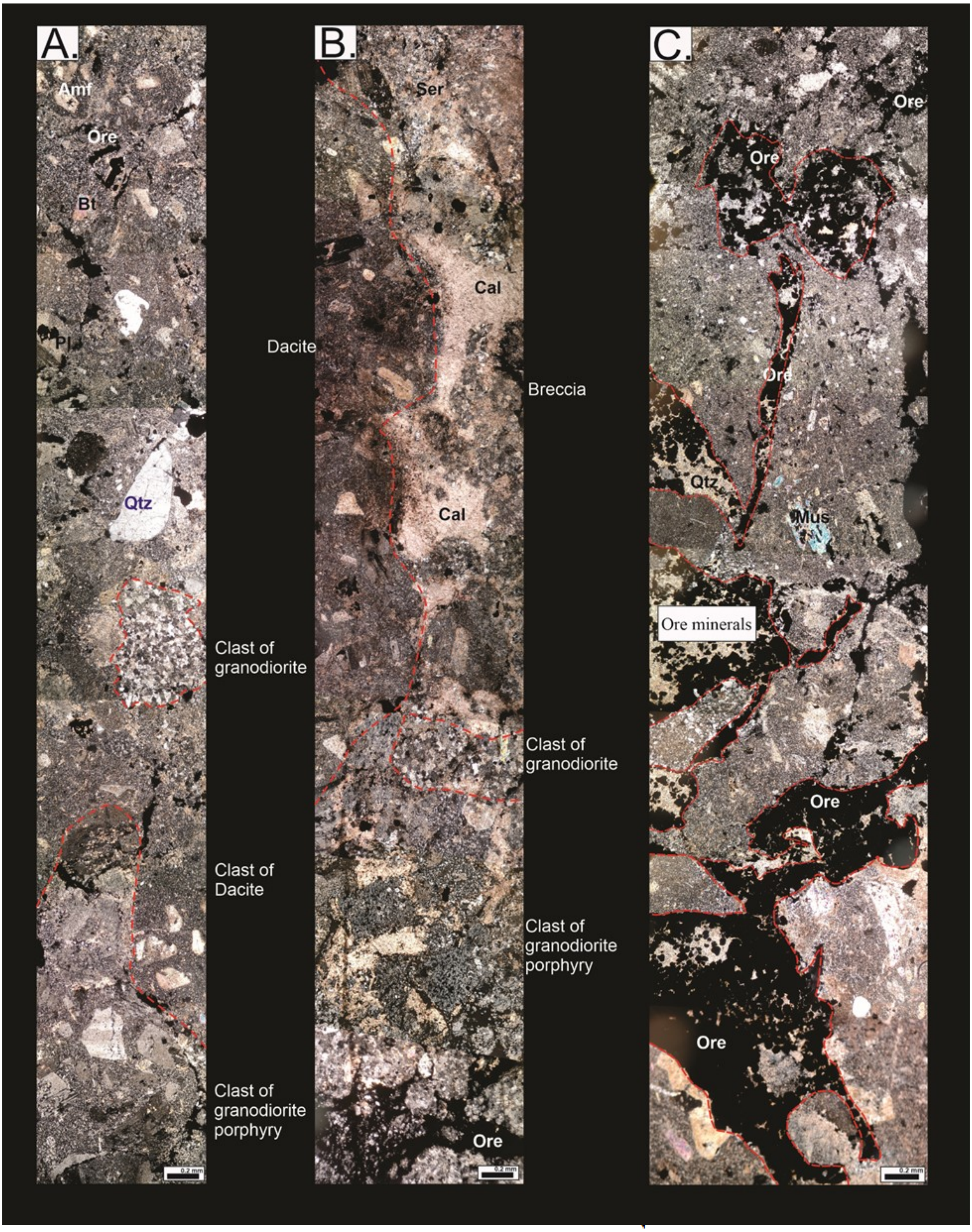

Fig. 4. Thin section of breccia types Shand deposit, **A**) Granodiorite bearing breccia; clast of granodiorite, dacite and dacite porphyry, **B**) Contact of intrusive breccia and host rock **C**) Magmatic-hydrothermal breccia hosted granodiorite porphyry; Qtz-quartz, Pl-plagioclase, Cal-calcite, Mus-muscovite, Bt-biotite, Ore-ore minerals

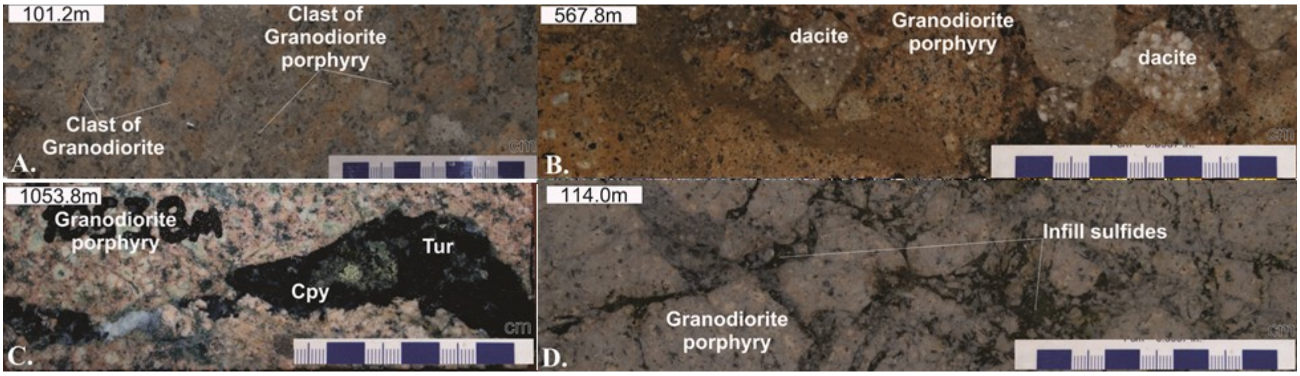

Fig. 5. **A**) at 108 m, Intrusive breccia with clasts of granodiorite and granodiorite porphyry **B**) at 527 m, Intrusive breccia with clasts of granodiorite porphyry, granodiorite and plagioclase granodiorite porphyry, **C**) Granodiorite porphyry with tourmaline and sulfide breccia, **D**) Granodiorite porphyry with infill minerals (Cpy-chalcopyrite, Py-pyrite, Mo-molybdenite and calcite).

mostly granodiorite porphyry, with 10-15% of the clasts host rocks within a matrix of hydrothermal infill minerals commonly indicate of high temperature and salinity (e.g. tourmaline, feldspar) (Fig. 5C). Potassic alteration is dominated through with quartz, carbonate, tourmaline and sulfide within the breccia matrix and disseminated intrusive rock. Pyrite and chalcopyrite are main sulfides that are most common in the granodiorite porphyry hosted breccia, and occur mainly within the matrix with galena, minor molybdenite, bornite, sphalerite, gold and magnetite. Gangue minerals occur as chlorite, quartz, carbonate and tourmaline in the matrix (Fig. 5D).

DISCUSSION

Many experts have implied to classified breccia both on the basis of genetic and descriptive, such as Sillitoe (1985), Baker et al. (1986), Lawless and White, (1990), Sillitoe (1985) classified ore related hydrothermal breccia into magmatic hydrothermal breccia, hydromagmatic breccia, magmatic breccia, intrusive breccia and tectonic breccia. The diatremes, particularly their contact zones, may localize part of the high sulfidation Au mineralization (Sillitoe, 2010). Intrusive, hydrothermal and tectonic breccias occur in many porphyry type systems (John et al., 2010). Several type breccias processes are noted in the drillhole at the Shand Cu-Au deposit. Based on observations of the petrography and drillhole logging of the intrusive breccias with magmatic-hydrothermal breccia and intrusive breccia which are commonly dominated in the lower part and shallow part/ depth system by granodiorite porphyry hosted breccia, granodiorite hosted breccia and with rarely dacite. The upper part of intrusive breccia system is commonly barren to poorly mineralized, whereas absolutely lower/ deep part of magmatic-hydrothermal breccia system typically contains significant copper, molybdenum and (gold) mineralization.

They may be displayed to belong to a single metallogenic system and those breccia process may occur multiple times as further magmatic fractionation and exsolution occur and infill minerals. On the other hand, we need more detailed observations which magma crystallization age of breccia clasts and hydrothermal fluid processing of breccia matrix and cementation. There are ranges in the composition of the breccia matrix and fragments and in the dimensions and geometry of these breccias that reflect their variable origins and emplacement.

CONCLUSION

There are at least two types of breccia have recognized in the Shand Cu-Mo deposit. Those are magmatic-hydrothermal breccia and intrusive breccia, which were found at the Shand deposit, respectively. Magmatic hydrothermal breccias matrix comprising dissemination of chalcopyrite-magnetite-pyrite, molybdenite and contributed on Cu-Mo (Au) mineralization and intrusive breccias caused by the emplacement of an intrusive body, but not associated magmatic hydrothermal fluids and poorly mineralized which mainly dominate variably oriented lenses and patchy zones at intrusive margins.

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