

Discovery of agate geode and nodules at Mount Conner, Semporna, Sabah

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Abstract: An exposure of agate geode and nodules in Mount Conner, Sabah, provides an essential aspect to the geological formation in Semporna. This paper briefly report results from petrography analyses on the agate geode and nodules and its significance to the volcanic rocks and sedimentary rocks formation in Mount Conner. The geode and nodules can be divided into agate, and nodules and most of them are sub-rounded. Nodules are usually small in size and display brownish colour. It commonly occurs in volcanic rocks (dacite and rhyolite) and contained amygdale filled by secondary mineral such as microcrystalline and macrocrystalline quartz. In contrast, sedimentary rocks in Mount Conner contain both nodules and geodes, which nodules shows similar characteristic with nodules in volcanic rocks and geodes contained empty vesicles or spaces surrounded by colourless to milky white quartz crystals. Both geode and nodules exhibit conchoidal fracture, while geode shows vesicle features and nodules in volcanic rocks show amygdale texture. The formation of geodes and nodules in Mount Conner might as result of precipitation under low temperature from hydrothermal solution.

Keywords: Geode, Mount Conner, nodule, Semporna

Abstrak: Penemuan geod akik dan nodul di Gunung Conner, Sabah, telah memberikan aspek yang penting kepada formasi geologi di Semporna. Kertas ini secara ringkasnya melaporkan hasil analisis petrografi terhadap geod akik dan nodul, dan kepentingannya terhadap formasi batuan vulkanik dan batuan sedimen di Gunung Conner. Geod akik dan nodul boleh dibahagikan kepada akik, kalsedoni dan nodul, serta bersifat separa bulat. Ciri-ciri yang terdapat pada nodul yang tersingkap pada batuan vulkanik (dasit dan riolit) ialah ia bersifat padat dengan tiada ruang diantara nodul, berwarna kecoklatan dan mempunyai saiz-saiz yang kecil. Manakala, batuan sedimen di Gunung Conner pula mengandungi kedua-dua jenis seperti nodul dan geod. Nodul mempunyai ciri-ciri seperti yang tersingkap pada batuan vulkanik dan geod pula mempunyai vesikel didalamnya yang turut mengandungi kristal kuarza yang tidak berwarna dan berwarna putih susu. Kedua-dua geod dan nodul mempunyai retakan konkoidal dan tekstur amigdal. Pembentukan geod dan nodul di Gunung Conner mungkin disebabkan oleh mendakan dibawah suhu yang rendah daripada larutan hidrotermal.

Kata kunci: Geod, Gunung Conner, nodul, Semporna

INTRODUCTION

The occurrences of geodes and nodules can be found all over the world, and it is mostly associated mostly with volcanic rocks and sedimentary rocks. Geode and nodules tend to have rough, and dull-looking spherical objects which resemble mud balls, however, inside geode have a cavity that contains various types of silica crystals (Makhlouf *et al.*, 2015). Those silica crystals generally show varieties of colour due to elements impurities. Colourless quartz crystals are the most dominant in Mount

Conner, Semporna, accompanied by minor milky white quartz. Some quartz rarely shows other colour such as pink, purple, yellow and smoky grey. Geodes are usually filled by quartz crystal however other types of minerals such as calcite, barite, selenite, marcasite, sphalerite, and pyrite might be present (Makhlouf *et al.*, 2015).

The natural geological formation of agate geode and nodules are developed when the gas bubbles remain trapped in the magma, then the silicon deposits itself into a space full of the bubble while forming layers

of walls before start solidifying itself. The difference between geode and nodules is geode contains empty spaces and hollow inside while the nodule is compacted totally without spaces. A discovery of agate geode and nodules exposed at the outcrops of dacite and rhyolite and sedimentary rock in Mount Conner, Sabah. The sedimentary rocks consist of sandstone and mudstone. With this background understanding of agate geode, this paper will discuss the various characteristics of the geode and nodules in the chosen study area.

GEOLOGICAL SETTING

The Semporna Peninsula is characterized by Miocene volcanic rock (Kirk, 1968; Hutchison, 1989; Bergman *et al.*, 2000), which shows subduction and OIB-like signatures (James *et al.*, 2019). In Semporna and Dent peninsulas of south Sabah, evidence of Sulu arc discovered on land (Chiang, 2002; Hall, 2012). Semporna is unique in terms of geological setting because most of the land rocks show volcanic arc-subduction setting (James *et al.*, 2019) (Figure 1). The recent tectonic movement had also uplifted the Quaternary coral limestone and formed a group of islands. Part of the Semporna town itself is built on the limestone formation (Morris, 1973) which is surrounded by volcanic rocks. Radiocarbon dating on coral limestone shows age ranges between 18,900 and 36,000 B.P (Taira & Wataru, 1971).

Mount Conner area is mainly covered by dacite and rhyolite lavas. At the south of Mouth Conner, there is an exposure of sedimentary rock outcrop which is underlain by volcanic rocks. The Quaternary deposit in the Mount Conner area formed as part of the extensive marine sediments of the Semporna area. The source of the sediments are from the Upper Tertiary and

Quaternary volcanic rock in the surrounding area, which continuously deposited since Early Quaternary to Recent (Kirk, 1962; Lee, 1988). Sediments that are associated with the Quaternary are divided into 2 groups namely Older Quaternary and Younger Quaternary sediment (Kirk, 1962). The Older Quaternary consists of volcanic pebble beds, tuffaceous sandstone, clay, and sandy clay overlain the volcanic rock. This sediment forms the area between volcanic hills at Mount Conner and the Mound Bod Gaya area.

Younger Quaternary sediment or recent alluvium occurs in coastal flats and lower river valleys. Raised coral limestone of younger sediment overlies older Quaternary sediment and volcanic rocks. Raised coral limestone consists of coral and shell debris. The large deposit of raised coral limestone occurs at the Semporna Town area and Bum Bum Island (Kirk, 1962). Observation in the outcrop of volcanic rocks in Mount Conner indicates that nodules unearthed within the dacite and rhyolite lavas but very limited.

CHARACTERISTICS AND PETROGRAPHY

From the hand specimen, nodules in dacite and rhyolite nodules are dark brown and sub-rounded. Whereas for the sedimentary rock, agate geode and nodules can be found in abundance in the layer of shales, but absent of any geode or nodule. McBride *et al.* (1999) explained that in mudstones, only small and volumetrically restricted cavities are presumed to be as nodules, geodes, and vugs. Those geodes and nodules mostly weathered on the surface, and some detached from their host rocks. In this study, the characteristic of the agate geode and nodules are based on types, roundness, colour, diameter, and crystal (Table 1). All the geode and nodules have

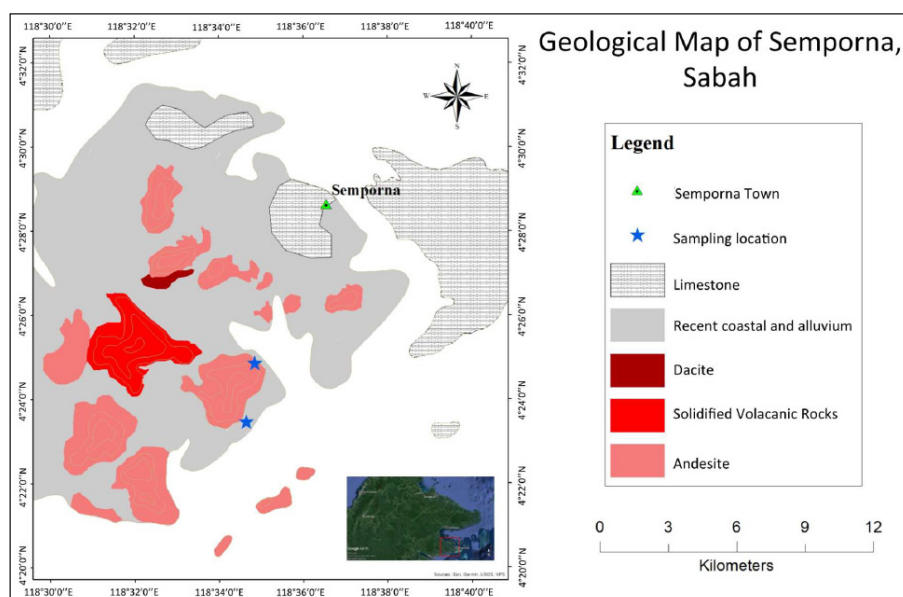
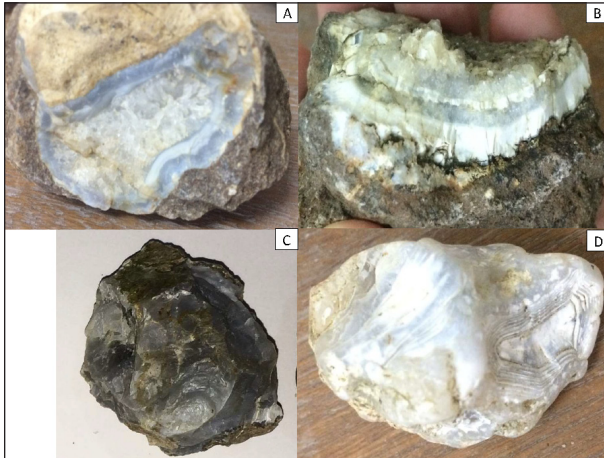


Figure 1: Geological map of Semporna, Sabah.

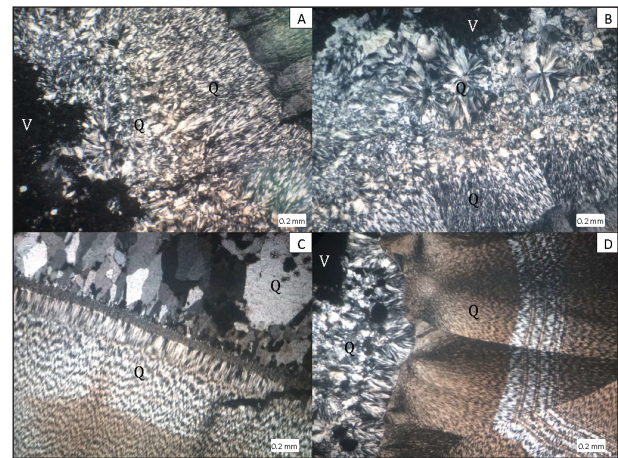
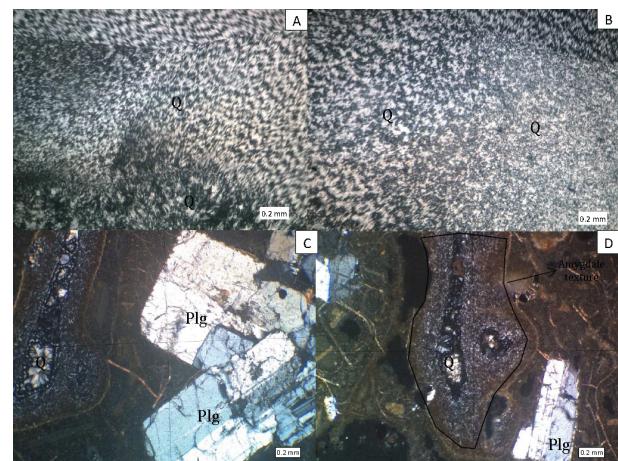
Table 1: Characteristics of agate geodes and nodules.

	Type	Roundness	Colour	Diameter (cm)	Crystals
Geodes	Agate	Subrounded	Colourless, Clear greyish, Milky white	4 – 12	Quartz (colourless)
Flint nodules	Chalcedony	Subrounded	Milky white, Brownish	7	-
Volcanic rocks nodules	Nodules	Subrounded	Brownish	5	-

**Figure 2:** A – B) Agate geode (sedimentary rocks) from Mount Conner, Semporna, Sabah. C – D) The nodules from Mount Conner, Semporna, Sabah.

similar roundness which is sub-rounded, which indicate gas bubbles do trap in quick flowing magma. The sizes are various and range from 4 to 12 cm in diameter, and some are wider in geodes compared to nodules. Variety of sizes and shapes in geodes might indicate the original cavity as an indication of the precursor for organism or mineral as the dissolved material based on their following formation (Makhlouf *et al.*, 2015). Agate geode contains a variety of colours such as colourless, clear greyish, and milky white. The quartz crystals are colourless and milky white, and showing euhedral shape for the inward-projecting crystals. Bands of white and colourless observed in geodes and nodules. The occurrences of coloured banding within geodes might indicate uneven or interrupted growth patterns (McBride *et al.*, 1999). Nodules (chalcedony) have an external layer of agate, and in the middle is mostly milky white, light brown, or brownish of quartz minerals (Figure 2).

Petrography analyses show that agate and nodules are composed of a composition of quartz or chalcedony, and both exhibit conchoidal fracture. The grain size is very fine and shows an aphanitic texture. The conchoidal fracture is similar to geode and nodules from sedimentary rock. The regrowth of silica in geode continues to form from margin and later toward the center (Figure 3a –

**Figure 3:** A - B) Geode from sedimentary rocks shows radial or mosaic structure, while the extinction is mostly parallel. C - D) The geode (sedimentary rocks) exhibit periodic extinction bands along with the fiber direction. Q = quartz, V = vesicle.**Figure 4:** A - B) Flint nodules from sedimentary rocks shows the twisted fibers that exhibit only certain sections of the fibers to be extinct at one time. C – D) The volcanic rocks nodules contain cavities filled with secondary mineral, chalcedony. The amygdale texture is observed in volcanic rocks nodules. Q = quartz, V = vesicle, Plg = plagioclase.

3b). Macrocrystalline quartz appears to be slightly more significant in the center compared to the surrounding in a geode (Figure 3a, 3b, 4c and 4d). Rhyolite contains more cavities that filled with a secondary mineral such as

chalcedony (0.2 mm-2.0 mm) compared to dacite lavas. The amygdale texture can be observed that filled with quartz (Figure 4c and 4d) as a results of bubble transport and extraction (Gilg *et al.*, 2003). Microcrystalline quartz makes up the almost the entire of geodes and nodules (Figure 3 and Figure 4). Macrocrystalline quartz may form from a silica solution while chalcedony forms from a gel (Moxon, 2014). Moxon (2014) further explained that the microcrystalline quartz and chalcedony might have formed in different silica saturation environment form in different silica environments.

DISCUSSION

The formation of agates connects the volcanic and hypogenic solutions from sources of various ions and organic matter (Lucyna *et al.*, 2016). The geode crystallizes in vesicles of former gas, or fluid bubbles may have formed by crystallization from the same silica source from the process of participation of hydrothermal fluids resulting in formation of chalcedony layers and macrocrystalline quartz crystals (Gotze *et al.*, 2009). Hydrothermal fluids also participated during the formation of agates in sedimentary host rocks (Gotze *et al.*, 2009). It is ubiquitous to find geode and nodules in volcanic rock because gas bubbles are trapped in the magma and created them. The formation of geode and nodules in sedimentary rock is formed slowly from an accumulation of debris, mud, and other sediments. Landmesser (1988) suggested that agate geode formed at low temperatures related to sedimentogenetic and diagenetic conditions.

Taijin & Sunagawa (1994) further suggest that precipitation of geode in low temperature from the hydrothermal solution which invaded into geode opening showing embryonic polymerised particles achieving nanometer size. Furthermore, continuous supply from the aqueous silica at constant low temperature may result in the silica crystallization (Commin-Fischer *et al.*, 2010). Nodules in Mount Conner show no sign of a cavity or completely no vesicle. This suggests that the precipitation of silica had filled it up entirely by leaving no space or vesicles in the nodules (Makhlouf *et al.*, 2015).

CONCLUSION

Conclusively we found out the following: (1) geodes, and nodules size at mount Conner Semporna is relatively small compared to average geodes and nodules elsewhere; (2) the lack of cavity in the nodule found in mount Conner Semporna is also an indication of silica saturated saturation or alternatively continuous supply of silica from aqueous solution, it could also mean the continuous supply of silica from aqueous. There are various other possibilities with the formation of geode and nodule found at the mount Conner Semporna, one of the many possibilities include the geode formed as a result of precipitation under low temperature from a

hydrothermal solution that invaded into the opening of the geode consequent to its embryonic polymerised particle at nanometer; the occurrences of geodes and nodules can be found in Mount Conner, Semporna. Specifically, nodules are abundant in volcanic rocks outcrops as the volcanic rocks is a host rocks since the quartz-chalcedony is not a primary mineral, while sedimentary rocks act as host rocks for geodes and nodules. The types of geode and nodule divided into agate, chalcedony, and nodule. Colourless and milky white quartz crystals are more developed in geodes. Nodules appeared to be fully compacted or fully filled by secondary minerals with no space inside it. In mount Conner Semporna given the samples analyzed both in the field and in the laboratory, we believe that agate and chalcedony from sedimentary rocks and nodules from volcanic rocks were found in mount Conner Semporna. Therefore, it is quite clear that the presence of geode in mount Conner in Semporna shows the massive volcanic activities that would have taken place before their emplacement. That may also have affected the sedimentary rocks that host these geodes and nodules.

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