

THE APPLICATION OF VOLCANIC FACIES CONCEPT IN THE DESCRIPTION OF THE “OLD ANDESITE FORMATION”

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Abstract

“Old Andesite Formation” was ascribed to the ancient succession of calc alkaline volcanic rocks widely distributed in southern part of Sumatera, Java and parts of Nusa Tenggara. The term “formation” according to Marks (1957) was badly defined and should be rejected. Since this type of rocks is also recognized in many other parts of Indonesia, he suggested to apply the local names for those correlable to the formation. The idea might be in line with the “Stratigraphic Code of Indonesia” published by the Indonesian Association of Geologists (Martodjojo & Djuhaeni, 1996).

The formation was first introduced by Verbeek and Fennema (1896) and widely used by Westerveld (1941) and van Bemmelen (1949) describing the Tertiary magmatic activity producing subaerial volcanic deposits. Later it also includes the subaqueous deposits and the secondary products of the rocks. Related to the formation, Soeria-Atmadja et al (1994) concluded that two stages of magmatic activity were recognized, namely at the time spans of 40 Ma to 18 Ma and from 12 Ma to 2 Ma. The former might correspond to the “Old Andesite Formation”, while the latter might have been related to the reactivity of magma producing the proto modern volcanic arcs.

An attempt has been made to apply the volcano facies concept introduced among others by Cas and Wright (1987) to describe the ancient volcanic rock successions leading to the reconstruction of the ancient volcanic center locations. In Southern Mountain of Central Java the application of such concept has resulted in the identification of eruption cycles of volcanic activity and the location of volcanic centers within the Tertiary “Old Andesite Formation”. The concept at present becomes an important guide in the regional base metal and hydrocarbon exploration.

Keywords: volcano facies concept, old andesite formation, ancient volcanoes, base metal and hydrocarbon exploration

Abstrak

“Formasi Andesit Tua” merupakan batuan gunungapi hasil suksesi masa lampau yang berkomposisi kapur alkali dan tersebar luas di Sumatra Selatan, Jawa dan Nusa Tenggara. Menurut Marks (1975) istilah “formasi” merupakan definisi yang tidak tepat dan harus diganti. Penggunaan formasi untuk jenis batuan yang dikenal di

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berbagai tempat di Indonesia ini disarankan menggunakan nama lokal. Pemikiran ini sejalan dengan *Sandi Stratigrafi Indonesia* yang diterbitkan oleh Ikatan Ahli Geologi Indonesia (Martodjojo & Djuhaeni, 1996).

Istilah formasi dikenalkan pertama kali oleh Verbeek dan Fennema (1896) dan digunakan secara luas oleh Westerveld (1941) dan van Bemmelen (1949) untuk menggambarkan kegiatan magmatik Tersier yang menghasilkan endapan gunung api di darat. Kemudian hal ini juga melibatkan endapan bawah laut dan produk sekunder batuan. Berkenaan dengan formasi tersebut, Soeria-Atmadja (1994) menyimpulkan bahwa terdapat dua periode kegiatan magmatisme yaitu pada rentang waktu 18 jtl – 40 jtl dan dari 2 jtl – 12 jtl. Produk magmatisme yang tua berhubungan dengan “Formasi Andesit Tua”, sementara yang berikutnya berhubungan dengan aktivasi ulang yang menghasilkan busur gunungapi masa kini.

Cas dan Wright (1987) telah mencoba menerapkan konsep fasies gunung api untuk menggambarkan sukseksi batuan gunung api masa lampau dan merekonstruksi lokasi pusat gunung api. Penerapan konsep ini di Pegunungan Selatan Jawa Tengah telah dapat mengidentifikasi perulangan erupsi kegiatan gunung api dan lokasi pusat gunung api yang menghasilkan “Formasi Andesit Tua” berumur Tersier. Konsep ini menjadi penunjuk yang sangat penting di dalam eksplorasi logam dasar dan hidrokarbon secara regional.

Kata kunci: konsep fasies gunungapi, formasi andesit tua, gunungapi purba, eksplorasi logam dasar dan hidrokarbon

INTRODUCTION

The identification of the volcanic products in Indonesian region has recently become important for various reasons. The advanced application of plate tectonic theory in Indonesian archipelago in the first hand, introduced the recognition of traces of ancient magmatic belts consisting mainly of magmatic and volcanic rocks. At first the rythmical distribution of the magmatic and volcanic rocks in western part of Indonesia were postulated by van Bemmelen (1949) as the manifestation of the “undation theory”.

Applying the newly developed concept of the plate tectonic theory, Katili (1975, 1989) repostulated these striking features as the traces of the ancient magmatic belts. The thought was augmented by many investigators who thoroughly described the ancient subduction zones extending from the present Sumatera to Kalimantan.

Simanjuntak (1986) analyzed the tectonics of Eastern part of Indonesia particularly Sulawesi Eastern arm. In relation to the hydrocarbon basin studies, Situmorang (1982) presented his account on the tectonic setting of western part of Sulawesi. There were many other investigators who put forward the ideas on the development on the Indonesian geology based on the application of Plate Tectonic Theory, among others Hamilton (1979), Audley-Charles (1981, 1986) and Barber (1981, 1985) The promulgation of the analysis was supported by the recognition of the existence of the ancient magmatic and volcanic belts of Indonesia.

The importance of the ancient magmatic belts identification was demonstrated among others Carlile and Mitchell (1994) to reveal the base metal distribution in Indonesian archipelago. Moreover, the promulgation of the epithermal concept (Hedenquist, 1987) on the mineralization of gold associated with volcanic activities has drawn much attention on the search of ancient volcanic belts, particularly those of Tertiary age.

Among the ancient volcanic belts, the succession of calc alkaline volcanic rocks spread over in Sumatera, Java, Nusa Tenggara and many other places in other islands (Marks, 1975) was considerably significant, based on its very wide distribution. To distinguish it from the Quaternary volcanic product which was resemblant in type and composition, the naming "Old Andesite Formation" was ascribed. The term "formation" according to Marks (1957) was badly defined and should be rejected. He suggested, instead, to apply the local names for the rocks correlable to the formation. The suggestion was in line with the "Stratigraphic Code of Indonesia" published by the Indonesian Association of Geologists (Martodjojo & Djuhaeni, 1996), however the thorough investigation was needed to describe the genesis and characteristics of the formation. The attempt to apply the volcano facies concept to reveal the genesis of

the “Old Andesite Formation” is being carried out in Southern Mountains, central part of Java, where the formation is well exposed (Hartono, 2000). Hopefully the study will contribute to the proper terminology of the “Old Andesite Formation” in light of the “Indonesian Stratigraphic Code”.

“THE OLD ANDESITE FORMATION”

The “Old Andesite Formation” was first introduced by Verbeek and Fennema (1896) and widely used by Westerveld (1941) and van Bemmelen (1949). The formation described the Tertiary magmatic activity producing subaerial volcanic deposits. Later it also included the subaqueous deposits and the secondary products of the those volcanic rocks. The sedimentary deposits of shallow marine environment associated with the formation of the volcanic deposits were treated as parts of the formation.

The volcanic cycles might have recurred several times. It was presumed that the first cycle occurred in Lower Miocene and followed by repose period where the the erosion took place. Epiclastic materials might have been deposited during the erosion period. The rocks consisted of conglomerates, breccias and sandstones. In the later stage the finer materials mainly clays and marls and even limestones and coral reefs were formed in the marine surroundings. The limestone and coral reef development might have been very strongly influenced by the amount of the volcanic materials transported to the sea. It was presumed that the reactivity of the following cycles might have taken place after the marine limestone formation.

The composition of the rocks were predominantly andesites. The term “old” was therefore used to distinguish the rock succession from the “younger” andesites produced by the modern volcanic activities of the Quaternary age. The distinction was

mainly based on the geomorphological features, where the “Old Andesite Formation” has intensively been eroded forming the leveled ruins, whilst the “young” andesites were readily recognized in the association with the cone-shaped strato volcanoes. According to Marks (1957) the distinction was misleading and consequently it might cause that many Upper Tertiary and Pleistocene rock sequences with andesitic composition such as Notopuro-Jombang formations of Kendeng, were ascribed “Old Andesite Formation” of Oligocene and Miocene age. It was further concluded that the “Old Andesite Formation” was badly defined. The author suggested to reject the name and instead to use purely local names.

The “Old Andesite Formation” distributes quite widely in Sumatera, southern part of Java, Nusa Tenggara and in places in Sulawesi and Irian. Based on the wide and elongated geographic distribution of the rocks, it was presumed that the rocks might have been erupted from the fissure. The recent investigators among others Sutanto et al. (1994), Soeria-Atmadja et al. (1994, 1998), were in the opinion that the volcanic rocks were produced by volcanic centers located along the volcanic arcs associated with the ancient subduction zones. The authors further revealed several stages of volcanic rocks emplacement within the rock succession. It seems therefore, quite adequate to describe in more detail the genesis of the “Old Andesite Formation” leading to the redefinition of the formation as suggested by Marks (1957).

The age of “Old Andesite Formation” has long been questioned, particularly due to the lack of fossils in the formation. However, the opinion put forward by van Bemmelen (1949) suggesting the age of Oligocene to Miocene was generally accepted. Based on comprehensive studies on chemical composition and age dating, Soeria-Atmadja et al. (1994) however recognized two stages of magmatic activities, namely at the time spans of 40 Ma to 18 Ma and from 12 Ma to 2 Ma. The former

might correspond to the “Old Andesite Formation”, while the latter might have been related to the reactivity of magma producing the proto modern volcanic arcs. The findings lead to the conclusion that the “Old Andesite Formation” consists of two “formations” with the hiatus in between. Consequently the present volcanic activities might have begun in the upper Tertiary age. This conclusion raise the question on the status of the stratigraphic position of Tertiary and the Quaternary ages. The current opinion presumed that the tectonic activity might have taken place terminating the Tertiary, before entering the Quaternary age. These propocative prepositions might indicate the importance of further studies on the age and the origin of the “Old Andesite Formation”. It may be worth noted that many earlier investigators had proposed to rename the “Old Andesite Formation”.

THE APPLICATION OF THE VOLCANIC FACIES

The facies analysis in volcanic terrain was first introduced by Reading (1978) and Selley (1978). Later the concept was comprehended by Williams & MacBirney (1979). Vessel & Davies (1979) proposed the volcanic facies model based on the thorough study of Fuego volcano. The sedimentary cycles of volcanoclastic sediments were triggered by major eruptions. In turns, it might influence the coral reef development in the marine surroundings. Walker and Wilson (1983) studied the volcanoclastic facies and presented the quantitative models of the volcanic facies in subaerial environment. Cas & Wright (1987) was in the opinion that in studying the ancient volcanic succession, the volcanic facies approach was most convinient to identify, describe and interpreting distinctive intervals and/or the associations of rocks which recur many times.

Modifying the earlier concept proposed by Vessel & Davies (1979), Bogie & MacKenzie (1998) described in more detail the characteristics of the facies (Fig. 1). It was proposed to divide the volcanic facies into central, proximal, medial and distal. The Central Facies was characterized by the composition of siliceous dome, vent breccia, agglomerates and intrusives. The Proximal Facies was characterized by the alternation of lava, tuff breccia and lapilli tuff. The Medial Facies was predominated by lahar deposits and tuff. On the plain at the lower volcano's slopes, the Distal Facies composed of lacustrine siltstone, conglomerates, and intercalations between sandstones and tuff.

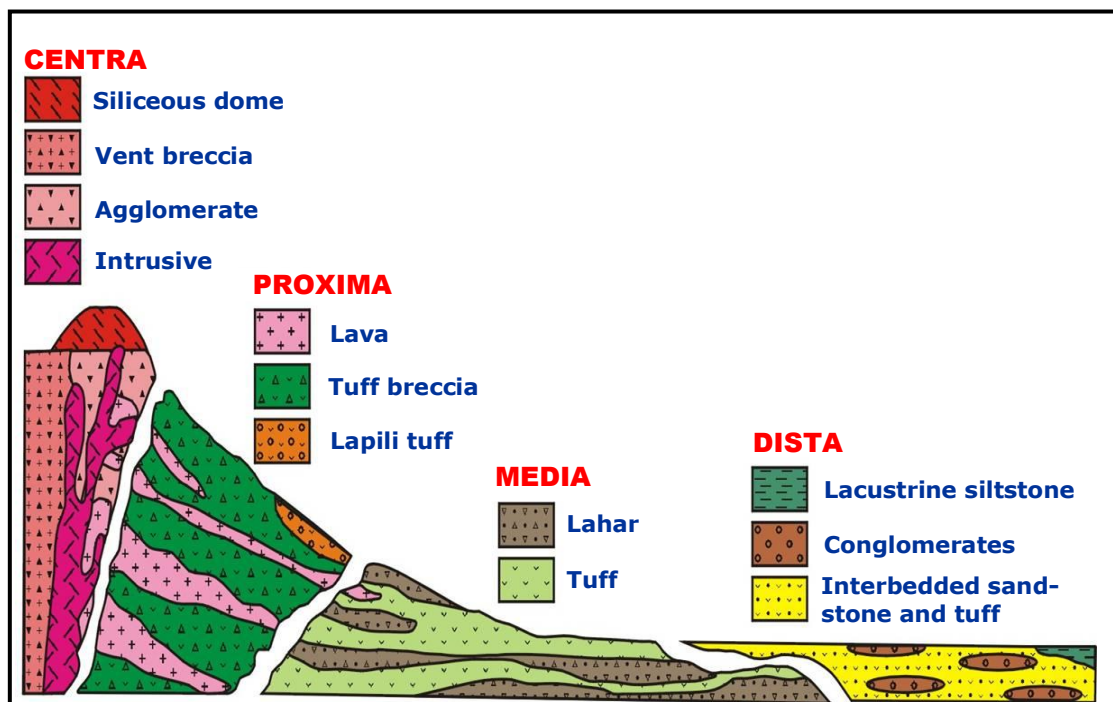


Fig. 1. The volcanic facies concept and its characteristics, according to Bogie & MacKenzie (1998).

The volcanic facies concept was extended by Lajoie & Stix (1992) to cover the subaqueous environment. The concept adopted the turbidite mechanism in the deposition of the volcanic rocks under the water's surface. The volcanic rock deposition model of the subaqueous environment was earlier put forward by Fischer

& Schmincke (1984) who divided the types of deposition into underwater pyroclastic flows and the slumping or secondary flows. The latter was associated with the turbidity current and mass flow.

The description of volcanic facies commonly covers the most distinctive properties. Selley (1978) proposed 5 types of characteristics to describe, namely geometry, lithology, sedimentary structures, paleocurrent or sediment movement pattern and fossils. The first 4 elements constituted the physical properties of the rocks showing the time and space where the rocks were formed. The last element concerning the fossil was very useful to interpret the relationship between the facies.

The present attempt was carried out to describe the “Old Andesite Formation” based on the application of the volcano facies concept. The delinention of the ancient volcanic rock successions of the formation was the aim of the study. The application of the volcanic facies concept was expected to solve the problem in locating the ancient volcanic centers. Hence the individual volcano unit hopefully could be outlined.

The area in Southern Mountain of Central Java was selected to carry out such a study, mainly based on the adequate data base available and secondly on the relatively well exposed “Old Andesite Formation” in this area (Hartono, 2000). In addition, the data was collected from Kulon Progo area, where van Bemmelen (1949) had intensively studied the petrogenesis and the stratigraphic sequence of “Old Andesite Formation” encountered in this area. Here the magmatic body was well exposed and the contact between the magmatic rocks and the eruptive materials demonstrated the syngenetic emplacement. The author discussed the role of late magmatic activities in the formation of the economic minerals. In this region, three eruption centers were already recognized, namely Gajah, Ijo and Manoreh. Although each center produced

similar rock types, the individual body of the volcano might be delineated based on the distribution and origin of the ejecta. The initial dip of the rocks played important role in the interpretation. The volcanic rock succession in Kulon Progo was unconformably underlain by the clastics and limestones of Jongrangan Formation.

In the studied area which is located in the vicinity of Pacitan, Southern Mountain of Central Java, 3 eruption centers were tentatively known. The most striking volcanic facies representing Central Facies was located at Bayat area, Klaten which composed of dioritic intrusions. Geomorphologically it still retained the horseshoe-shaped topography presumably reflecting the ruin of ancient caldera. The Proximal Facies was traceable in the surroundings. It consisted of pyroclastic breccias, autoclastic breccias, epiclastic breccias and agglomerates. This facies was equivalent to Nglanggran Formation.

The abundance of pyroclastic flows and falls consisting of white tuffs, dacitic pumice tuffites and dacitic breccias might represent the Proximal Facies of a very large caldera. Judging from the thickness which exceeded about 1000 meters, the center of activity must have been a large caldera as the result of a Plinian type eruption presumably at about the same scale of Toba eruption. The thorough study on the delineation of the ancient source of such a large volcanic activity was part of the study to describe the ancient individual volcanic bodies in this area. The study also revealed the possible recycle episodes of the volcanic activities within the Tertiary "Old Andesite Formation". At least, three episodes had been recognized (Surono, oral communication, 2006). The interpretation was supported by the age determination of the intrusives abundantly exposed in the area.

Terminating the volcanic activities, the erosion might have taken place. Later, it was interpreted that the volcanic arc has shifted somewhat northward (Soeria-Atmadja

et al., 1994) presumably associated with the changing velocity of the tectonic plate movement. In the marine surroundings, the Distal Facies might have been formed represented by the intensive deposition of clastic sediments. The rock sequence is presently known as Sambupitu and Nglarangan Formations. Further on, marine limestones and coral reefs of Wonosari Formation developed, partly in the area of Distal Facies (in Punung, near Pacitan) and partly in the open shallow sea environment. Afterwards the uplifting might have taken place until the present days as demonstrated by the evidence of the “dry valleys” and the terraces along the valleys and along the coastal line (Samodra, oral communication, 2006).

The interpretation of the paleo-environment has lead to the construction of the origin of the individual volcanic body. At this stage the authors propose the lithologic unit division, taking into account the individual unit of the ancient volcanic bodies. The already proposed names of the formation might be adopted. The lithologic unit based on the lithology and the characteristics of individual volcanic body may lead to better understanding of the stratigraphic unit in the light of the stratigraphic code.

DISCUSSION

The attempt to apply the volcanic facies in the description of the volcanic products was increasingly significant. First, because of the wide distribution of both ancient and modern volcanic rocks in Indonesia and secondly, the important roles attained by the volcanic products in the economic mineral exploration of base metals. Similarly, the role was played in the exploration of hydrocarbon (Kusumastuti, 1999).

The “Old Andsite Formation” in Southern Mountain area, Central Java has been chosen as the object of the present study. Based on the investigation of Soeria-Atmadja et al (1994), the locations of the volcanic arcs in Java island, might have

been shifting back and forth in Tertiary time, resulted in the overlapping of the arcs. This condition complicates the identification of the individual ancient volcanic body, because the recurrence of the activities might have taken place at the same location. The overlap might occur not only between episodes of activities, but also between the different ages of the volcanic belts.

In such a situation the application of the volcano facies concept would become very difficult if it is not impossible. The volcanic group or volcanic skeleton concept however, might still be applicable to delineate the particular distribution of the rocks. The renaming of “Old Andesite Formation” in line with the “Indonesian Stratigraphic Code” can therefore, still be done on the partial basis.

CONCLUSIONS

The application of volcanic facies concept might contribute to the understanding of the genesis of the volcanic rock units in terms of time and space. The information presumably important in the exploration of economic mineral deposits both base metals and hydrocarbon.

The status of “Old Andesite Formation” in terms of “Stratigraphic Code of Indonesia” might be clarified by the application of the volcanic facies concept. The thorough description of the individual ancient volcanic body by applying the volcanic facies concept may contribute to the proper renaming of the formation.

The attempted application which was carried out in the studied area at the vicinity of Pacitan, Southern Mountain, Central Java, has successfully revealed the identification of ancient volcanic centers as well as the delinention of the individual volcanic body. Based on such lithologic identification principles, the renaming of at

least parts of the “Old Andsite Formation” might be feasible in consistency with the “Stratigraphic Code of Indonesia”.

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