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The Evolution of Gajahmungkur Paleovolcano, Wonogiri, Central Java, as A Reference to Revize the Terminology of "Old Andesite Formation"

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Abstract

Gajahmungkur is a Tertiary paleovolcano located in Wonogiri Regency, Central Java. The volcanic product of this volcano are widely distributed and composed of important elements of the stratigraphic sequence in the Southern Mountain area. The volcanic products so far have been simply classified as "Old Andesite Formation" which apparently is not in line with the stratigraphic code and the Indonesian Stratigraphic Code. The description of paleovolcano therefore might contribute to the revision of the "Old Andesite Formation". The evolution of Gajahmungkur paleovolcano commenced with the formation of a submarine volcano, and then at the second phase a composite volcano emerged above sea level forming a volcano island. The third phase was the self destruction resulting in a formation of a caldera. Pumiceous components dominated the products. At the fourth phase, the activities began to decline producing more basaltic rocks. The statistical analysis of the interrelation between various physical properties of the clastic rocks leads to the identification of volcanic facies and the location of the paleovolcano vent.

Keywords: Gajahmungkur paleovolcano, statistical interrelation, volcanic facies, Old Andesite

Sari

Gunung Gajahmungkur yang terletak di Kabupaten Wonogiri, Jawa Tengah merupakan gunungapi purba yang berumur Tersier. Produk gunungapi purba ini tersebar luas dan membentuk elemen penting dalam urutan stratigrafi di Pegunungan Kidul. Sejauh ini, batuan gunungapi Tersier digolongkan sebagai "Formasi Andesit Tua". Penamaan ini tidak sesuai dengan aturan tatanama stratigrafi maupun Sandi Stratigrafi Indonesia. Karena itu pemerian terhadap gunungapi purba dapat membuka jalan untuk menyempurnakan tatanama "Formasi Andesit Tua". Evolusi Gunungapi Purba Gajahmungkur dimulai dengan pembentukan gunungapi bawah laut dan pada fase kedua terjadi pembentukan sebuah gunungapi komposit yang membangun sebuah pulau. Pada fase ketiga terjadi penghancuran diri yang membentuk sebuah kaldéra. Produk letusan didominasi oleh batuan piroklastika pumis. Pada fase keempat, aktivitas menurun dan menghasilkan batuan yang lebih basaltis. Analisis secara statistik terhadap hubungan antar karakteristik fisik batuan klastik menjadi dasar bagi pengenalan fasies gunungapi dan lokasi pusat kegiatan.

Kata kunci: *Gunungapi purba Gajahmungkur, interrelasi secara statistik, facies gunungapi, Andesit Tua*

Introduction

The investigated area is located in Wonogiri Regency, Central Java, at the longitudes 110°47'43"-110°57'17" East and latitudes 7°52'28" – 7°52'7" South (Figure 1). The Tertiary volcano of Gajahmungkur is part of the Southern Mountain. The range consists of various types of volcanic rocks sub aerially and subaqeously deposited. The age ranges between Eocene to Miocene (Bothe, 1929; van Bemmelen,

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1949). However the recent investigations showed younger ages up to Pliocene which moved the upper unconformity boundary of the rock sequence from Mid-Upper Miocene to Upper Pliocene (Surono *et al*., 1992) or even to Pleistocene (Samodra *et al*., 1992). On the other hand, some other investigators favored to assign Cenozoic Era to the volcanic rock sequence of the Southern Mountain (Smyth *et al*., 2008).

The Tertiary volcanic activity of Southern Mountain so far has been simply described as a single formation called "Old Andesite Formation" with the age supposedly ranges between Oligocene to Miocene. The subaqeously deposition of the volcanic rocks syngenetically deposited with shallow and littoral marine deposits adds the complication of the stratigraphy of the area. Therefore, the volcanic sequence of Southern Mountain is described as a formation. However the terminology has so far been controversial as among others pointed out by Marks (1957). He further suggested re-describing the terminology. Moreover the Stratigraphic Code of Indonesia published by the Association of Indonesian Geologists is not in favor to such a description (Martojoyo *et al.*, 1973; Martojoyo and Djuhaeni, 1996).

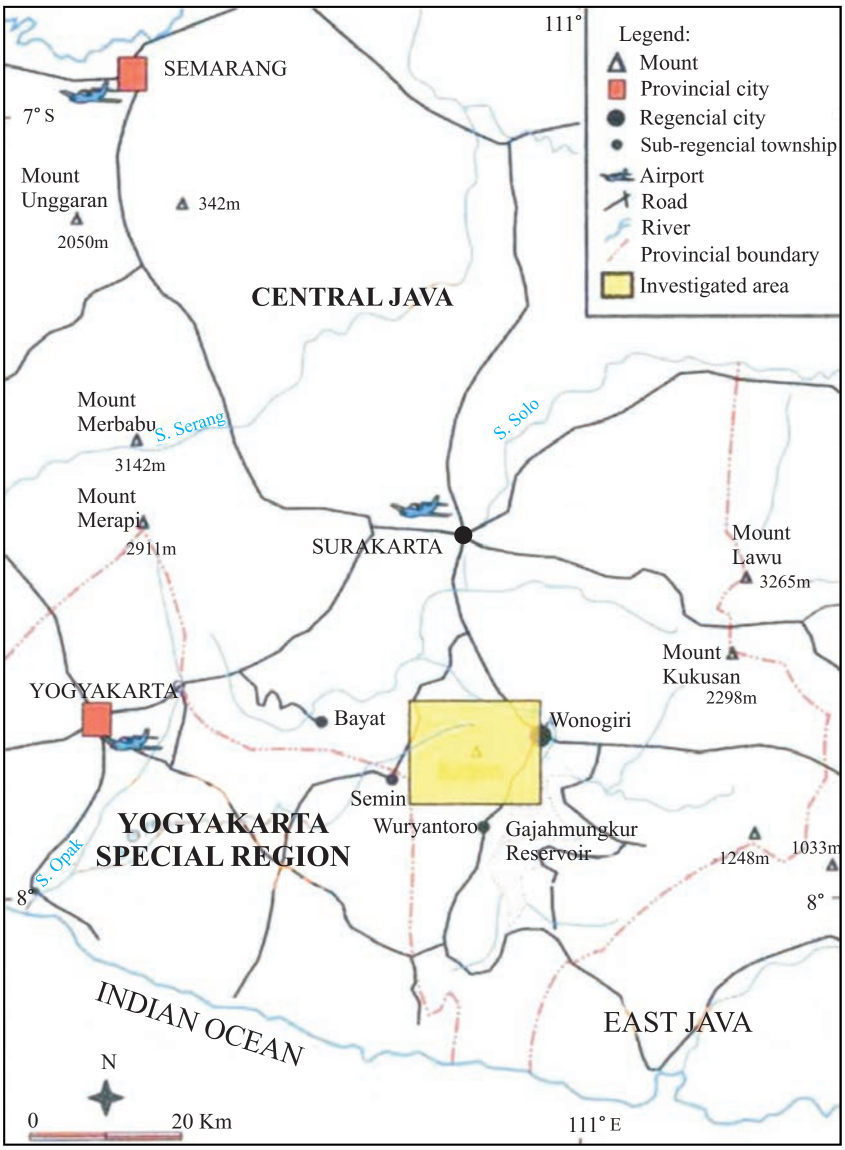

Figure. 1 Locality map of the investigated area, where the Gunung (Mount) Gajahmungkur is situated.

The present investigation attempted to fully apply the lithologic unit description in line with the code. Gajahmungkur Volcano has been selected as the focus of the investigation taking into account the complexity of the depositional environment of the volcanic rocks produced by the volcano. The description and delineation of the volcanic rock units give the idea of the development of Gajahmungkur Volcano. Hence the status and position of the rock sequence in the formation might be constructed. The same method would be able to be applied in other area in the so called "Old Andesite Formation".

Methodology

The investigation mostly relied on the physical rock determination in the field. Petrographic analysis has also been carried out to support the result of the field evidence. The remote sensing method was intensively used in the initial phase of the investigation. The digital analysis of the Alos images produced in 2007 with 10 m resolution was integrated with radar image prepared in 1997 with a resolution of 90 m. The Alos image was fused with the topographic map resulted in SRTM.

The image analysis was aided by the software of ER Mapper 6.4, MapInfo 8.0 SCP, and Global Mapper 8. The topographic expression obtained from the images has clearly depicted the development of the volcanic activity. A very impressive horse shape caldera was readily exhibited and guided further detailed investigation in the field.

In accordance with normal mapping procedure, the random sampling with GPS aided coordinate location was carried out. It was conducted particularly for the statistical analysis of the distribution of volcanoclastics. The process involved the dimension and orientation of the fragments in the field and under the microscope to observe the same phenomena in minerals. The sampling procedure was guided by the general distribution of volcanic rock based on volcano facies method developed by Vessel and Davies (1981).

Results of Investigation

The very impressive geomorphologic expression of Gajahmungkur Volcano complex is the horse shoe shape caldera with the undulated topography of the volcanic products. These phenomena clearly depict the self destruction of Gajahmungkur Volcano at the latest stage of the activity combined with the sector failure (Figure 2). The undulated topography typically exhibited the deposit produced by sector failure as recently demonstrated by Mount Saint Helens eruption in 1980 (Lipman and Mullineaux, 1981).

The stratigraphic sequence of Gajahmungkur Volcano complex is commenced with the oldest rocks consisting of micro diorite. The rock is overlain by a tuff unit with the lithology of alternations between fine- and coarse- tuffs, fine- grained breccia, and calcareous sandstone. The rocks contain benthonic foraminifera fossils indicating a shallow marine environment. Overlying the rocks, predominantly andesitic lava was flowed down. The flow was interrupted with the intercalation of fine- and coarse-grained sandstones. Auto breccias were also observed. Part of the lava flows exhibits pillow structures with the aphanitic texture containing mafic minerals.

Based on the characteristic mentioned above, presumably the volcano was formed in the submarine environment. The rock sequence was intruded by the pyroxene andesite. At the same time the amphibole andesite intrusions took place. The radiometric age dating confirmed these intrusions of having the same age of the Middle Miocene age (Surono *et al*., 1992).

All those volcanic products were finally overlain by an intensive sub-aerial deposition of pumiceous breccia. The deposit indicates typically cataclysmic eruption of the Katmaian type. The sandstone, fine breccia, and clay intercalations were present exhibiting the reworked products of the pumice deposit. Among the pumice components, angular fragments of metamorphic rocks consisting predominantly of schist were found. The fragments supposedly abraded from the inner wall of the diatrema during the powerful outburst of Plinian type.

Pumiceous breccias might have been deposited under the pyroclastic flow mechanism of Krakatau type. Base surge deposits were clearly identified showing cross bedding stratifications. The rock partly consists of massive tuff deposit presumably the result of a high temperature cooling of a great pile of tuff. The radiometric age determination using hornblende indicated 9.6 ± 0.3 my (Setijadji

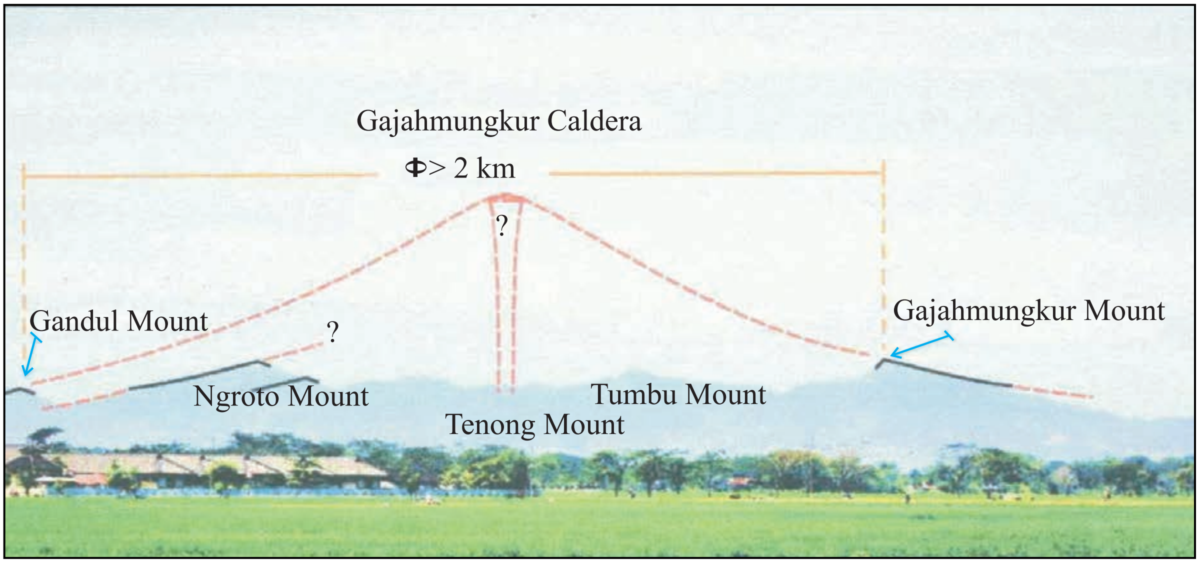

Figure 2. The reconstruction of Gunung Gajahmungkur proper shows the ancient Gajahmungkur Volcano. Three remnants of calderas are observable, namely Gajahmungkur-Gandul Caldera (the largest), unnamed caldera, and Ngroto Caldera. In the central part the basaltic andesite domes namely Tenong Hill and Tumbu Hill are also observable. These domes developed in the Gajahmungkur Caldera (somma) indicating the terminating stage of the ancient Gajahmungkur Volcano. The crater is about two kilometers across (Hartono, 2010). The photograph was taken from NW of Gajahmungkur by H. G. Hartono.

and Watanabe, 2009), whilst the other one using zircon was resulted in 16.0 ± 0.7 millions years to 17.0 ± 1.1 million years (Surono, 2008). Based on the general correlation it was concluded that the age was presumably Early Miocene to Middle Miocene. The deposition environment was mainly terrestrial; however the littoral and shallow marine deposits were also identified.

The volcanic product of finer materials containing calcareous- and pumiceous- tuffs might have been deposited in a marine environment. The sub-aqueous calcareous tuff represents such a deposit containing fossils. The fragments of large foraminifera in places were abundantly recognized. Fragments of plankton fossil were also present. The low energy depositional environment was probably predominant a showing shallow marine condition. The pumiceous tuff was named as Semilir Formation. The latest phase was the development of the basaltic rocks in the caldera represented by the Tenong and Tumbu lava domes.

The development of Gajahmungkur paleovolcano is illustrated as follows: first, a submarine volcano was born, then it developed to become a volcano island, and finally it destructed itself (Figure 3).

Beside the topographical expression, the statistical analysis of the grain size and the phenocryst of the rock forming minerals (RFM) concluded that the volcano facies could be recognized based on the following verified criteria:

- *The interrelation between the grain sizes.* The grain size distribution, the ratio of sizes, the ratio of the fall materials, and the steepness of the ratios represent the specific type of volcano facies.
- *The physical distribution of igneous rock phenocryst.* The diameters of the RFM phenocryst identify the central, proximal, and medial facies. The amount of glass proportion of the RFM identifies the central, proximal, and medial facies.

The statistical analysis of various types of chemical elements however proved to be insignificant in delineating the volcano facies. The proportion between effusive materials might in cases confirm the interrelation of various physical dimensions of the clastic materials.

Discussion

The physical properties of the rock sequence in volcanic products are readily identifiable including

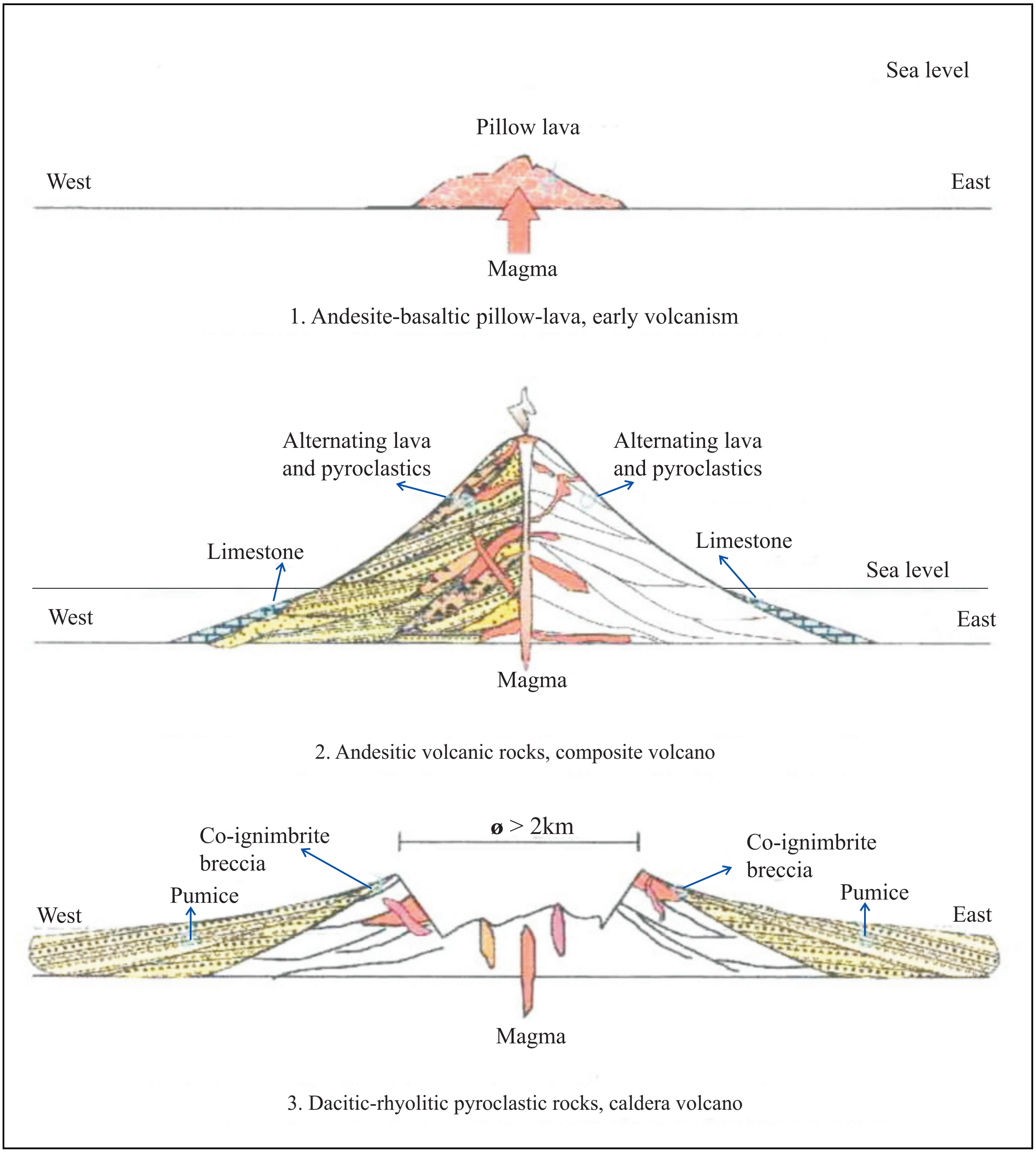

Figure. 3. The illustration shows the development of Gajahmungkur Volcano starting with the formation of lava flows with pillow structure indicating subaqueous deposition (above), followed by the formation of a composite strato volcano island (middle), and finally the self destruction resulting in the formation of caldera (below).

the environmental condition of the deposition. Hence, the lithologic rock unit in line with the Stratigraphic Code of Indonesia can be constructed. The volcanic rock facies analysis might lead to the determination of the vent or the central of volcanic activity of a particular rock unit. The volcanic rock sequence therefore, can be identified based on the lithologic unit produced by a particular observation with the vent as the center. In such a case the individual volcanic products can be delineated.

The Tertiary volcanic products so far were grouped into a unit without distinguishing between the individual volcanic rock units. The strongly eroded topography of the volcanic body hampered the recognition. It was therefore quite reasonable to group the andesite rocks of the Tertiary age as older andesite in view of the readily recognize Quaternary volcanoes. However with the analysis of various interrelations between the physical properties of the clastic rocks, the locality of the vent can be interpreted. The "Old Andesite Formation" might be divided into the formations based on group of volcanic bodies identifiable in the formation.

The identification of individual Tertiary volcano in particular in the area occupied by Old Andesite Formation might lead to the renaming of the formation in line with the Stratigraphic Code of Indonesia.

Conclusions and Recommendation

From the above discussion, the following conclusions might be drawn:

1. The history of the volcanic activities of the Gajahmungkur paleovolcano can be constructed based on the interrelation of the physical properties of the deposit;
2. The application of volcanic facies might contribute to the solution of the terminology of "Old Andesite Formation" which was not in line with the Stratigraphic Code of Indonesia.

It is suggested therefore to apply the concept and delineate the individual volcanic bodies of Tertiary age already ruined by the intensive erosion. The geologic mapping in old volcanic terrain is the key to solve such a problem.

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References

Bothe, A. Ch. D., 1929. Djiwo Hills and Southern Range, *Fourth Pacific Science Congress Excursion Guide,* 14 pp.

Hartono, G., 2010. *Peran Paleovolkanisme Dalam Tataan Produk Batuan Gunungapi Tersier Di Gunung Gajahmungkur, Wonogiri, Jawa Tengah*. Disertasi Doktor di Fakultas Teknik Geologi, Universitas Padjadjaran, Bandung, p.74-176.

Lipman P.W. and Mullineaux, D. R., 1981. The 1980 Eruption of Mount St. Helens. *US Geological Survey Professional. Paper 1250,* Washington.

Marks, P., 1957. Stratigraphic Lexicon of Indonesia, *Scientific Publication No. 31, Geological Series*, Geological Survey of Indonesia, Bandung, 145 pp.

Martojoyo, S., Koesmono, M., and Sudradjat, A., 1973. *The Indonesian Stratigraphic Code.* Indonesian Association of Geologists.

Martojoyo, S. and Djuhaeni, 1996. *The Indonesian Stratigraphic Code.* Indonesian Association of Geologists, Jakarta, 25 pp.

Samodra, H., Gafoer, S., and Tjokroseputro, S., 1992. *The Geological Map of Pacitan Quadrangle, scale 1:100.000*. Geological Research and Development Center, Bandung.

Setijadji, L. D. and Watanabe, K., 2009. Updated Age Data of Volcanic Centers in Southern Mountains of Central-East Java Island, Indonesia. *Proceedings of International Conference of Earth Science and Technology*, Gajah Mada University, Yogyakarta, p. 1-7.

Smyth, H.R., Hall, R., and Nichols, G.J., 2008. Cenozoic Volcanic Arc History of East Java, Indonesia: The stratigraphic record of eruptions on active continental margin. *The Geological Society of America, Special Paper 436*, p. 199-222.

Surono, Sudarno, I., and Toha, B., 1992. *The Geologic Map of Surakarta Quadrangle, scale 1:100.000*. Geological Research and Development Center, Bandung.

Surono, 2008. The Sedimentation of Semilir Formation in Sendang Village, Wuryantoro, Wonogiri, Central Java. *Journal of Geological Resources*, 18(1), p.29-41.

Van Bemmelen, R. W., 1949. *The Geology of Indonesia*, Vol. IA, The Hague, Martinus Nijhoff, 732 pp.

Vessel, R. K and Davies, D. K., 1981. Non Marine Sedimentation in Active Fore Arc Basin, *SEPM Special. Publication.*, No. 31, p. 31- 48.