

RESEARCH ARTICLE

Characteristics of Ultramafic Igneous Rock Ophiolite Complex in Asera District, North Konawe Regency, Southeast Sulawesi Province, Indonesia

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Abstract

The research area is located in Asera District, North Konawe Regency, Southeast Sulawesi Province which has ultramafic rock lithology. The purpose of this study is to determine the characteristics of ultramafic igneous rocks using petrographic and geochemical analysis. Petrographic analysis aims to determine the types and abundance of minerals present so that rock types can be determined based on the classification of Travis (1955) and Streckeisen (1976). The geochemical analysis aims to determine the oxide/major element so that it can determine the type of magma based on the AFM classification according to Irvine and Baragar (1971) and the origin of the magma / original rock formation environment based on Pearce (1977). Petrographic analysis results showed that ultramafic rocks in the study area consisted of 2 types of rocks namely peridotite consisting of wherlit and lherzite and serpentinite. The results of geochemical analysis indicate that the type of magma in the study area is tholeiitic series and the origin of the magma/rock formation environment comes from the expansion of the oceanic floor or mid oceanic ridge (MOR) which is ultramafic.

Keywords: Asera, North Konawe, Ultramafic, petrography, geochemistry

1. Introduction

The ophiolite and pelagic sedimentary rocks in the East and Southeast Arm of Sulawesi are called the East Sulawesi Ophiolite Belt. This belt consists of mafic and ultramafic rocks accompanied by pelagic and melange sedimentary rocks in several places. Ultramafic is dominant in the Southeastern Arm, but the mafic rocks are dominant further north, especially along the North coast of the Southeast Arm of Sulawesi. Complete ophiolite sequences are found in the Eastern Arm, including mafic and ultramafic rocks, pillow lava and pelagic sedimentary rocks which are dominated by deep sea limestone and layered cherty intercalation (Suroño, 2013).

In the geological map of the Kendari Lasusua Sheet with a scale of 1: 250,000 (Rusmana et al., 1993), the Asera District of North Konawe Regency, Southeast Sulawesi Province (Figure 1) is on the Ophiolite (Ku) Mandala line of eastern Sulawesi in the lime age. The constituent rocks in the Ophiolite (Ku) lane are harzburgite, lherzolit, wherlit, websterite, serpentinite, dunit, and gabro rocks. These rocks are rocks which, if weathered, can form nickel laterite in lateralization processes which are generally composed of mafic minerals with low silica (SiO₂) content of less than 45% (Ahmad, 2002).

The constituent minerals of ultramafic igneous rocks are olivine, pyroxene and hornblende which are in a fresh state is dark colour. Decomposition of these primary minerals which causes the elements carried in the solution will then precipitate at a certain place. This process runs dynamically and slowly, so that the laterite profile is formed which is the development of the laterization stages.

2. Research Methods

The method used in this study is divided into four stages namely: (1) Desk Study, (2) fieldwork (3) laboratory analysis and (4) data interpretation.

2.1. Desk Study

At this stage secondary data collection and literature review of the results of previous studies were carried out relating to the geological conditions of the study area.

2.2. Fieldwork

Field work includes surface geology observation and mapping and representative sampling, geomorphological observations and geological structures.

2.3. Laboratory Analysis

This analysis includes petrography and geochemistry. Petrographic analysis begins with sample preparation into thin sections, then analyzed using a Nikon type polarization microscope. Petrographic analysis aims to determine the types and abundance of minerals present so that rock types can be determined based on the classification of Travis (1955) and Streckeisen (1976). The geochemical analysis aims to determine the oxide / major element so that it can determine the type of magma based on the AFM classification according to Irvine and Baragar (1971) and the origin of the magma / original rock formation environment based on Pearce (1977). Petrographic analysis was carried out at the Geological Engineering Laboratory of the Faculty of Earth Sciences and

Technology of Halu Oleo University and geochemical analysis in the form of XRF (X-Ray Fluorescence) analysis was carried out at PT. Minertech Indonesia.

The interpretation of the data in this study includes all relevant data from the results of field and laboratory work which are evaluated and compiled to produce research objectives.

2.4. Data Interpretation

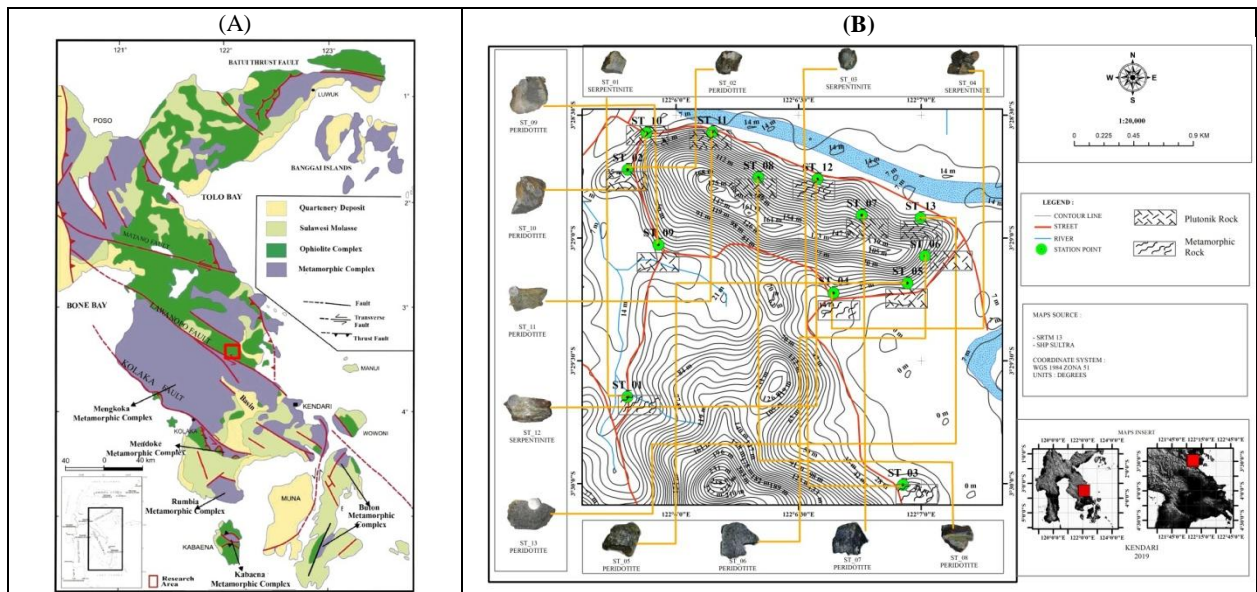


Fig 1. (A) Regional geology of the study area (modified from Surono, 2013). (B) Characteristics of ultramafic rocks in the study area.

3. Results and Discussion

The number of stations in this study was 13 stations (Figure 1B), but there were 8 representative samples analyzed by petrography. After petrographic analysis, geochemical analysis is then performed based on petrographic analysis.

3.1. Characteristics of Ultramafic Rocks

3.1.1. Ultramafic Rock Petrography

Table 1. Characteristics of ultramafic rocks based on petrographic analysis

Rock group	Mineral content (%)					Rock Name	Sample Code
	OI (%)	Opx (%)	Cpx (%)	Srp (%)	Opq (%)		
Peridotite	50	10	30	-	10	Wherlit	ST_05
Peridotite	45	20	25	-	10	Lhezorlit	ST_02
Peridotite	45	15	32	5	2	Lhezorlit	ST_06
Peridotite	43	35	15	-	7	Lhezorlit	ST_07
Peridotite	40	20	32	5	3	Lhezorlit	ST_08
Serpentinit	5	-	-	90	5	Serpentinit	ST_01
Serpentinit	-	-	-	95	5	Serpentinit	ST_03
Serpentinit	10	-	25	65	-	Serpentinit	ST_04

A. Peridotit Group

Generally rocks in the study area are included in the peridotite group. Based on the results of petrographic analysis, peridotite rock types are divided into 2, namely wherlit (ST_05) and lhezorlit (ST_02, ST_06, ST_7 and ST_08) (Streckeisen, 1976). The two rock types are distinguished by the presence of olivine, orthopiroxene and clinopiroxene minerals present in peridotite rocks.

i). Wherlit

Petrographic analysis results on ST_05 showed that the mineral composition in rock samples consisted of 50% olivine minerals, 10% orthopiroxene minerals, 30% klinopiroxene and 10% opaque minerals (Figure 2).

Petrographic analysis results showed that the characteristics of ultramafic rocks in the study area were divided into 2 groups of rocks (Table 1), namely peridotite and serpentinit groups (Travis, 1995) (Figure 2). Peridotite groups are divided into wherlit and lhezorlit which are characterized by the minerals olivine, orthopiroxene, and klinopiroxene, in these rocks and serpentine groups which are characterized by the presence of serpentine mineral (Streckeisen, 1976) (Table 2).

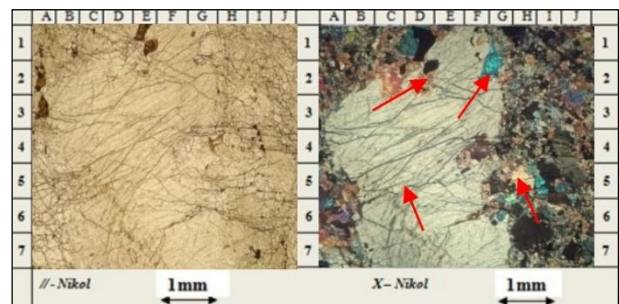


Fig 2. Microscopic appearance of sample point ST_05. Olivine mineral (Ol), orthopiroxene mineral (Opx), klinopiroxene mineral (Cpx) and Opaque mineral (Opq).

The results of plotting using the Streckeisen (1976) classification of mineral compositions (Figure 2) show that the characteristics of ultramafic rocks at this station include wherlite rock types (Figure 3).

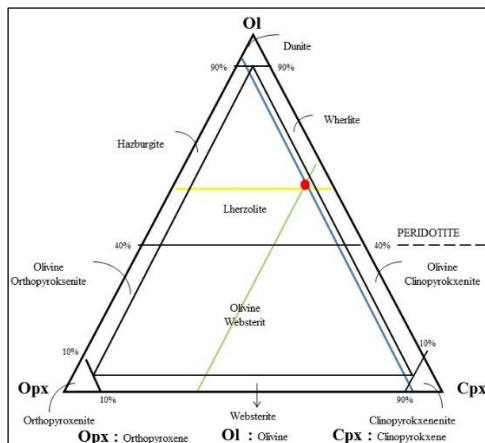


Fig 3. Classification of ultramafic rocks according to Streckeisen (1976).

ii). Lhezorlit

Petrographic analysis results on ST_02 showed that the mineral composition in rock samples consisted of 45% olivine minerals, 20% orthopyroxene minerals, 25% clinopyroxene and 10% opaque minerals (Figure 4).

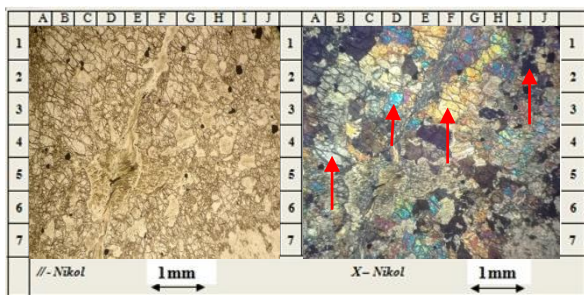


Fig 4. Microscopic appearance of sample point ST_02. The mineral olivine (Ol), ortho-pyroxene mineral (Opx), clinopyroxene mineral (Cpx) and Opaque mineral (Opq).

The results of plotting using the Streckeisen (1976) classification of mineral compositions (Figure 4) show that the characteristics of ultramafic rocks at this station include lherzilit rock types (Figure 5). The same characteristics of ultramafic rock in the form of lherzilit are also found in ST_06 ST_07 and ST_08 (Table 2).

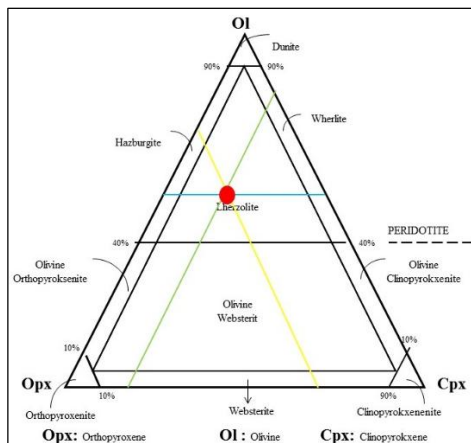


Fig 5. Classification of ultramafic rocks according to Streckeisen (1976).

B. Serpentinite Group

The serpentine group is based on the presence of abundant serpentinite minerals with a little extra mineral olivine and pyroxene and opaque minerals. The serpentine mineral is formed from the chemical changes of the olivine and pyroxene minerals so that it undergoes the serpentinization process.

Petrographic analysis results on ST_01 showed that the mineral composition in rock samples consisted of 90% serpentine minerals, 5% olivine minerals and 5% opaque minerals (Figure 6).

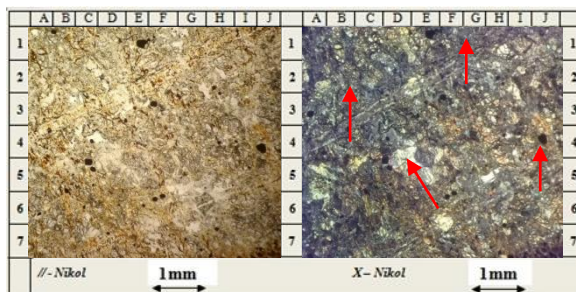


Fig 6. Microscopic appearance of sample point ST_01. Serpentin (Srp) mineral, olivine (Ol), orthopyroxene mineral (Opx), and Opaque mineral (Opq).

Figure 6 shows that the mineral serpentine with a 90% mineral percentage generally fills fractures in minerals due to the structure that works, and the effect of alteration that converts the minerals olivine and pyroxene into serpentine minerals. Petrographic observations show that opaque minerals whose presence is around 5% are thought to be chromite minerals. The results of the analysis show that the rocks at this station have been serpentinized into serpentinic rocks. Referring to the abundance of serpentine minerals in rocks, the characteristics of ultramafic rocks at this station include serpentine type ultramafic rocks (Travis, 1955). Serpentine type ultramafic rocks are also found in ST_04 in the presence of 65% serpentine minerals, 10% olivine minerals and 25% clinopyroxene minerals (Table 2).

Table 2. Oxides/constituent elements of ultramafic rocks Asera District North Konawe Regency Southeast Sulawesi Province.

Elements	Rock Name	
	Peridotite	Serpentin
	Sample Code	
	ST_02	ST_04
Fe	6,281 (wt%)	5,027 (wt%)
Co	0,02 (wt%)	0,007 (wt%)
Ni	0,319 (wt%)	0,291 (wt%)
Al ₂ O ₃	1,298 (wt%)	1,692 (wt%)
SiO ₂	37,82 (wt%)	38,119 (wt%)
CaO	1,79 (wt%)	2,114 (wt%)
MgO	29,749 (wt%)	30,112 (wt%)
Cr ₂ O ₃	0,243 (wt%)	0,451 (wt%)
MnO	0,159 (wt%)	0,219 (wt%)
Fe ₂ O ₃	7,219 (wt%)	0,62 (wt%)
Na ₂	0,017 (wt%)	0,019 (wt%)
Al	0,208 (wt)	0,019 (wt)
Ca	0,627 (wt%)	1,694 (wt%)
Mn	0,033 (wt%)	0,068 (wt%)
P	0,003 (wt%)	0,003 (wt%)
S	0,038 (wt%)	0,013 (wt%)
Cr	0,269 (wt%)	0,236 (wt%)
K ₂ O	0,009 (wt%)	0,005 (wt%)

C. Determination of the Types and Origins of magma

i). The main element of ultramafic rocks

The determination of the oxide / main element of ultramafic rocks in the study area was carried out on 2 samples

representing rock units contained in the study area, namely the peridotite rock group and the serpentinite rock group that had been previously performed petrographic analysis to determine the mineral content contained in the rock. Geochemical analysis is carried out to determine the oxides / main elements contained in these ultramafic rocks. The results of geochemical analysis showed that the oxide / element content in both samples was low SiO₂ with 37.82 (wt%) and 38.119 (wt%) content. The content of SiO₂, Al₂O₃, and K₂O is quite low while the content of MgO and FeO and Fe₂O₃ is quite high (Table 2). The high content of MgO and the low content of SiO₂ are the characteristics of ultramafic rocks, where ultramafic rocks are rich in magnesium and iron minerals and low in silica (Rollinson, 1993). Following are the results of the analysis of the main elements carried out by PT. Minertech Indonesia (Table 2).

ii). Types of Magma

Based on the results of the geochemical analysis in the form of XRF, the types of magma plotted on the AFM diagram (Irvine and Baragar, 1971) on the ultramafic rocks in the study area are included in the tholeiitic series (Figure 7).

This type is very common in tectonic settings in the form of ocean floor expansion zones or commonly referred to as mid oceanic ridge (MOR) (Wilson, 1989). This is characterized by low SiO₂ and K₂O values and rich in ferromagnetic compositions such as MgO and FeO (Table 2).

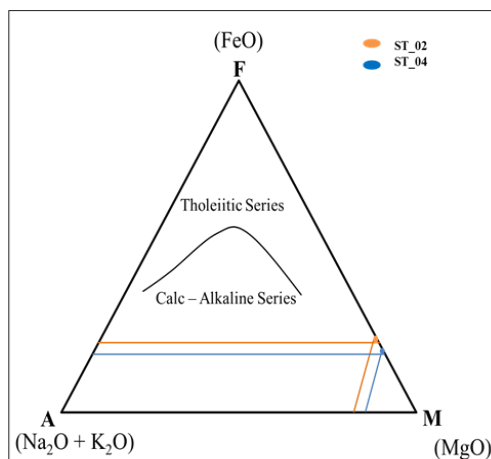


Fig 7. Plotting results in the classification of types of magma according to (Irvine and Baragar 1971).

The types of magma consist of two groups, namely alkaline and subalkalin. These alkaline rocks are rich in alkaline and are usually not saturated with silica while subalkalin rocks are saturated with silica. This subalkalin group is divided into two groups namely tholeiitic series and cal-alkaline series.

Tholeiitic rocks are more rich in Fe compared to MgO than cal-alkaline rocks and generally have less silica variation. The calc-alkaline group shows more silica and alkali enrichment. Magma series describes the spatial variation of magma. The farther from the trench that is formed, the type of magma is transformed into tholeiitic, then calc-alkaline is getting farther away becoming alkaline (Wilson, 1989).

The classification of magma types is based on the content of the main elements in rocks in the form of K₂O + Na₂O, FeO and MgO elements, which are plotted into the AFM triangle (Irvine and Baragar, 1971) (Figure 8), so based on these results and the results of petrographic and geochemical analysis, then the research area has a type of magma that is tholeiitic Series which is ultramafic.

iii). Origin of Magma

The origin of magma forming ultramafic igneous rocks in the study area can be determined using the Pearce triangle diagram, 1977, which is based on the comparison of the main elements of ultramafic rocks in the form of FeO, MgO, and Al₂O₃ elements. Based on the triangle diagram, the tectonic setting of ultramafic rocks in the study area is included in oceanic ridge and floor, or mid oceanic ridge (MOR) (Figure 8).

Based on the results of geochemical analysis on ultramafic rock samples in the study area, ultramafic rocks have a K₂O value of less than 0.1 so it can be concluded that the type of MOR that forms these rocks is the normal type (type N). Type N or normal type MORs are formed at shallow depths, which are between 60 - 80 km from the upper mantle (Wilson, 1989). K₂O value is used for this interpretation because the value of the element is at least in the MOR.

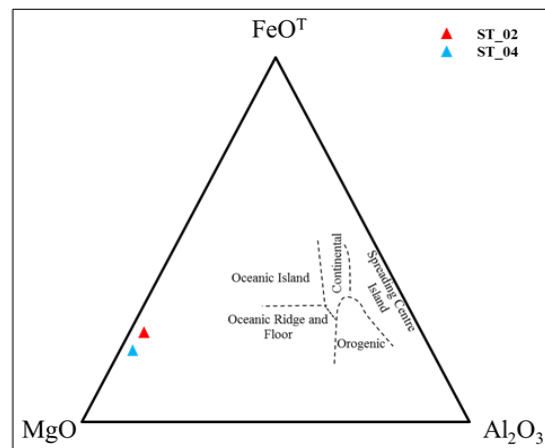


Fig 8. Results of plotting on the classification of the origin of magma according to (Pearce, 1977).

Based on research conducted by several experts including Surono 2013, Robert Hall, 2012 that ophiolites in the Southeast Arm of Sulawesi were formed in an ocean floor expansion environment (MOR). By referring to this matter, which is supported by petrographic data and geochemical data, it can be interpreted that the research location was formed due to ocean floor expansion (MOR). The formation process first takes place in the mid-ocean expansion, followed by the movement of material originating from the mantle in accordance with the movement of the expansion. Based on the results of the withdrawal of absolute age by Surono (2010) on pelagic sedimentary rocks in the Eastern Arm of Sulawesi, the ultramafic rocks revealed in the East Arm and Southeast Arm of Sulawesi have Late Cretaceous age. Based on these, the ultramafic rocks in the Southeast Arm of Sulawesi might form in the Late Cretaceous which is marked by the rifting process. Southeast Sulawesi experienced a drift from the Australian Continent moving towards Sulawesi's current position (Hall, 2012). Based on the reconstruction carried out (Hall, 2012) shows that Southeast Sulawesi is part of the Australian Continent which is currently in the Southeast part of Sulawesi Island.

Hall (2012) estimates that the expansion of the ocean floor that occurred in the Late Cretaceous caused rocks that characterize the oceanic floor to form. This process was followed by the movement of the Australian Continent towards Eurasia / Sundaland which was accommodated by India - Australia Transform. The subduction process began at the Beginning of Paleocene on the edge of Sundaland. This subduction caused the movement of the Australian Continent to move towards Eurasia. In addition, the subduction also led to the formation of North Sulawesi Province which is an archipelago formed (Hall, 2012). The subduction process stops

at the Late Oligocene and there is initial contact between Sula Spur and the North Sulawesi Archipelago Bow. This subduction process continues and causes collision events in the Early Miocene which causes the ocean floor to rise to form the foreland basin. This collision event is often also referred to as soft collision. As a result of the continued subduction process, the second collision event occurred at the Pliocene, known as a hard collision between the results of the first collision (Sula Spur and the North Sulawesi Archipelago Bow) and Eurasia / Sundaland which formed Sulawesi as seen today (Hall, 2012).

Based on this concept and the results of petrographic and geochemical analysis, the rock area is ultramafic, with a type of magma tholeiitic series and is formed in the oceanic ridge area (Best, 2003; Pearce, 1977 Pearce et al, 1984), which is the ocean bloom zone (MOR) originating from the Australian continent which was exposed to the surface due to the collision process forming Sulawesi as seen today (Hall, 2012)

4. Conclusions

Based on petrographic analysis that the characteristics of ultramafic rocks in the study area consisted of 2 groups namely peridotite groups consisting of wherlit and lherzite and serpentinite groups. Petrographic results supported by geochemical data indicate that the type of magma in the study area shows tholeiitic series based on the percentage of the main elements in the form of FeO, Na₂O + K₂O and MgO plotted in the AFM triangle. The origin of the magma / rock formation environment in the study area is the oceanic ridge and floor expansion (MOR) based on the percentage of main elements in the form of FeO, MgO, and Al₂O₃.

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References

Ahmad, W., 2002, Nickel Laterites-A Short Course : Chemistry, Mineralogy, and Formation of Nickel

Laterites (unpublished), 98 p.

- Best, M., G., 2003, Igneous and Metamorphic Petrology 2nd Edition, Blackwell Publishing Company, Australia.
- Hall, R. 2012. Late Jurassic-Cenozoic Reconstruction of the Indonesian Region and the Indian Ocean. *Tectonophysics* 570-571, 1- 41.
- Irvine, T.N and Baragar, W.R.A., 1971. A Guide to the chemical classification of the common volcanic rock. *Canadian Journal of Earth Science* 8,523-248.
- Pearce T.H, Gorman B,E and Birkett T.C. 1977. The relationship between major element chemistry and tectonic environment of basic and intermediate volcanic rocks, *Earth Planet Sci*
- Pearce, J.A., Lippard, S.S., Roberts, S.,1984. Characteristics and tectonic significance of suprasubduction zone ophiolites. In: Kokelaar, B.P., Howells, M.F. (Eds.), *Marginal Basin Geology. Volcanic and Associated Sedimentary and Tectonic Processes in Modern and Ancient Marginal Basins* Geological Society of London Special Publication, vol.16, pp. 77-94.
- Rollinson, H., 1993., *Using Gheochemical data : Evaluation, Presentation and Interpretation*, longman grup, UK
- Rusmana E., Sukido, Sukarna, D., Haryanto E. & Simandjuntak T.O., 1993 Geological Map of Lasusua Sheet - Kendari, Sulawesi, scale 1: 250,000, Center for Geological Research and Development, Bandung.
- Streckeisen, A.L., 1976, Classification of The Common Igneous Rocks by Means of Their Chemical Composition: A Provosional Attempt, *Neues Jahrbuch For Mineralogie, Monatshfte*.
- Surono 2013. *Geology of Southeast arm Sulawesi*. Center for Geological Research and Development.
- Surono. 2010. *Geologi Lengan Tenggara Sulawesi*. Publikasi Khusus, Badan Geologi, KESDM, 161p.
- Travis, B.R.,1995. *The Rock Book*. New York. Quarterly of the Colorado School of Mines.
- Wilson, M. 1989. *Igneous petrogenesis a global tectonic Approach*. Chapman & Hall.



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