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Sandstone Provenance of Walanae Formation as a Parent Rock in Bulukumpa area, Bulukumba Regency, South Sulawesi

*(*Provenance *Batupasir Formasi Walanae sebagai Bahan Induk Tanah di Daerah Bulukumpa Kabupaten Bulukumba, Sulawesi Selatan)*

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ABSTRACT

The Walanae Formation has a wide distribution in the southern arm of Sulawesi, this rock formation was deposited during the formation of the basin due to the Walanae strike-slip fault. The Walanae Formation in the study area comprises sedimentary rocks and pyroclastic rocks, which give different soil characteristics. This study aims to determine the types of sandstones, rocks of origin, and provenance of sandstones in the study area by using spot sampling at representative stations and petrographic analysis. The sandstones of the study area are divided into two groups based on Folk (1974), namely arkose lithic and feldspathic litharenite. Based on the type of quartz, rock fragments, and associated minerals, the origin of the sandstones in the study area are plutonic igneous rocks, volcanic rocks, sedimentary rocks, and metamorphic rocks. The results show that the types of provenance sandstones in the study area are magmatic arc and recycled orogenic.

Keywords: Magmatic Arc; Provenance; Recycled Orogenic; Sedimentary Rock; Walanae Formation

ABSTRAK

Formasi Walanae memiliki sebaran luas di lengan selatan Sulawesi, formasi ini terendapkan selama pembentukan cekungan akibat Sesar Geser Walanae. Formasi Walanae di daerah penelitian disusun oleh batuan sedimen dan batuan piroklastik, yang membentuk karakteristik tanah yang berbeda. Studi ini bertujuan untuk mengetahui jenis batupasir, batuan asal (provenan) batupasir daerah penelitian menggunakan metode pengamatan *spot sampling* pada stasiun yang representatif serta analisis petrografi. Batupasir daerah penelitian terbagi menjadi dua kelompok berdasarkan Folk (1974) yaitu *lithic arkose*, dan *feldspathic litharenite*. Berdasarkan jenis kuarsa, fragmen batuan dan mineral asosiasi, batuan asal batupasir daerah penelitian berasal dari batuan beku plutonik, batuan vulkanik, batuan sedimen dan batuan metamorf. Hasil penelitian menunjukkan tipe provenan batupasir daerah penelitian adalah *magmatic arc* dan *recycled orogenic*.

Kata Kunci: *Magmatic Arc*; *Provenance*; *Recycled Orogenic*; Batuan sedimen; Formasi Walanae

1. INTRODUCTION

Sedimentary rock was formed from the accumulation of material resulting from the weathering of pre-existing rocks or the results of chemical activities or organisms, which are deposited

layer by layer on the earth's surface and then petrified (Boggs, 2009). One of the widely distributed sedimentary rocks in South Sulawesi is Walanae Formation. The sedimentary rock of Walanae Formation has shown characteristic layered interbedded sandstone, claystone, and limestone (Sukamto, 1982). The age of this formation is Late Miocene to Pliocene (Sukamto, 1982), it is predominantly Pliocene in age (Grainge & Davies, 1983). Based on nannofossils found in Soppeng area indicated the paleoenvironment in shallow marine condition (Farida et al., 2020).

The Walanae Fault greatly influenced the formation process of the Walanae Formation. The sandstone component consists of materials like quartz minerals, feldspar, and rock fragments, which has medium to coarse grain size (Ardiansyah et al., 2015). The rocks are formed from pre-existing rock, and provide different characteristics to the soil that is formed (Wilson et al., 2017), so analysis is needed to determine the origin of sedimentary rock known as provenance. Provenance information is necessary to interpret paleogeography (landscape features) when there is no rock record (Nugraha & Hall, 2018).

This research uses an analysis of rock samples in the laboratory using a QFL diagram (Dickinson & Suczek, 1979) to determine the provenance type of research area. The results then show the relationship between the characteristics of sedimentary materials from a source rock and the origin of sedimentary material in an area. This research was carried out in the area of Belulu River, Jojjolo Region, Bulukumpa District, Bulukumba Regency, South Sulawesi Province (Figure 1). Astronomically, this area is located at 120°10'48" BT – 120°15'46.8" East Longitude - 05°20'2.4" BT – 05°24'00" South Latitude, mapped on the 2011 Earth Map of Indonesia, scale 1:50.000 published by Badan Koordinasi Survei dan Pemetaan Nasional (Bakosurtanal).

2. METHODOLOGY

The field data collection was carried out using spot sampling or random sampling by looking at changes in rock texture and carrying out a detailed rock description at an outcrop that was considered representative from Inceptisols and Ultisols. A total of eight selected samples are then prepared into thin sections for observation in the laboratory.

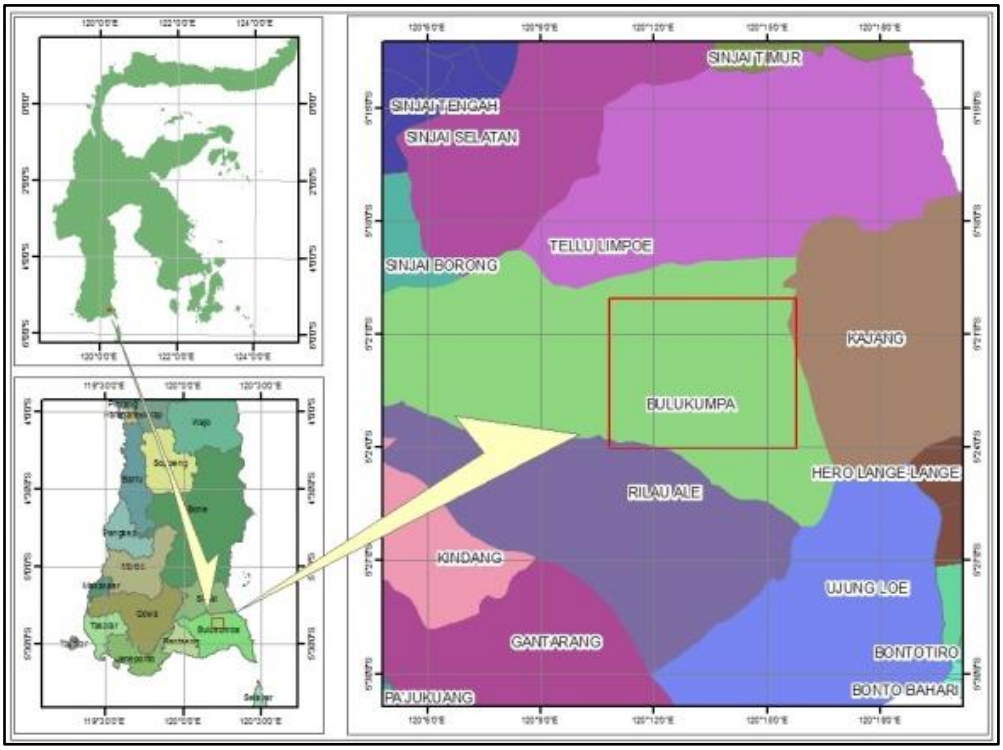


Figure 1. Location map of the study area in Bulukumpa area.

Laboratory analysis includes petrographic observations of each thin section of rock samples that have been prepared using a Nikon Eclipse LV100N Polarization. Observations were carried out using the point counting method to determine the abundance of minerals that make up the sandstone in the research area. According to the petrographic observation, plotting was then carried out on the Qt-F-L triangle using the grain parameters is point counting (Dickinson & Suscek, 1979), Figure 2.

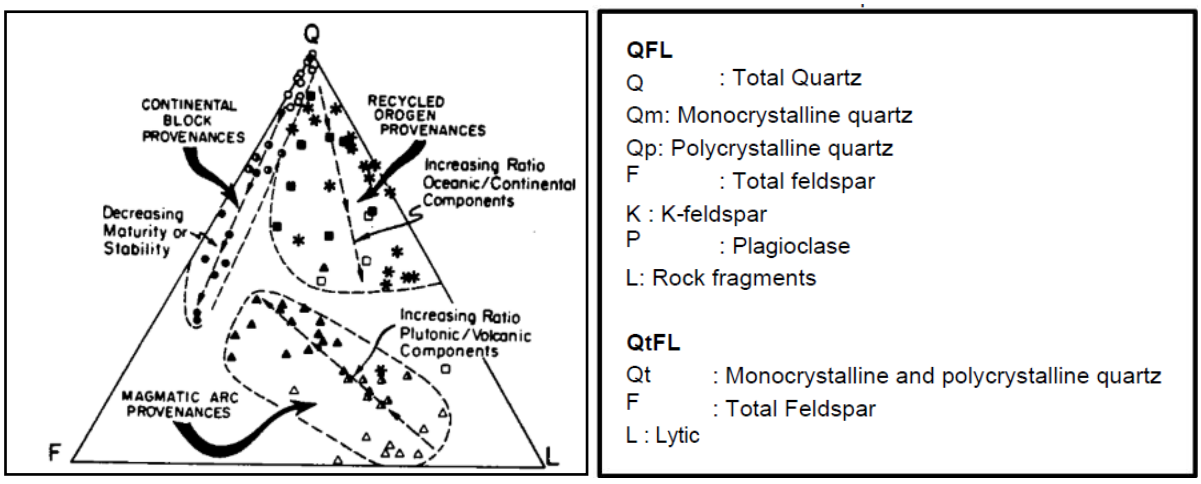


Figure 2. QFL Triangle Diagram according to Dickinson & Suczek (1979).

3. RESULT AND DISCUSSION

3.1. Type of Sandstone

The material composition of sandstone consists of monocrystalline quartz (Qm), polycrystalline quartz (Qp), K-Feldspar, plagioclase, rock fragments, pyroxene, a little hornblende, calcite, and opaque minerals. Feldspar and quartz are the most dominant elements in the sandstone of Walanae Formation in the research area. Monocrystalline quartz is more abundant than polycrystalline quartz. Feldspar consists of orthoclase and a little plagioclase. Rock fragments are almost all volcanic rock (Table 1).

Table 1. Percentage of the material composition of sandstone Walanae Formation in the study area under microscope polarization

Sample	Q		F		R			Mineral	Ground Mass
	Qm	Qp	Ort	Plg	Ls	Lm	Lv	Accessories (%)	and Cement (%)
ST2-BTP-PTR	17	-	10	4	-	-	24	10	34
ST3-BTP-PTR	21	2	9	5	-	-	12	24	27
ST6-BTP-PTR	12	-	11	6	-	-	16	8	42
ST8-BTP-PTR	20	-	10	4	-	-	18	15	31
ST9-BTP-PTR	18	-	13	5	-	-	21	6	37
ST10-BTP-PTR	26	-	11	2	-	-	18	10	33
ST11-BTP-PTR	23	3	9	4	-	-	21	8	32
ST13-BTP-PTR	23	-	4	5	-	-	16	17	35

Rock naming uses Folk (1974) classification which is based on an abundance of quartz, feldspar, and rock fragments that have been normalized. The plotting result on the QFR diagram (Figure 3) shows that the sandstone of the research area is divided into two types, namely Lihitic Arkose and Felspatic Litharenite.

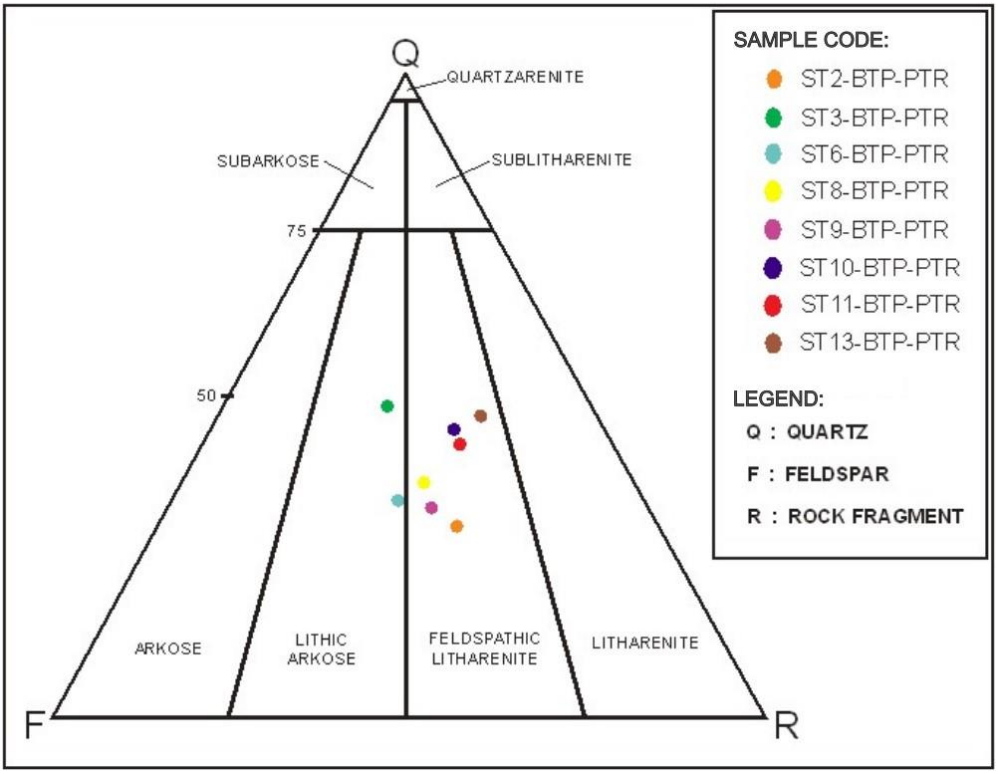


Figure 3. Q-F-R classification diagram by Folk (1974) for determining the type of sandstone

3.2. Provenance

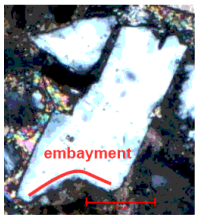
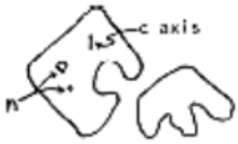
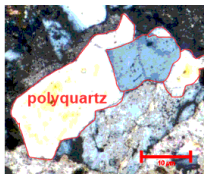
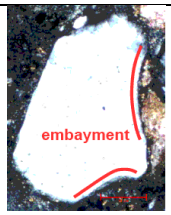
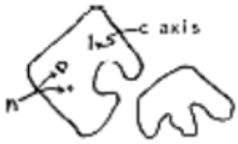
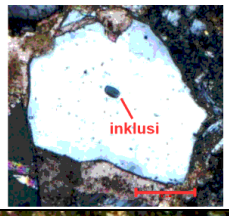
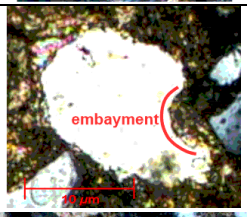
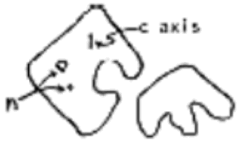
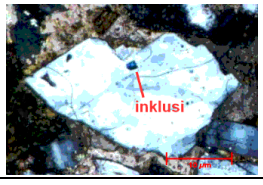
Determination of provenance is carried out by analyzing quartz, rock fragments, and mineral associations. Analysis of quartz type according to Dickinson & Suscek (1979) and characteristic of quartz variations in relation to genetics according to Krynine (1940) in Folk (1974). According to Tucker (2003), a lithic fragment in sediment rock shows the provenance. Furthermore, the mineral association can also be an indication of provenance with the assumption that certain minerals are generally only found in certain rocks:

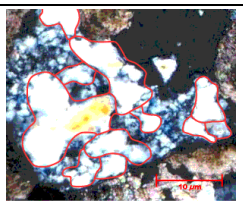
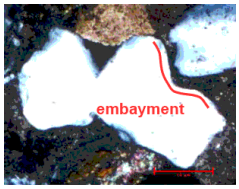
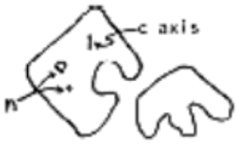
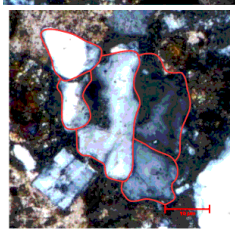
1. Quartz

Monocrystalline quartz, consisting of plutonic quartz and volcanic quartz, is found in almost the thin section of the sample. Monocrystalline quartz in the sandstone of Walanae Formation in the research area shows the provenance the rock is from plutonic and volcanic igneous rock. Polycrystalline quartz was found in samples ST3-BTP-PTR and ST11-BTP-PTR with characteristics of grain number more than 3. Polycrystalline quartz in the sandstone of Walanae Formation in the research area also shows provenance from metamorphic rock.

According to the result of the analysis type of quartz using Krynine (1940) classification in Folk (1974), Table 2, sandstone in the research area shows the characteristics of quartz are from the metamorphic rock, plutonic rock, and volcanic rock.

Table 2. Grouping of sandstone provenances based on the Genetic Classification of Quartz (Krynine, 1940)

Samples	Quartz on Research Area	Quartz based on Krynine Classification 1940	Quartz Type
ST3-BTP-PTR			Quartz of Volcanic Rock
			Quartz of Plutonic Rock
			Recrystallized Metamorphic
ST2-BTP-PTR			Quartz of Volcanic Rock
			Quartz of Plutonic Rock
ST11-BTP-PTR			Quartz of Volcanic Rock
			Quartz of Plutonic Rock

			
ST8-BTP-PTR			Recrystallized Metamorphic
			Quartz of Volcanic Rock
			Recrystallized Metamorphic

2. Rock Fragment

Rock fragments in sandstone can also be an indication of the provenance of sediment rock. According to Ganai et al. (2023), rock fragments will indicate the provenance of the sediment rock. Rock fragments found in the sandstone of Walanae Formation in the research area based on petrographic observation are fragments of volcanic rock, sedimentary rock, and metamorphic rock (Figure 4).

1) Volcanic rock fragment, was found in all the sandstones in the research area. The forming minerals show the quartz and feldspar interlocking each other and also a groundmass of some of the phenocrysts it contains.
2) Schist fragment, was found in 2 sandstone samples ST9-BTP-PTR and ST8-BTP-PTR. Consists of dominant minerals such as muscovite and quartz that show foliation.
3) Sedimentary rock fragment, was found in 2 samples of sandstone samples ST8-BTP-PTR and ST11-BTP-PTR. has a silica groundmass in clay, was found microcrystalline quartz, and brownish minerals that are weathered due to sedimentation processes.

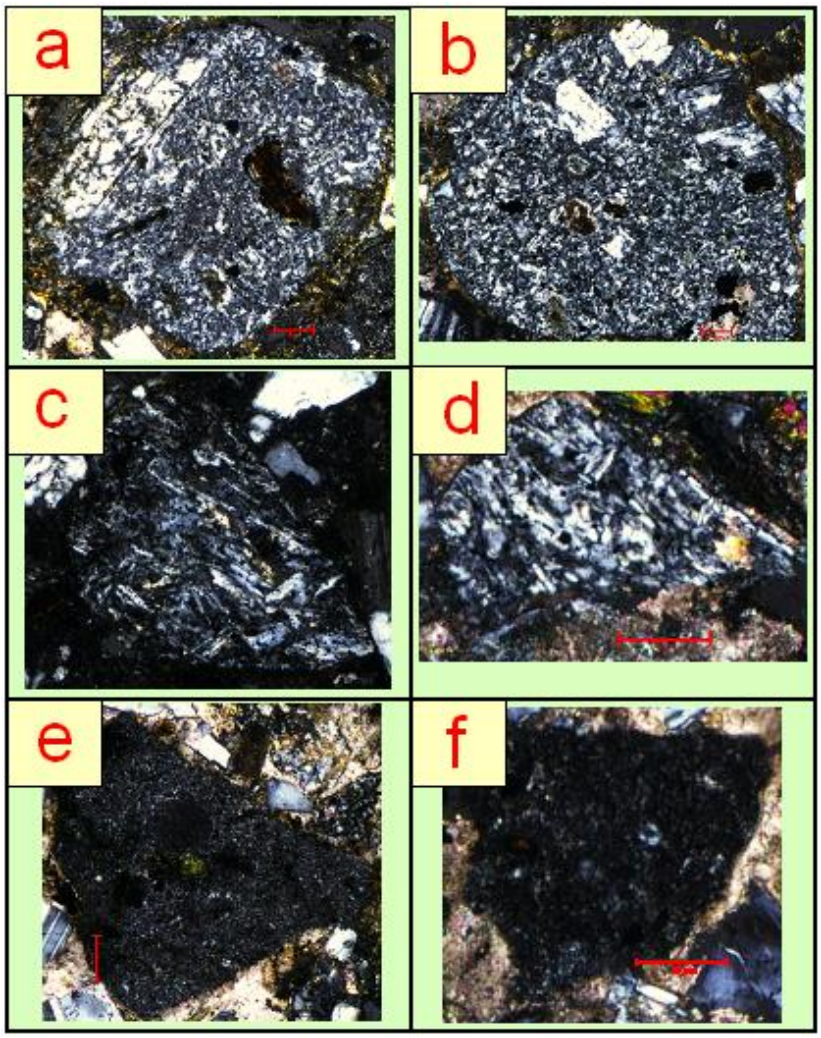


Figure 4. Rock fragments in the sandstone of the Walanae Formation, there are felsic volcanic igneous rock ST2-PTR (a) ST6-PTR (b) schist fragment ST9-PTR (c) ST8-PTR (d) and also the sedimentary rock fragments ST11-PTR (e) ST8-PTR (f)

3. Mineral associations

The accessory minerals such as augite the type of clinopyroxene that have phenocryst mineral that have sieve texture strengthens indicate the provenance of the sandstone from volcanic rock. The presence of augite is an indicator of the presence of nutrient-bearing minerals in the soil from parent rocks originating from volcanic rocks (Ahmad et al., 2019).

Sieve texture is the texture of phenocryst minerals that formed as a result of the corrosion magmatic process. In this case, the decompression in minerals due to sudden changes in magma temperature and pressure usually occurs in the form of extrusive igneous rock which is associated with the volcanic process. Clinopyroxene with a sieve texture was found in samples ST2-BTP-PTR and ST3-BTP-PTR.

3.3. Provenance Type

According to Dickinson & Suscek (1979), the relation between provenance and basin is determined by tectonic area (Table 3), which directly controls the distribution of different types of sandstone. The provenance is grouped into three, there are continental block, magmatic arc, and recycled orogen provenance. Provenance type determination was carried out using a Qt-F-L diagram according to Dickinson & Suscek (1979), based on the abundance of quartz, feldspar, and lithic (Figure 5).

Table 3. The abundance of sandstone components through petrographic analysis using point counting method with Qt-F-L parameters

Sample	Qt (%)	F (%)	L (%)	Tectonic Environment
ST2-BTP-PTR	30	27	43	Magmatic Arc
ST3-BTP-PTR	47	29	24	Recycled Orogenic
ST6-BTP-PTR	34	34	32	Magmatic Arc
ST8-BTP-PTR	37	30	33	Recycled Orogenic
ST9-BTP-PTR	32	31	37	Magmatic Arc
ST10-BTP-PTR	46	22	32	Recycled Orogenic
ST11-BTP-PTR	43	22	35	Recycled Orogenic
ST13-BTP-PTR	48	19	33	Recycled Orogenic

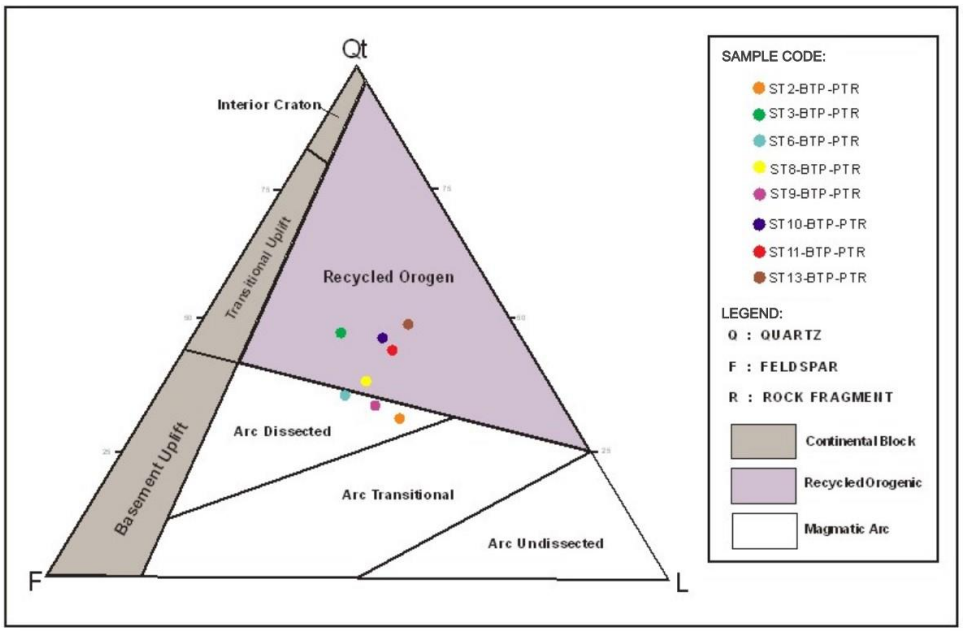


Figure 5. Plotting result on the Qt-F-L diagram for determining sandstone provenance type of Walanae Formation (Dickinson & Suscek, 1979)

According to the petrographic observation, plotting was then carried out on the Qt-F-L triangle, showing that the type of sandstone provenance is magmatic arc and recycled orogenic. The magmatic area was an area consisting of volcanic plateaus and was located along an active island arc or on continental margins, with the resulting detritus component originating from orogenic activity. The type of provenance forms of sandstone that consists of more volcanic rock debris but the other side is also rich in quartz-felspar from the plutonic. There are three samples that represent the magmatic arc area, each sample includes ST2-BTP-PTR, ST6-BTP-PTR, and ST9-BTP-PTR.

Recycled orogenic areas are a repetition of orogenesis occurring in the tectonic area with uplift, folding, and erosion. There are five samples that represent the recycled orogenic areas, each sample includes ST3-BTP-PTR, ST8-BTP-PTR, ST10-BTP-PTR, ST11-BTP-PTR, and ST13-BTP-PTR.

In order to determine the source association of rock components of the recycled orogenic type, plotting was carried out on the Qp-Lv-Ls triangle diagram (Dickinson & Suczek, 1979) which then shows the sandstone is from the Recycled Orogen associated with Arc Orogen (Figure 6).

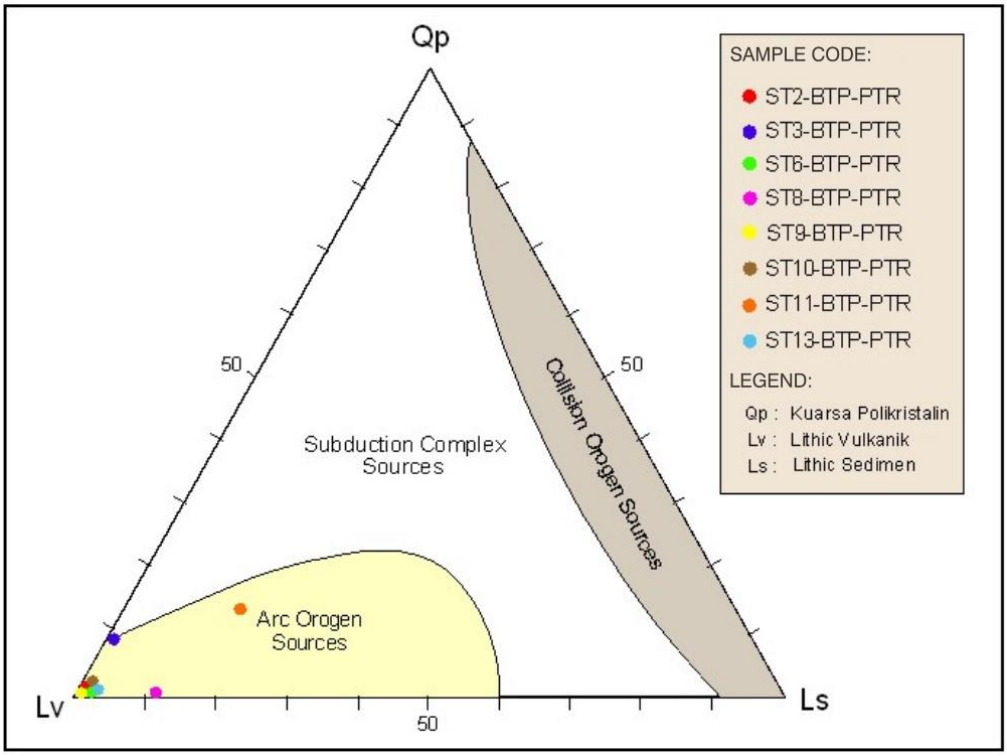


Figure 6. Plotting result on Qp-Lv-Ls diagram by Dickinson & Suczek (1979) which shows the association of arc orogen source

The tectonic environment of the two provenance types above are correlated, it's because the location of the tectonic areas is the same in terms of the provenance rock formation process (volcanic orogenic), Figure 7.

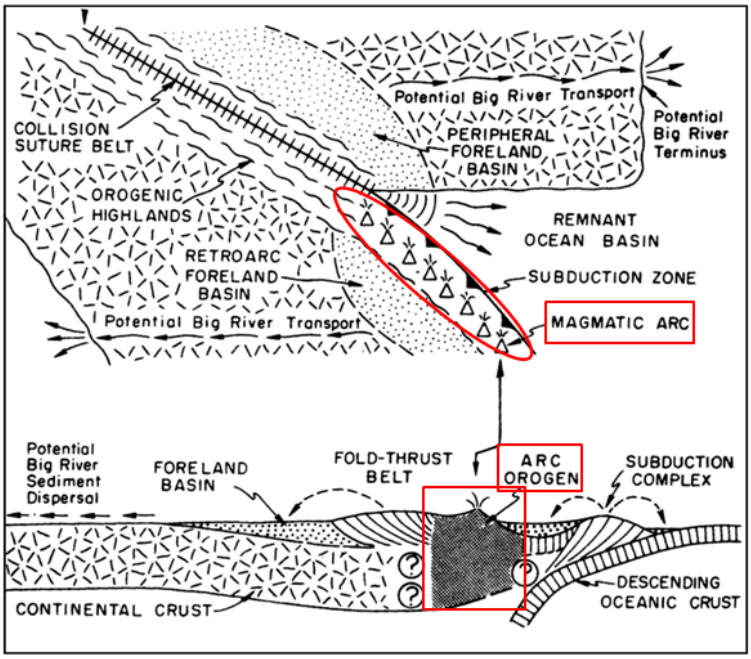


Figure 7. The sandstone provenance type of the study area is based on Dickinson & Suczek (1979)

3.4. Correlation of Geological Formation of Provenance

The correlation of the rock with the surrounding rock formation is a parameter that can be used to know the provenance of the rock. That correlation could be done by using parameters of the presence of the rock formations around the study area that are older and have similar characteristics to the rock materials that characterize these formations.

Based on the stratigraphic structure of South Sulawesi compiled by Sukamto (1982), Suyono & Kusnama (2010) explained that the Walanae Formation is a depositional environment in the form of a depression that stretches in a Northwest – Southeast direction with the main forming factor being the Walanae Fault and its age Late Miocene to the Pliocene.

The formations that were formed before the Walanae Formation which are also located on two sides of the Walanae depression such as the lava and volcanic breccia of Kalamiseng Formation, shale, and claystone of Salo Kalumpang Formation, volcanic Camba with interbed sedimentary rock at the bottom of Camba Formation, carbonate sediment of Tonasa Formation, and the intrusions that consist alkaline-potassic that associated with volcanic activity of Kalamiseng Formation and Camba Formation.

Based on the explanation above, it's possible to correlate the assumed provenance of the Sandstone of the Walanae Formation and the surrounder geological formation which is older and assumed that occurred weathered and sedimentation so that the material became a component of the sandstone of the Walanae Formation. The material from igneous rock whether plutonic or volcanic is possible to correlate with magmatism activities in the Early Paleocene including intrusion and other magmatism activities in the southern arm of Sulawesi (Figure 8).

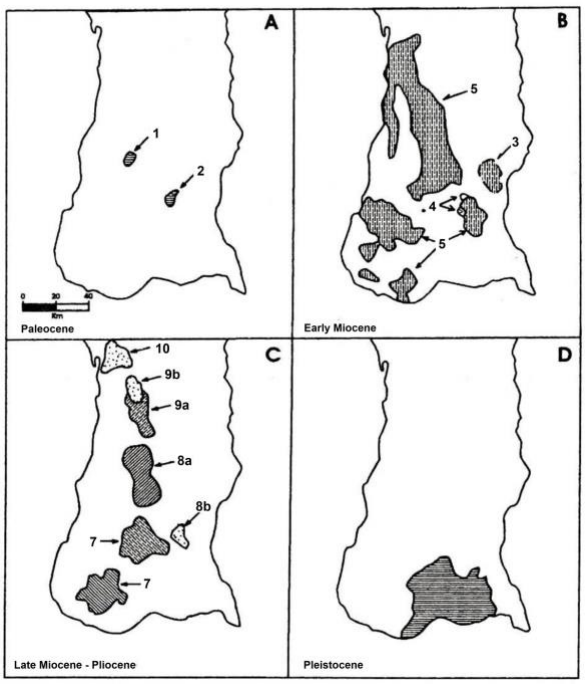


Figure 8. Magmatism on Quarter in shoutern arm of Sulawesi (Yuwono *et al*., 1988)

The material from sedimentary rock is possible to correlate to Salo Kalumpang Formation which has sedimentary rock such as claystone, shale, and sandstone. The formation is in the Early Eocene – Late Oligocene and is located right on the eastern of the Walanae depression. At the northern part of the Walanae depression, there is the Mallawa Formation which is an older sediment formation and also assumed the provenance for the northern part of the Walanae Formation.

Meanwhile the material from the metamorphic rock, provenance is possible to correlate to Langi Volcanic consists of lava and pyroclastic deposits with an andesitic to trachy-andesitic of Paleocene and located in the eastern southern Walanae Formation which has been identified have low-middle metamorphism. Furthermore, it is also possible to assume the metamorphic rock materials are from the basement complex or bedrock that was exposed in Bantimala and

Barru which is a metamorphic rock complex of the Upper Cretaceous and is located in the eastern Walanae Formation (Figure 9).

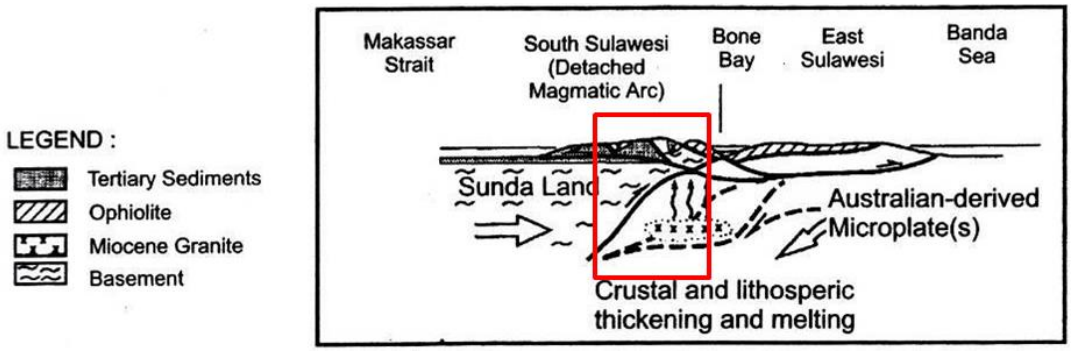


Figure 9. West-East cross-section of South Sulawesi (Darman & Sidi, 2000)

4. CONCLUSION

Based on the petrographic analysis of the sandstone Walanae Formation, conclude that the type of sandstone Walanae Formation in the research area is divided into two, there are Lithic Arkose and Feldspathic Litharenite. Lithic Arkose develops to form the soil order Inceptisols and Feldspathic Litharenite develops to form the order Ultisols. Type quartz, rock fragments, and mineral association shown that the provenance of sandstone Walanae Formation is igneous rock, sedimentary rock, and also metamorphic rock. Based on analyze the tectonic setting in the QFL triangle, the provenance type of sandstone Walanae Formation in the research area is Magmatic arc at the dissected arc and recycled orogen part with the type of provenance in zone arc orogen sources.

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