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Provenance Determination Of Sandstone Based On Petrographic Analysis In Bambaira And Ako Areas, Pasangkayu District, West Sulawesi Province

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ABSTRACT

West Sulawesi has a very connections with the tectonic process of the Makassar Strait, where the Makassar Strait is influenced by the process of plate expansion, as a result of the process formed a sedimentary basin composed of sedimentary rocks with rocks of diverse origin, the determination of rock origin (provenance) can help to reveal the tectonic setting and rock origin in the, to see the mineral content of existing sandstone constituents in the research area microscopically, the parameters used in determining the origin of rocks are quartz, feldspar and lithic fragments, the calculation of rock constituent minerals using the point counting method and then normalized for plotting on the provenance diagram and tectonic setting. The results of petrographic analysis on sandstone obtained the name of the Rock is lithic graywacke and quartz wacke. Rocks of origin in the research area are from Plutonic igneous rocks, volcanic igneous rocks, metamorphic rocks and sedimentary rocks, which are known based on the presence of monocrystalline quartz and polycstaline Quartz minerals, orthoclase minerals, sanidine minerals, volcanic lithic and sedimentary lithic,while the tectonic setting in the research area is magmatic arc and recycle orogen.

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1. INTRODUCTION

West Sulawesi has a connections with the process of expansion of the Makassar Strait. West Sulawesi is affected by the compression phase so that it forms ascending faults and folds, this is caused by the collision process of continental and continental plates (kolisi) (Bergman.,drr.,1996 in Zakaria and Sidarto, 2015). From tectonic activity in the form of collisions between continental and continental plates that occur on continental edges, bedrock that is below the surface can be lifted and form mountainous plateaus, over time there is a sedimentation process that results in these rocks being eroded and transported into basins and accumulated with other rocks so that rock Formations are deposited. The Lariang Basin is composed of several rock Formations,including the Lariang Formation (Simandjuntak,et al., 1993) and is currently known by a new name, the Lisu Formation (Calvert and Hall, 2003). Members of the Lisu Formation themselves consist of interlocking claystones, sandstones and conglomerates The presence of sandstone in the Lisu Formation is interesting to study, the composition of sandstone is influenced by the character of the original rock, the nature of the sediment process in the deposition Basin, and the type of

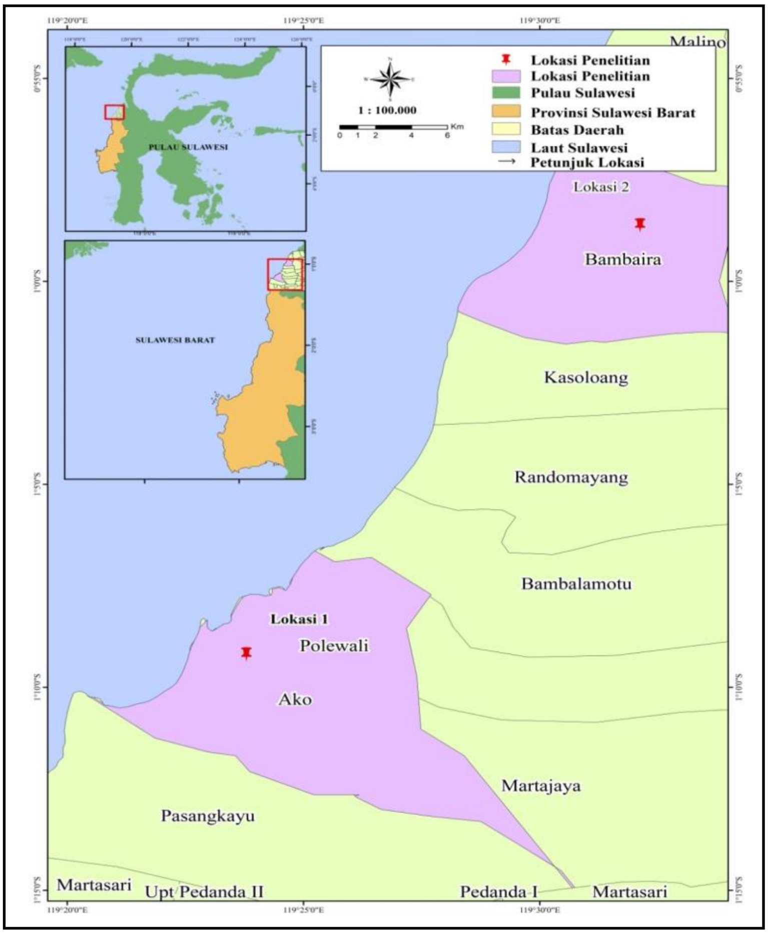

Figure 1. Map of the research area, with red point representing the observation area in Ako area and Bambaira area.

transportation that connects the original rock with the deposition Basin. The main relationship between the rocks of origin and the depositional basins is regulated by the activity of tectonic plates, which ultimately control the distribution of different types of sandstones (Dickinson and Suczeck,1979). Sandstone itself is very good to be used in the determination of rock origin because the characteristics of the minerals contained in sandstone are still very easy to distinguish. To determine the origin of the rocks in the sandstone is necessary petrographic analysis which will then calculate the presence of minerals that can be used in the determination of rocks of origin such as quartz, feldspar and lithic based on mineral composition will then be normalized and plotted using the classification of provenance by Dickinson and Suzeck (1979).

Regionally, the research area is included in the geology of Pasangkayu with a scale of 1: 250,000 (Simandjuntak,et al.,1993). And re-do geological mapping regionally by Calvert and Hall, 2003.

In the period before the Middle Miocene there was a difference between Western Central Sulawesi (Mintakat Sulawesi Barat) and the Sulawesi neck area (Mintakat Sulawesi Utara), during the Middle Miocene – early Pliocene, the two areas were in the same deposition environment, namely in one volcanic arc (Elburg et al.,2023; Van Leeuwen and Muhardjo, 2005; Van Leeuwen., 2006), during that period, in West Sulawesi Mintakat deposited Lisu Formation (Surono and Hartono, 2013). The Lisu Formation, consisting of the claystone affair, greywacke and greywacke conglomerates. The thickness of this Formation is about 2000 meters and is from the early Miocene – late Pliocene, the Lisu Formation was deposited in a shallow marine deposition environment, and was overlain by the misaligned Pasangkayu Formation (Calvert and Hall, 2003) (Figure 2).

The Formation of sedimentation basin in the research area is related to tectonic processes in the Makassar Strait, the Makassar Strait is influenced by the collision activity of the continents (kolisi) (Bergman.,drr., 1996 in Zakaria and Sidarto, 2015), this is evidenced by the existence of compression phase ynag occurs with evidenced by the presence of ascending faults and folds. The mountainous plateau formed is the result of collisional activity between continental and continental

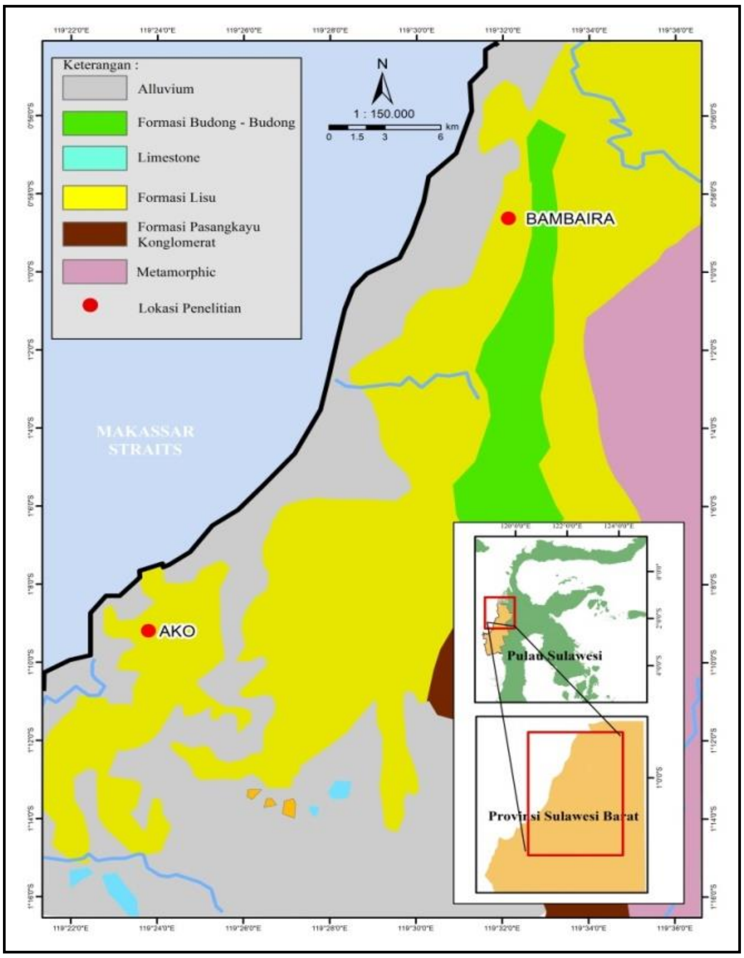

Figure 2. Distribution map of Lariang and Karama rock Formations in West Sulawesi (modified by Calvert, 2006).

plates that occur on continental edges so that the rocks experience uplift (Bergman et al,,1996 in Zakaria and Sidarto).

2. METHOD

This study used quantitative methods. Sampling was conducted in two (2) areas located in Pasangkayu, namely three (3) sandstone samples in Bambaira area and four (4) sandstone samples in Ako area. In determining the name of the rock and rock origin seen from the percentage of mineral composition of quartz, feldspar and lithic (QFL) this is because these minerals are the main constituent minerals of sandstone and the characteristics of these minerals can provide an overview of the sedimentation process of existing sandstone in the research area. To facilitate the author in the determination of quartz, feldspar and lithic minerals used ImageJ application with point counting method the use of this application only includes photographs of petrographic incisions of sandstones then point to determine the types of minerals and can be calculated how many of these minerals. After knowing the results of the calculation of qfl minerals and then carried out normalizing and plotting using the provenance classification by Dickinson and Suzeck (1979) will be known rock origin and tectonic order of sandstones in the Lisu formation research area and naming sandstones using the classification of Pettijohn (1975).

3. RESULTS AND DISCUSSION

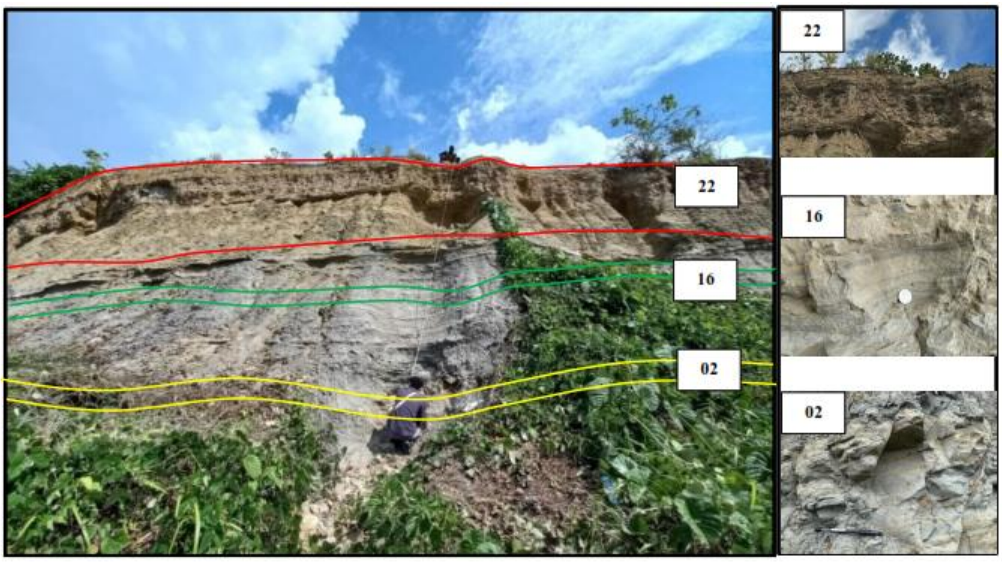

Figure 3. Sedimentary rock outcrop in Bambaira area, Pasangkayu Regency, with photo direction N 168° E

3.1. Figure Layout

The sedimentary rock outcrop encountered in Bambaira area, Pasangkayu Regency has a thickness of 8.33 m. These outcrops are insitu outcrops originating from the Lisu Formation, the direction of Northeast – Southwest distribution, as well as the position of the rock N 113ºE / 20º.

Mineral Details Determining Provenance In Bambaira District Sandstone:

a) Quartz

The Quartz minerals that can be observed in the research area are :Plutonic rock quartz (outer igneous rock) is found in all samples in the Bambaira area, Pasangkayu Regency, with sample code BR – 02, this type of Quartz has characteristics in the form of parallel or straight blackout angles until slightly wavy, this type of quartz is found in the form of monocrystalline or single crystal, found in the form of cavities in Plutonic Quartz due to the trapping of air bubbles or gas when the mineral is formed. Volcanic rock quartz (outer igneous rock) found in two samples of sandstone in the sample BR -16 and BR - 22 Bambaira area, Pasangkayu, this type of Quartz has a parallel blackout angle, cavities are also found in this mineral is estimated to be formed as a result of air bubbles or gas trapped when the mineral is formed, there is embayment corrosion on the mineral side. Recrystallized Quartz, found in the BR-22 sample, this type of quartz is a type of quartz derived from metamorphic rock minerals found interlocking, has a parallel extinguishing angle until slightly wavy.

b) Rock Fragments

Volcanic rock fragments, found in the three samples, namely in BR-02, BR-16, and BR - 22 in Bambaira, Pasangkayu Regency, based on the results of petrographic analysis of volcanic rock fragments in general have a gray – black absorption color, low – medium relief, have a grain size of 0.03-0.3 mm, with subhedral mineral shapes – anhedral, degree of subrounded roundness, its constituent minerals in the form of quartz and feldspar minerals and also biotite interlocking (interlocking), some crystals that have a brownish color caused by the weathering process during the sedimentation process takes place from the Constituent minerals of rocks that are relatively not resistant to weathering. Sedimentary rock fragments, found in BR-02, BR – 16, and BR-22 sandstone samples found in Bambaira, Pasangkayu Regency, based on petrographic analysis of sedimentary rock fragments in general have a gray – black color, medium relief, have a grain size of 0.01 – 0.3 mm, anhedal mineral form, degree of subrounded roundness, has a clay-sized silica base mass and also found some microcrystalline quartz minerals and weathered minerals as a result of the sedimentation process taking place from the Constituent minerals that are not resistant to weathering.

c) Feldspar
Feldspar volcanic rock, found in BR – 02, BR – 16, and BR – 22 sandstone samples in Bambaira area, it is characterized by the presence of sanidine minerals although in general the presence of sanidine Minerals is only (1%), while the characteristics of sanidine minerals are brown absorption color, subhedral shape, 1-way hemisphere, no fraction, no pleochroism, medium relief, mineral size 0.1 mm, grayish-white interference color, dark angle 32, oblique Dark type, Carlsbad twins.

3.2. Ako District Sandsrtone

The sedimentary rock outcrop found in the Ako area, Pasangkayu Regency has a thickness of ±9.73 m. this outcrop is insitu, an outcrop originating from the Lisu Formation, the direction of distribution is northeast – southwest, with a rock position of N 76 ° E / 32 °. Mineral Details Determining Provenance In Ako District:

a) Quartz
The polycrystalline Quartz minerals that can be observed in the research area are: Plutonic rock quartz (outer igneous rock) is found in all samples in the Ako area, Pasangkayu Regency, with sample codes AKO – 01, ako – 08, AKO – 10, and AKO – 26, this type of Quartz has characteristics in the form of parallel or straight blackout angles until slightly wavy, this type of quartz is found in the form of monocrystalline or single crystal, found in the form of cavities in Plutonic Quartz due to the trapping of air bubbles or gas when the mineral is formed. Volcanic rock quartz (outer igneous rock) found in two sandstone samples, namely in samples Ako-08 and Ako-26 ako area, Pasangkayu Regency, this type of Quartz has a parallel blackout angle, cavities are also found in this mineral it is estimated to be formed as a result of air bubbles or gases trapped when the mineral is formed, there is embayment, namely corrosion on the mineral scales. Sekistose Quartz found in samples Ako – 01, Ako – 10 and Ako-26, this type of Quartz has inclusions with Mica minerals, with parallel extinguishing angles until slightly wavy, the grains are interlocking.

b) Rock Fragments
Volcanic rock fragments, found in samples AKO – 01, AKO-08, AKO – 10, and AKO-26, sandstone samples found in the area of Ako, Pasangkayu Regency, based on petrographic analysis of volcanic rock fragments in general have a gray – black absorption color, low – medium relief, have a grain size of 0.03-0.8 mm, with a subhedral mineral shape – anhedral, degree of subrounded roundness, the Constituent minerals in the form of quartz and feldspar minerals and also biotite interlocking (interlocking), apparently some crystals that have a brownish color caused by weathering during the sedimentation process takes place from the Constituent minerals of rocks that are relatively not resistant to weathering. Sedimentary rock fragments, found in AKO-01, AKO-08, AKO – 10, and AKO – 26, sandstone samples found in the area of ako, Pasangkayu Regency, based on petrographic analysis of sedimentary rock fragments in general have a gray – black color, medium relief, have a grain size of 0.04 – 0.7 mm, anhedal mineral form, subrounded degree of roundness, has a clay-sized silica base mass and also found some microcrystalline quartz minerals and weathered minerals as a result of the sedimentation process taking place from rock constituent minerals that are not resistant to weathering.

c) Feldspar
Volcanic rock Feldspar, found in AKO – 08 and Ako-10 sandstone samples in the Ako area, is characterized by the presence of orthoclase minerals although in general the presence of orthoclase Minerals is only (2%), while the characteristics of orthoclase minerals are that they have brown color absorbs, subhedral shape, 1-way hemispheres, uneven fractions, pleochroism does not exist, medium relief, mineral size 0.6 mm, white interference color, dark angle 37, oblique dark type, twin does not exist.

3.3. Determination of provenance type research area

Table 1. Abundance of sandstone constituent components through petrographic observations with QFL parameters

Kode Sampel	Kuarsa		Feldspar		Litik	
	Kuarsa Monokristalin (Qm)	Kuarsa Polikristalin (Qp)	Plagioklas (P)	K-Feldspar (K)	Litik Sedimen (Ls)	Litik Vulkanik (Lv)
	%	%	%	%	%	%
AKO - 01	81.00	4.52	0.45	0.00	6.33	7.69
AKO - 08	74.77	5.86	1.35	5.86	7.66	4.50
AKO - 10	81.90	5.71	3.33	1.90	3.33	3.81
AKO - 26	93.72	3.24	0.84	0.00	1.67	1.26
BR - 02	88.43	2.31	3.24	1.85	2.78	1.39
BR - 16	94.56	0.84	1.26	1.26	1.67	0.42
BR - 22	91.75	1.94	0.97	1.94	2.43	0.97

Ako area, minerals that can be identified in the form of quartz minerals with monocrystalline quartz and polycrystalline Quartz, plagioclase minerals, and also lithic fragments in the form of Lithic from sedimentary rocks and also lithic from volcanic rocks, K – feldspar which is found in the form of orthoclase but only found in two sandstone samples, namely the ako – 08 and AKO – 10 samples.

Bambaira area, minerals identified in the form of quartz minerals with monocrystalline quartz and polycrystalline Quartz, plagioclase, lithic fragments in the form of sedimentary Lithics and volcanic Lithics, and K-feldspar minerals found are sanidine minerals.

The results of the plotting on the qfl triangle diagram are based on the results of petrographic analysis that has been carried out. The parameters used in determining the type of provenance is to look at the content of the minerals that make up the sandstone in the research area, namely monocrystalline Quartz (Qm) and polycrystalline Quartz (Qp), feldspar (F) and lithic fragments (L).

Table 2. Calculation of Mineral provenance with parameter Qt-F-L

Kode Sampel	Qt (Qm + Qp)	F (P + K)	L (Lv + Ls)
	%	%	%
AKO - 01	85.52	0.45	14.03
AKO - 08	80.63	7.21	12.16
AKO - 10	87.62	5.24	7.14
AKO - 26	96.23	0.84	2.93
BR - 02	90.74	5.09	4.17
BR - 16	95.4	2.51	2.09
BR - 22	93.69	2.91	3.4

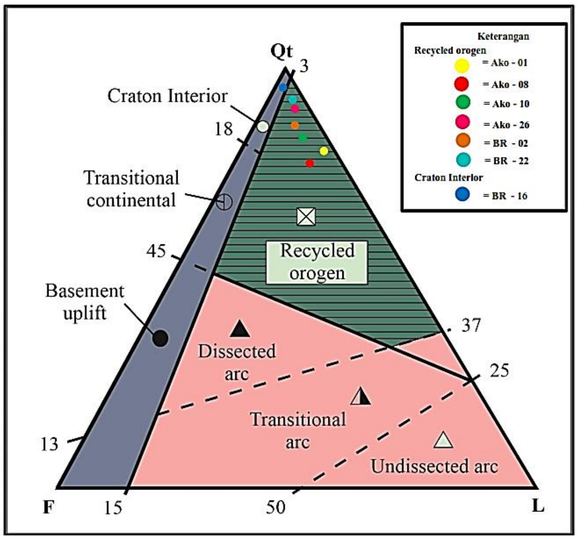

Figure 3. Plotting results on Qt-F-L diagram for determination of type Provenance according to Dickinson Dickinson and Suczeck (1979).

While the determination of rock origin using QmFLt triangle diagram according to Dickinson and Suczeck (1979) by looking at the content of minerals that make up the existing sandstone in the research area is monocrystalline Quartz (Qm) and polycrystalline Quartz (Qp), feldspar (F) and lithic fragments (L).

Table 3. Recapitulation of plotting results on Qt-F-L diagram for determination of provenance type according to Dickinson et al (1979).

No	Kode Sampel	Tipe *provenance*	Rock Name
1	BR - 02	*Recycled Orogen*	*Lithic graywacke*
2	BR - 16	*Craton Interior*	*Quartzwacke*
3	BR – 22	*Recycled Orogen*	*Quartzwacke*
4	AKO - 01	*Recycled Orogen*	*Quartzwacke*
5	AKO - 08	*Recycled Orogen*	*Quartzwacke*
6	AKO - 10	*Recycled Orogen*	*Lithic graywacke*
7	AKO - 26	*Recycled Orogen*	*Lithic graywacke*

Table 4. Search results for Mineral Resources with parameters Qm-F-Lt

Kode Sampel	Qm	F (P + K)	Lt (Lv + Ls) + Qp
	%	%	%
AKO - 01	81.00	0.45	18.55
AKO - 08	74.77	7.21	18.02
AKO - 10	81.90	5.24	12.86
AKO - 26	93.72	0.84	5.44
BR - 02	88.43	5.09	6.48

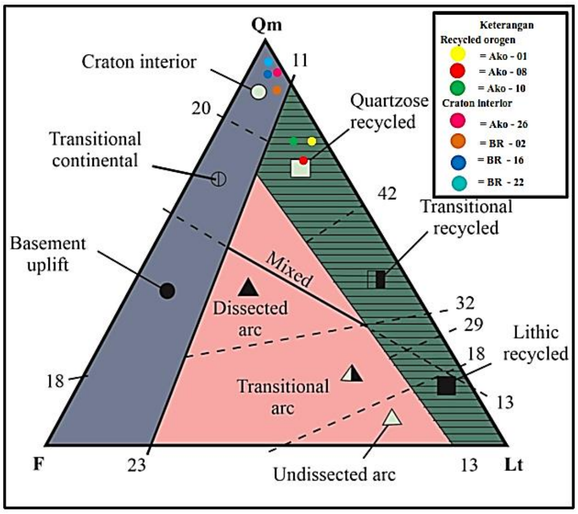

Figure 6. Plotting results on Qm-F-Lt diagram for determination of type Provenance according to Dickinson and Suczeck (1979).

Based on the results of determining the provenance type of the research area based on the Triangle diagram by Dickinson and Suczeck (1979), it is known that the rock origin in the research area comes from the recycle orogen and craton interior tectonic order,where the tectonic order in the research area has a close relationship with regional tectonic activity that works in the Formation of deposition basins in the research area.

According to Zakaria and Sidarto (2015) the development of tectonics in the research area began since the Paleogene, tectonic activity that took place resulted in the process of expansion (rifting) in the Makassar Strait and formed a deposition Basin in the research area known as the Lariang Basin.

Tectonic activity that still continues until the Oligocene to Miocene, causing the compression phase in the form of collision, namely the growth of the Eurasian continental plate which is included in the area of West Sulawesi with the Indo-Australian plate, which is in East Sulawesi, from this activity causes lifting, pensesingan and folding in the western part of Sulawesi and forming a volcanic arc in the late Mioesen.

After the Formation of the deposition basin, during the Miocene – Pleistocene (Calvert & Hall,2003), tectonic activity caused a regression phase,namely a decrease in sea level so that the deposition environment turned into a shallow marine environment (Aznal, 2023). The ongoing tectonic activity causes rocks that are below the surface to be lifted (exhumation) and form high land, the sedimentation process that continues to work causes rocks that are high in the area around West Sulawesi to experience erosion, the erosion of rocks and minerals are then transported and accumulated with other rocks and undergo a process of compaction and lithification so that new

Table 5. Recapitulation of plotting results on Qm-F-Lt diagram for determination of type provenance according to Dickinson et al (1979).

No	Kode Sampel	Tipe *provenance* (Batuan Asal)	Nama Batuan
1	BR - 02	*Craton Interior*	*Lithic graywacke*
2	BR - 16	*Craton Interior*	*Quartzwacke*
3	BR – 22	*Craton Interior*	*Quartzwacke*
4	AKO - 01	*Recycled Orogen*	*Quartzwacke*
5	AKO - 08	*Recycled Orogen*	*Quartzwacke*
6	AKO - 10	*Recycled Orogen*	*Lithic graywacke*
7	AKO - 26	*Craton Interior*	*Lithic graywacke*

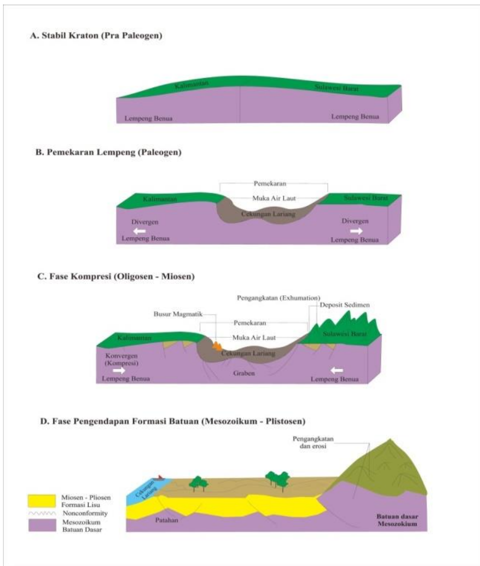

Figure 7. Tectonic environment and deposition basins research area.

Formations are deposited, namely Lisu Formations consisting of several types of rocks including sandstone. Rocks from the Lisu Formation are known to be associated with tectonic environments in the form of recycle orogen and continental block which are reviewed directly based on the results of analysis on mineral content that can be used as a determinant of rock provenance.

Recycle orogen, in this tectonic environment, the original rocks come from recycled areas, namely rocks from tectonic processes in the form of pensesingan, folding and lifting processes. Rocks of origin in this environment are composed of a variety of rocks, namely Plutonic and volcanic igneous rocks, metamorphic rocks and sedimentary rocks. The Sandstone content in Lisu Formation is dominated by Quartz minerals which indicates that the recycle orogen is associated with arc orogen, which is the Earth's crust that contains a variety.

In the continental block tectonic environment, the original rocks are known to come from the continental crust bordering the magmatic arc, so that the original rocks in this area consist of Plutonic igneous rocks, metamorphic rocks and sedimentary rocks and can also be volcanic igneous rocks.

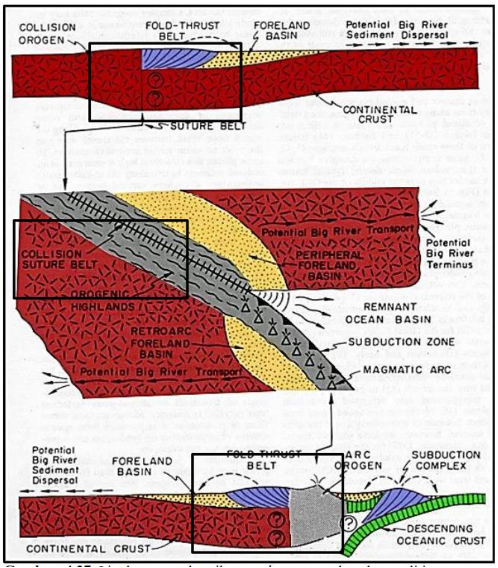

Figure 8. Environmental tectonics recycle Orogen research area according to Dickinson and Suczeck, 1979

3.4. Determination of the name of the rock

a) Bambaira

Sandstone samples taken in Bambaira area as much as 3 rock samples, including :

(A)

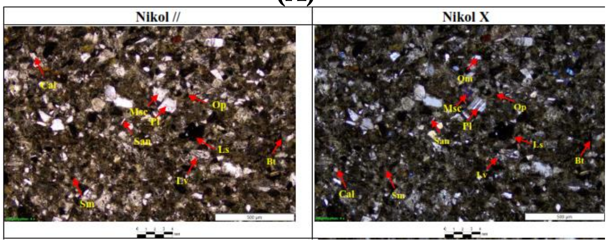

Figure 10. Petrographic features quartz wacke lithology, BR-4 BP with mineral composition of monocrystalline Quartz (Qm) 54%, volcanic lithic (Lv) 3%, sedimentary lithic (Ls) 5%, opaque (Op) 6%, biotite (Bt) 5%, Muscovite (Msc) 5%, sanidine (San) 1%, cement (Sm) 12%, calcite (Cal) 6%.

(B)

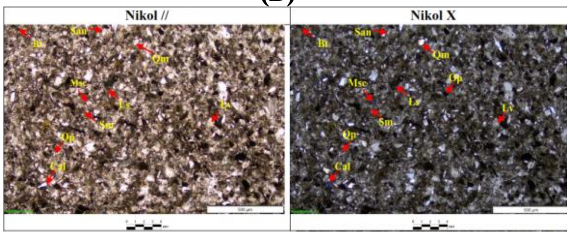

Figure 11. Petrographic features quartz wacke lithology, BR-16 BP with mineral composition of monocrystalline Quartz(Qm)50%, polycrystalline Quartz (Qp) 5%, volcanic lithic (Lv) 1%, sedimentary lithic (Ls) 5%, opaque (Op)10%, biotite (Bt) 5%, Muscovite (Msc) 4%, sanidine (San) 1%, cement (Sm) 14%, calcite (Cal) 5%.

(C)

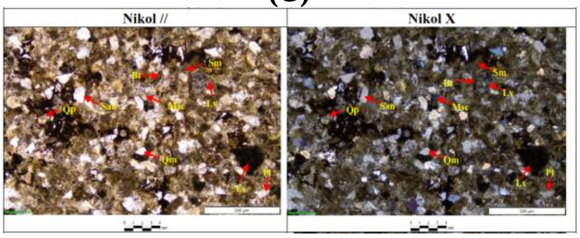

Figure 12. Petrographic features of quartzwacke lithology, BR-22 BP with mineral composition of monocrystalline Quartz (Qm) 60%, polycrystalline Quartz (Qp) 8%, volcanic lithic (Lv) 1%, sedimentary lithic (Ls) 4%, opaque (Op) 5%, biotite (Bt) 3%, Muscovite (Msc) 3%, sanidine (San) 1%, plagioclase (Pl) 1%, cement (Sm) 14%.

The results of determining the name of sandstones in the Bambaira area based on the classification of Pettijohn (1975), with mineral parameters of quartz, feldspar and rock fragments to obtain the name quartz wacke.

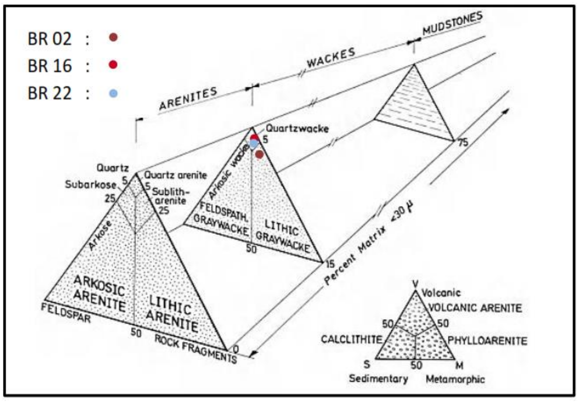

Figure 8. Environmental tectonics recycle Orogen research area according to Dickinson and Suczeck, 1979

b) Ako

Sandstone samples taken in the area of Ako as much as 4 rock samples, including :

(A)

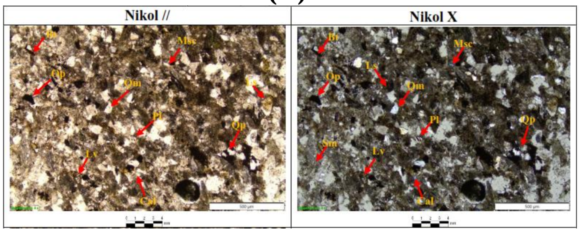

Figure 14. Petrographic features quartz wacke lithology, Ako-01 BP with mineral composition monocrystalline Quartz (Qm) 45%, polycrystalline Quartz (Qp) 5%, volcanic lithic (Lv) 1%, sedimentary lithic (Ls) 4%, opaque (Op) 15%, biotite (Bt) 3%, Muscovite (Msc) 2%, plagioclase (Pl) 2%, cement (Sm) 15%, calcite (Cal) 6%

(B)

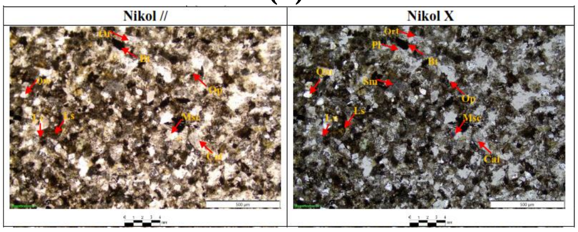

Figure 15. Petrographic features quartz wacke lithology, Ako-08 BP with mineral composition of monocrystalline Quartz (Qm) 67%, volcanic lithic (Lv) 1%, sedimentary lithic (Ls) 4%, opaque (Op) 6%, biotite (Bt) 4%, Muscovite (Msc) 2%, plagioclase (Pl) 2%, cement (Sm) 10%, Orthoclase (ort) 1%, calcite (Cal) 3%

(C)

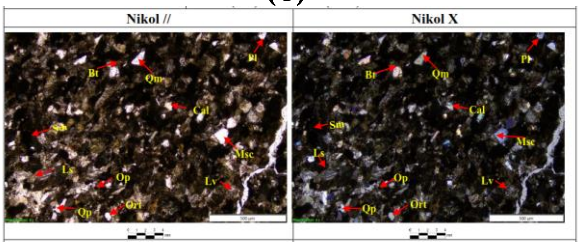

Figure 16. Petrographic features lithology lithic graywacke, Ako-10 BP with mineral composition monocrystalline Quartz (Qm) 36%, polycrystalline Quartz (Qp) 4%, volcanic lithic (Lv) 2%, sedimentary lithic (Ls) 8%, opaque (Op) 15%, biotite (Bt) 5%, Muscovite (Msc) 5%, plagioclase (Pl) 3%, cement (Sm) 15%, orthoclase (ort) 2%, calcite (Cal) 5%.

(D)

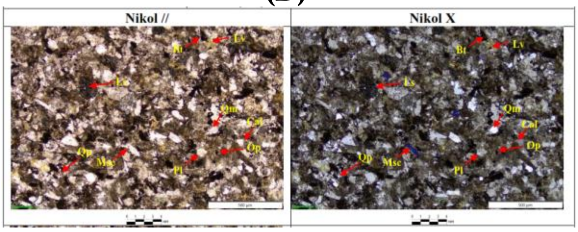

Figure 17. Petrographic features lithology lithic graywacke Ako-26 BP with mineral composition monocrystalline Quartz (Qm) 60%, polycrystalline Quartz (Qp) 3%, volcanic lithic (Lv) 2%, sedimentary lithic (Ls) 5%, opaque (Op) 5%, biotite (Bt) 6%, Muscovite (Msc) 2%, plagioclase (Pl) 2%, cement (Sm) 8%, calcite (Cal) 7%

The results of determining the name of sandstones in the Bambaira area based on the classification of Pettijohn (1975), with mineral parameters of quartz, feldspar and rock fragments to obtain the name quartz wacke and lithic graywacke.

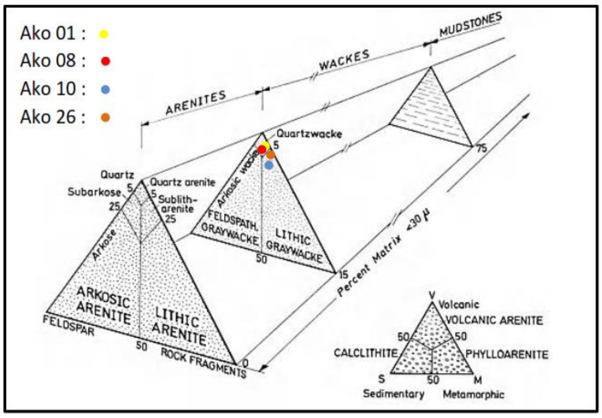

Figure 8. Determination of sandstone name based on Pettijohn classification (1975) in Nichols (2009) with mineral parameters quartz, feldspar and rock fragments to obtain the name quartzwacke and lithic greywacke

4. CONCLUSIONS

Based on the results of research conducted in Bambaira and Ako, Pasangkayu Regency, West Sulawesi province, as well as the results of processing and analysis of data, the conclusions obtained regarding the provenance of sandstone research area as follows :

Sandstones found in the study area are very fine grains of sand to fine sand with a fairly good sorting. The material composition of sandstone in the study area generally consists of monocrystalline Quartz (Qm), polycrystalline Quartz (Qp), K-feldspar, plagioclase, rock fragments (lithic), Muscovite, biotite, calcite and opaq minerals and cement. Quartz Mineral is the most dominant element in the Lisu Formation sandstones in the study area, based on the results of determining the name of sandstones using the naming classification of Pettijohn (1975) obtained 3 lithic greywacke sandstones in the sample BR – 02, AKO-10 and AKO -26 while 4 quartz wacke sandstones with sample codes BR – 16, BR – 22, AKO – 01, and AKO – 08.

Provenance determination is done by identifying the minerals that make up the sandstone by looking at the physical character of each mineral as for the minerals that can be used in determining the provenance of sandstone are quartz minerals with monocrystalline type (Plutonic quartz and volcanic quartz) and poliksritalin (secystose quartz and recrystallized quartz), feldspar minerals (plagioclase, sanidine which indicates feldspar minerals from volcanic igneous rocks, and orthoclase which indicates rocks from Plutonic igneous rocks).

Based on the results of the percentage of rock constituent components performed on a triangle diagram using the parameters Q – F-L according to Dickinson and Suczeck (1979) research areas generally have 6 source rocks derived from the tectonic order of the recycling area (recycle orogen). While based on the results of the percentage of rock constituent components performed on the Triangle diagram using the parameters Qm – F-Lt according to Dickinson and Suczeck (1979) research areas generally have 3 source rocks derived from the tectonic order of the recycling area (recycle orogen) with Quartz reshuffle (Quartz recycled) and 4 source rocks derived from the tectonic order of the continental block, namely in the interior craton

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