

Phenomenon of schistic breccia, autoclastic breccia and radiolarian chert, a Mesozoic tectonic trace in Bantimala Tectonic Complex Area, Pangkep Regency South Sulawesi Province

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Abstract. The presence of the schistic breccia and the autoclastic breccias and the radiolarian chert on the Bantimala tectonic complex is one of the interesting geological phenomena to study. In addition to knowing the position and stratigraphic relationships between radiolarian chert with autoclastic breccia as basement rock, the secular breccia may reveal Bantimala's tectonic environment in the Mesozoic time. This research uses secondary data assessment method from previous researcher and field investigation in the form of observation and rock sampling for petrographic and chemical analysis (X-Ray Fluorescence) to the chemical elements of rock. The appearance of a field indicating the presence of an alternating of the radiolarian chert with a schistic breccias and a sandstone insertion at the bottom of which is in the same composition as the schistic breccia and the autoclastic breccia as the source of some of its components, indicating the stratigraphy relation between radiolarian chert with schistic breccias are conformably, while the radiolarian chert with an autoclastic breccia is unconformably. The metamorphic rock components present in the schistic breccia and the autoclastic breccia are varied in the schistic breccias of about 42.94 - 91.44% SiO₂, while the autoclastic breccia 33 - 92.02% SiO₂ showing of protolith a mixing of sedimentary rocks, ultramafic, basalt and intermediates rocks. The result of plotting on the spider diagram of trace elements and rare earth elements indicates that the autoclastic breccias originate from the Mid-oceanic ridge basalt (MORB), while the schistic breccias are derived from MORB, OIB and active continental margin.

1. Introduction

The forming of the schistic breccia of the Bantimala tectonic complex is related to the subduction activity of the Western Pacific against the continent of Asia in the Mesozoic era. There is a deformation of rock and metamorphism on both plates that collide and rub against each other. Under these conditions according to Hall (1976) and Fiesta (2010, 2016) the deformation of plate rocks forms an autoclastic breccia and an avalanche in which the component material may originate from the crushed material of the plate to form a schistic breccia, then covered by radiolarian chert sedimentation as a continuation of deep marine sedimentation.

The oldest rocks exposed in Bantimala Tectonic Complex area are metamorphic rocks consisting of glaucophane schist, mica-hornblende schist, eclogite, granulite, phyllite quartzite in Cretaceous age



(Sukanto, 1975). Above this base rock is crushed by breccia rocks, sandstone and radiolarian chert of Jurassic - Cretaceous age (Sukanto, 1982) ..

Schistic breccia which is the lowest layer of the radiolarian chert of Bantimala complex which by the researchers referred to as schistic breccia sediment that shows very specific characteristics of the very poorly sorting, the bottom is unstratified, gradation grains fining upward, alternating with the chert, there is large blocks floating in the matrix groundmass of the sand, in the rocks there is the impression of tectonic deformation (tectonite texture), and on the layer of the chert above it is sometimes found a pebble schists in it..

2. Research Methods

This data collection is done through:

2.1. Literature review

Collect preliminary data relating to or support research, in the form of regional geological data including stratigraphy, tectonics, and structure.

2.2. Field research

Includes observation and sampling of rocks, measurement of structural and stratigraphic aspects as well as photo taking and outcrop sketches.

2.3. Laboratory Analysis

Laboratory analysis is done in two ways:

- Petrographic analysis which aims to know the type and texture of the other constituent minerals on thin section that are then identified then calculate the percentage of each type of mineral. This analysis was conducted in the petrography laboratory of Geology Department of Hasanuddin University.
- Geochemical analysis by XRF method, which aims to find out the chemical composition of major element and trace element / HFSE (Immobile).

3. Regional Geological and Tectonic Framework

The Bantimala tectonic complex is composed of metamorphic rocks such as glaucophane schist, hornblende-mica schist, eclogite, granulite, phyllite and quartzite in Triassic period (Sukanto, 1975), mélangé with components of schist, quartzite, metachert, metabasalt Jurassic- Cretaceous age and sedimentary rocks including shale, sandstone, claystone and radiolarian chert. The ophiolite blocks consist of harzburgite and serpentinite, formed of obducting on the Tertiary rocks in this area, while the sedimentary type of continental margin as Balangbaru-Paremba flysch in Cretaceous age, unconformably overlain by the Mallawa sandstone and Langi tuff in Paleocene-Eocene time.

The Cretaceous tectonic on Bantimala Tectonic Complex according to Iskandar Zulkarnaen (1999) and Maulana, et al. (2009), that the formation of high-pressure metamorphic rocks associated with low-grade rocks, mélangé and ultrabasa in the Bantimala Complex region is the result of the subduction of oceanic crust into the continental margin plate of the Jurassic to the Early Cretaceous age, about 114 to 132 million years. Based on calculation of pressure - temperature of garnet rocks - glaucophane shows temperatures around 580⁰ - 640⁰C and 18 - 24 kbar pressure (Miyazaki et.al, 1996). This condition occurs at depths of about 65 - 85 km at various levels and pressures. According to them, radiolarian chert at Bantimala Complex is unconformably with the schist breccia contained beneath which Albian - Cenomanian age about 100 million years (Wakita et al., 1994).

4. Schistic Breccia

The process of subduction of the Pacific plate against the Kalimantan continent in the Jura period begins the process of forming the Bantimala schist breccia. At that time, tectonic deformation, brecciation and metamorphism occur on both colliding and rubbing plates, accompanied by the formation of a trench as a settling environment. The continental and oceanic plate that has undergone a low-grade metamorphism is brecciated to form blocks of rock that display texture of tectonite.

On critical slope conditions based on Yamada's experiment, et al. (2009) and Festa, et al. (2009) submarine avalanches occur in trench areas, ripen material falling in the form of streams or slumping and widespread in the deep sea environment basement as chaotic materials between the continental and oceanic components.

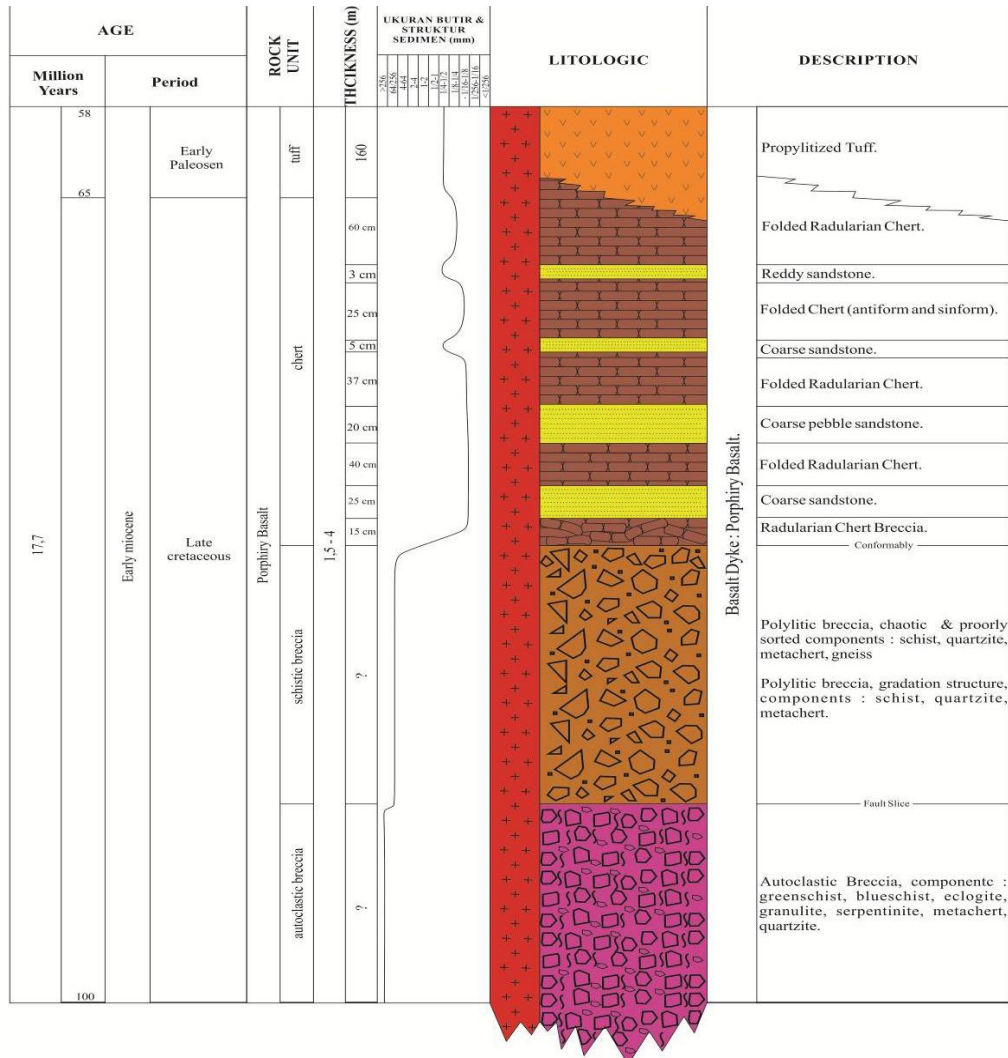
Based on the appearance of the field, schistic breccia layer at the bottom of Pateteyang River, Bantimurung there are at least four times avalanche / sedimentation of rework material that alternating with chert, that is:

- First sedimentation in the form of avalanches and slumping of coarse materials in the form of blocks / blocks of rocks with a thickness of at least 340 m. the size of fragments between 1 - 150 cm, angular and boudin shape. Components consist of chlorite schist, mica schist, amphibole schist, gneiss and quartzite.
- The second sedimentation, prior to this second sedimentation, is preceded by the deposition of a thin layer of chert and mixed of gravel and schistic sand with 20 cm thickness. Then there was an avalanche of pebble –sand material (2 - 40 cm), relatively fine more than the first avalanche, about 150 cm in thickness.
- The third sedimentation, also mediated by a layer of chert with a thickness of about 60 cm. This third layer is composed of coarse schistic sand with a thickness of 25 cm.
- The fourth sedimentation over the layer of chert (120 cm thickness), a thin layer of sand schist with a thickness of about 20 cm (table 1).

Characteristics of the schistic breccia component in the Bantimala tectonic complex show various rock types that are poly lithic consisting of material from rock rework of tectonic result deformation from schist, serpentinite, metachert, quartzite and gneiss. Component size varies from 1 - 150 cm with very poorly sorting, floating block components in groundmass of mud matrix, subangular-very angular component forms. The matrix and cement appear reddish indicating the cement of the chert as deep sediment (trench) or as a retransported sediment material. The component material exhibits tectonic impression (tectonite texture) in the form of lensis, cracks, pseudofoliation or slurry texture in chaotic sediments.

Petrographic observations on the components consisting of schist, chert, and sandstone showed the following results :

1. Components of fragments of schist and quartzite
 - Fragment schist (OL, 5C), composed of 40% muscovite minerals, 30% quartz, 20% chlorite, 5% actinolite, 5% opaque mineral, lepidoblastic texture, quartz muscovite schist
 - Quartzite fragments (OL, 5D), composed of 75% quartz mineral, 12% muscovite, and biotite 10%, opaque mineral 3%, granoblastic texture, quartzite rock name
2. Schist and greenschist
 - Schist olistolite sekis (OL, 2B), lepidoblastic texture composed of muskovite minerals 65%, 20% quartz, 5% chlorite, 6% albite, and 4% mineral, name of rock is schist muscovite.
 - Greenschist (ML, 3B), lepidoblastic texture composed of mineral actinolite 90%, 5% quartz, 3% chlorite, 2% opaque mineral, name of rock is actinolite schist.

Table 1. Lithologic column of schistic breccia and autoclastic breccia of Bantimala area

5. Autoclastic Breccia

Variations of physical conditions and plate interaction in subduction zones result in plate consumption and subduction, lithification degree differences and increased temperature and load pressure, and filling of crushed material and sediment to the bottom of the plate, resulting in chaotic rock formations between metamorphic and sediment (Festa, 2010).

The outcrop of the autoclastic breccias in the Bantimala complex area is composed of blocks of greenschist and serpentinite, eclogite, blueschist, granulite and metachert. The forms of boudin fragments and lenses are embedded in matrix and foliate scales that are relatively north-south, southeast-northwest and southwest-northeast. The size of the rock blocks is very varied ie 10-600 cm. The autoclastic breccia exposed in the southern part is monolithic, composed of green serpentine blocks and serpentinite, while the middle and west regions are mixed with greenschist, eclogite, blueschist, granulite and metachert.

Petrographic observations on autoclastic breccia components such as greenschist, blueschist, eclogite and granulite are as follows:

- Greenschist : compose of epidote and staurolite sillimanite schist

- Blueschist, glaucophane tremolite schist, amphibole schist and glaucophane schist
- Granulite (plagioclase, sillimanite, diopside)
- Eclogite omphacite, muscovite mica, garnet, quartz and biotite

Based composed on the mineral composition of the autoclastic breccia fragments show the oceanic crust protolith.

6. Radiolarian Chert

Radiolarian chert in the area of the tectonic complex Bantimala formed in trench areas in the subduction zone in the Jura-Kapur period. At the beginning of the formation of the chert, preceded by tectonic deformation produces metamorphism and landslide brecciation in the gravity flow system of various components of the breccias, followed by the formation of an adjacent layer of chert with the component sand of the schist having the same source as the schistic breccia. In its formation in the active subduction zone, the chert shows on the field of symptoms such as soft sediment deformation, slumpball, brecciation, minor folds (synform and antiform) and dragging symptoms, and boudin structure.

The presence of alternating with sandstones derived from the same sequence of sources with schistic breccias indicates the association of radiolarian chert with schistic breccia is aligned.

Based on microscopic observation, the chert is composed by small foraminifera fossils of 40%, microcrystalline quartz 55%, 2% muscovite and 3% opaque mineral. Sandstones as inserts in the lower layers of chert, containing 70% muscovite, 25% quartz and 5% opaque minerals.

7. Chemistry of Rocks

7.1. Trace Elements

The rock trace element in the study area is the result of the ICP MS analysis (table 2) plotted on the spider diagram which is normalized with the Prepared Mantle in the study area (figure 1).

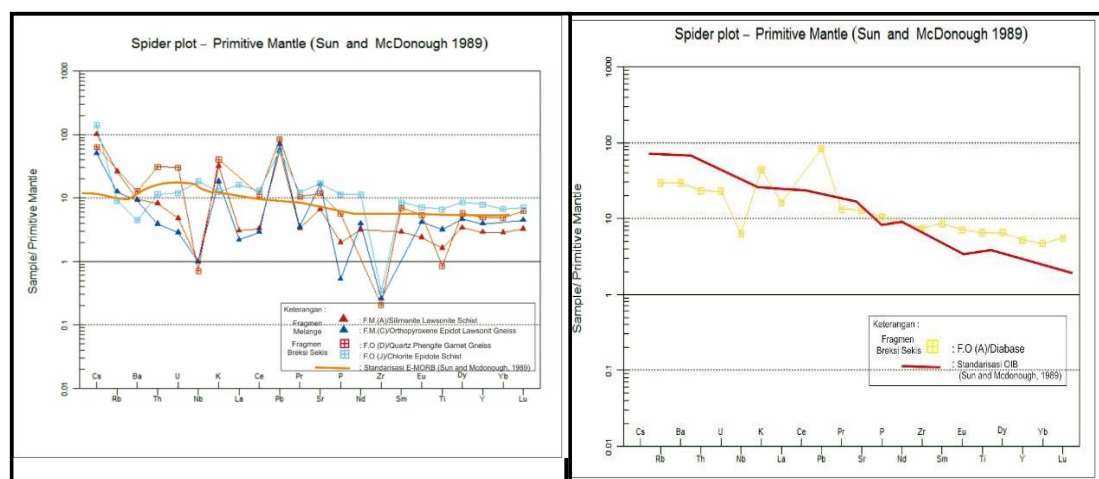


Figure 1. Spider diagram of trace elements on autoclastic breccia fragments and schistic breccia.

From the spider diagram with normalization of primitive mantle (Sun and McDonough, 1995) compared with the type of tectonic order (Sun and McDonough, 1989), the pattern of tectonic order is OIB in the sample and the schistic breccia fragments of diabase. The pattern of E-MORB tectonic order for sillimanite lawsonite schist sample, orthopyroxene epidot lawsonite gneiss, whereas in the sample of brecci fragment fragments ie quartz phingite garnet gneiss and chlorite epidote schist. OIB shows the pattern of the tendency to decrease while E-MORB shows the pattern of rising line, then descending and flattening, exhibiting fragile breccia fragments and autoclastic breccia fragments derived from the mid-oceanic ridge tectonic environment.

Table 2. Geochemical analysis results of autoclastic breccia and schistic breccias fragments

Sampel code	Autoclastic Breccias Fragment		Schstic Breccia Fragment		
	FM(A)	FM (C)	FO(A)	FO(D)	FO(J)
Rocks name	Silimanite Lawsonite Schist	Orthopyroxene Epidote Lawsonite Gneiss	Diabase	Quartz Phengite Garnet Gneiss	Chlorite Epidote Schist
Major element (wt%)					
SiO ₂	54.5	51.81	52.6	63.39	46.91
TiO ₂	0.57	1.04	1.55	0.55	1.63
Al ₂ O ₃	13.68	15.54	16.05	15.6	17.19
Fe ₂ O ₃	9.17	10.72	9.94	6.31	11.56
MnO	0.149	0.127	0.183	0.114	0.193
MgO	9.52	6.87	4.06	3.45	5.21
CaO	4.6	6.36	5.8	4.12	10.37
Na ₂ O	5.25	4.45	4.95	2.6	2.73
K ₂ O	1.01	0.59	1.33	1.25	0.39
P ₂ O ₅	0.055	0.017	0.249	0.138	0.266
Cr ₂ O ₃	0.087	0.036	0.014	0.019	0.078
S	0.037	0.002	0.168	0.002	0.005
LOI	1.9	2.8	3.3	2.3	3.1
Total	100	100	100	99.9	99.6
Trace elements (ppm)					
Be	0.049	0.049	0.8	0.7	0.049
Se	26	31	23	17	34
V	160	268	285	77	228
Cr	503	57	8	16	236
Ni	265	31	22	10	97
Cu	67	7	111	7	9
Zn	84	48	91	82	136
Ga	15.5	17.1	20.7	18.9	21.9
Ge	1.2	1.1	1.6	1.8	2.4
As	0.9	0.9	5	0.9	2
Rb	16.6	7.9	18.8	16	5.7
Sr	141	342	274	249	357
Y	13.1	17.8	23.9	22.5	35.8
Zr	2	2.9	83.9	2.3	3.8
Nb	0.7	0.7	4.5	0.5	13.1
Mo	0.4	0.3	0.7	0.3	0.2
Ag	0.09	0.09	0.2	0.2	0.09
Cd	0.049	0.049	0.43	0.15	0.07
In	0.049	0.049	0.05	0.07	0.06
Sn	3.4	2.4	2.7	2.9	2.4
Sb	0.2	0.4	1.1	0.3	0.7
Cs	0.8	0.4	1	0.5	1.1
Ba	66	64	207	89	31
La	2.1	1.5	11.2	8	11.1
Ce	5.8	5.1	27	20.3	23.3
Pr	0.92	0.97	3.65	2.89	3.38
Nd	4.3	5.3	16	13	15.4
Sm	1.3	2	3.8	3.1	3.8
Eu	0.4	0.7	1.2	0.9	1.2
Gd	1.6	2.6	4.6	3.5	5.3
Tb	0.33	0.49	0.69	0.58	0.86
Dy	2.5	3.4	4.8	4.2	6.3
Ho	0.5	0.7	0.9	0.8	1.2
Er	1.5	2.1	2.5	2.6	3.8
Tm	0.2	0.3	0.3	0.4	0.5
Yb	1.4	2	2.3	2.4	3.3
Lu	0.24	0.33	0.41	0.46	0.52
Hf	0.3	0.3	2.6	0.2	0.3
Ta	1.32	1.02	0.46	0.2	0.9
Tl	0.08	0.04	0.11	0.05	0.03
Pb	4	5	6	6	4
Bi	0.049	0.049	0.049	0.09	0.049
Th	0.7	0.33	1.98	2.63	0.98
U	0.1	0.06	0.48	0.63	0.25
Co	45	35	27	10	55
Li	102	45.6	22.9	18.1	27
Re	0.049	0.049	0.049	0.049	0.049
Se	0.99	0.99	0.99	0.99	0.99
Te	0.09	0.09	0.09	0.09	0.09
W	0.4	0.5	0.4	0.1	0.09

7.2. Rare Earth Elements

From the REE pattern diagram with normalized chondrites (Sun and McDonough, 1989) compared with the tectonic order type (Sun and McDonough, 1989), three types of tectonic order are found (figure 2). The first is the oceanic island basalt (OIB), the tectonic environment is obtained on samples of the schistic breccia fragments of diabase. The OIB pattern shows patterns where LREE elements (Light rare earth elements) are enriched compared with HREE (Heavy rare earth elements).

The pattern indicates that the tectonic surface of the research area is from the ocean floor seafloor (Mid-Oceanic Ridge and OIB), but with the concentration of europium (Eu) depleted in most samples except in the sample code F.M.A, as fractional of plagioclase crystallization indicates contamination with the continental arc. The depletion of the Eu element shows the subduction of oceanic crust (tholeiitic) in the continental crust characterized by the affinity of the calc-alkaline magma. From the above results it can be concluded that the fragments of the schistic breccia are derived from autoclastic breccia fragments, both of which are formed in the mid-Oceanic Ridge tectonic environment.

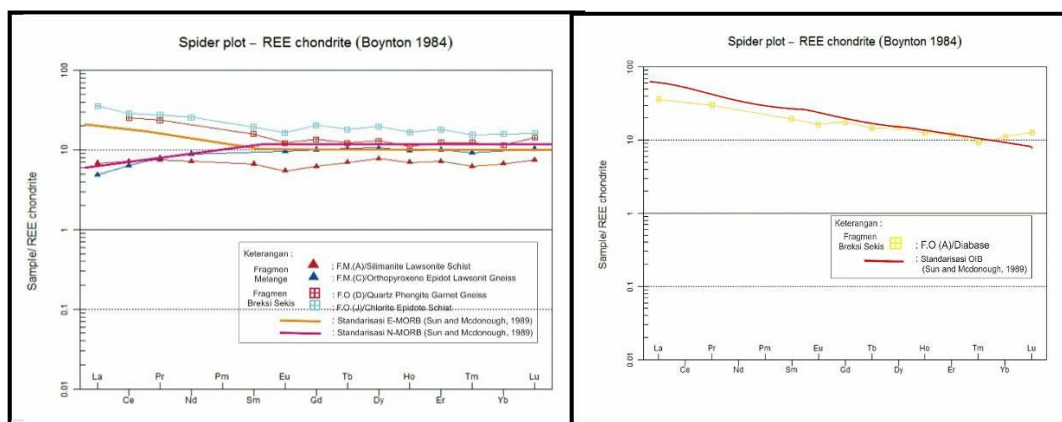


Figure 2. The REE spider diagram on the autoclastic breccia and breccia schistic fragments.

7.3. Tectonic Environment of Autoclastic Breccia Fragments and Schistic Breccias

The tectonic environment of the autoclastic breccia and schistic breccia of the research area based on the previous explanation is based on the spider diagram of element trace element and rare earth element showing the tectonic environment as follows (table 3).

Table 3. Tectonic environments based on trace elements and REE

Number of sample	Rocks name	Spider Diagram REE chondrite	Spider Diagram of primitive trace mantel
FM (A)	Silimanite Lawsonite Schist	EMORB	EMORB
FM (C)	Orthopyroxene Epidot Lawsonite Gneiss	NMORB	EMORB
FM (C)	Orthopyroxene Epidot Lawsonite Gneiss	NMORB	EMORB
FO (A)	Diabase	OIB	OIB
FO (D)	Quartz Phengite Garnet Gneiss	EMORB	EMORB
FO (J)	Chlorite Epidote Schist	EMORB	EMORB

The result plot of the autoclastic breccia and schistic breccia samples in the Th / Ta vs. Yb diagram (figure 3). In autoclastic breccia fragments, the result of MORB tectonic order for orthopyroxene lawsonite gneiss samples is one sample of autoclastic breccia fragments which do not classify tectonic order in this diagram of sillimanite lawsonite schist. In the sample of fragments of the schistic breccias of the sec-tition, the tectonic order of Within Plate Volcanic Zones in the diabase sample was obtained. The MORB tectonic order was obtained in chlorite epidote schist samples. Then the ACM tectonic order was obtained on quartz phengite garnet gneiss samples (table 4).

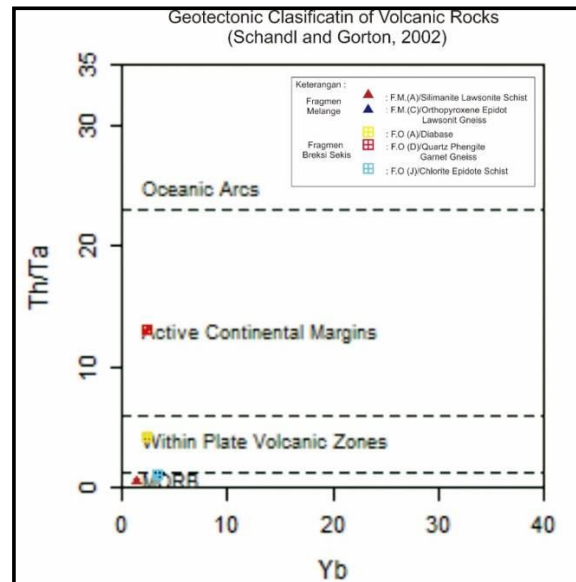


Figure 3. Geotectonic Diagram Th / Ta vs Yb (Geotectonic Classification of volcanic rocks – Schandl and Gorton, 2002)

Table 4. Tectonic Environment based on REE Chondrite and Trace Element

Number of. Sample	Rocks name	Spider Diagram REE chondrite	Spider Diagram of primitive trace mantel	TiO ₂ vs V	Nb/Yb vs TiO ₂ /Yb	Th/Ta vs Yb
FM (A)	Silimanite Lawsonite Schist	EMORB	EMORB	MORB	-	-
FM (C)	Orthopyroxene Epidot Lawsonite Gneiss	NMORB	EMORB	MORB	NMORB	MORB
FO (A)	Diabase	OIB	OIB	MORB	OIB	OIB
FO (D)	Quartz Phengite Garnet Gneiss	EMORB	EMORB	ARC	-	ACM
FO (J)	Chlorite Epidote Schist	EMORB	EMORB	MORB	EMORB	MORB

8. Mesozoic Tectonic Records

The exposure of high-pressure metamorphic rocks associated with low-grade metamorphic rocks and mélangé in the Bantimala tectonic complex area indicates that the area was once a subset of oceanic crust subduction into the continental margin plates of the Jurassic to Early Cretaceous for about 114 to 132 million years (Zulkarnain, 1999). The current conditions by garnet - glaucophane show temperatures around 580⁰ - 640⁰C and 18 - 24 kbar pressure. This condition occurs if the depth of about 65 - 85 km (Miyazaki, 1996).

The presence of a schistic breccia and an autoclastic breccia of radiolarian chert with schistic sand inserts indicates trace of subduction tectonic activity in the deep ocean trench environment, where deformation of the rock layers and the formation of gravity flow from the schistic breccia.

From the results of plotting on geotectonic diagrams and spider diagrams on element Trace element and Rare Earth Element. Can show the tectonic environment of the determination The autolastic breccia fragments are from the oceanic ridge midge, while the fragment of the schistic breccias a more varied tectonic environment ie MORB, OIB, and Active Continental Margin (ACM). The relationship of schistic breccia fragments to the autoclastic breccia fragments based on its tectonic environment are some of schistic breccia fragments derived from the autoclastic breccia derived from the Tectonic Environment of the Mid-Oceanic Ridge or the Floor of the Ocean.

The Bantimala tectonic complex is composed of mélangé rocks, breccia, and radiolarian chert, formed in subduction and accretion zones (Kaharuddin 1992, 2015, 2016; Zulkarnaen 199; Maulana et al. 2009; Wakita et al 1996).

The stratigraphic relationship between the autoclastic breccia and the schistic breccias showed in the field of tectonic slice contact, whereas between the schistic breccias with radiolarian chert are aligned or continuous sedimentation. Autoclastic breccia with the main component of greenschist (low grade), slightly high degree metamorphic rock (blueschist, eclogite, granulite) and serpentinite blocks indicate an uplift, occurring shortly after forming autoclastic breccia. This condition causes uplifting to form an accretion prism followed by deformation and erosion. The result of rock erosion forms a breccia in the gravity flow sedimentation system in the subduction zone. This is supported by the components of schistic breccia in the form of gneiss, quartzite, granodiorite, diabase and gabbro (continent source) mixed with greenschist, granulite, serpentinite and eclogite (oceanic source). The appearance of structures and the physical conditions of radiolarian chert that undergo subsedimentation deformation in the form of small folds, brecciation, slumping, drag and boudin indicate the environmental conditions of active tectonic sedimentation in the Cretaceous-Paleocene period, following the formation of Langi volcanic Paleogene Formation.

Conclusion

1. Schistic breccia composed by components of schist, quartzite, metachert, phyllite and gneiss, while the autoclastic breccia is composed by greenschist, blueschist, eclogite, granulite, serpentinite, metachert and quartzite. Schistic breccia are formed by the process of sedimentation gravity flow in the deep sea and autoclastic breccias are formed by deformation tectonics of oceanic and continental crusts.
2. Schistic breccia is at the bottom of the radiolarian chert, at the top of the layer fining and alternating with a layer of chert indicating the relationship between the two rocks is conformable with the age of Upper Cretaceous.
3. From the result of plotting of the spider diagram and geotectonic diagrams shows that autoclastic breccia is derived from the basal of Mid-Oceanic Ridge, while schistic breccia is more varied that is from MORB, OIB, and Active Continental Margin (ACM), there are some similar source in MORB.
4. High-pressure metamorphic rocks associated with low-grade (blueschist, garnet, eclogite, greenschist and phyllite) exposed in the area of Bantimala Complex and rock chemistry indicating the source of the oceanic and continental crust, can provide an interpretation that the formation environment is in the subduction tectonic region between oceanic plate and continental plate in the upper Mesozoic era.

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