THE PROVENANCE AND DIAGENESIS OF SANDSTONES OF THE EOCENE TANJUNG FORMATION IN THE KUALAKURUN AREA, CENTRAL KALIMANTAN

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ABSTRACTS

Kualakurun area is located in the western margin of Tertiary Barito Basin. The basin was filled by the Eocene Tanjung Formation consisting of conglomerate and sandstone in the lower part, mudstone with intercalated by coal seams in the middle part, and sandstones in the upper part. The sandstones consist of subarkose, sublitharenite, and felspathic litharenite. The framework grains dominantly consist of quartz with some lithic and feldspar fragments. The accessory minerals are muscovite and opaque minerals.

The provenance of sandstone fragments of the Tanjung Formation were derived from Continental Block (Craton Interior) and Recycled Orogen (Quartzose Recycled), which most probably were derived from the pre-Tertiary rocks of the Schwaner Mountains (Cretaceous granites and tonalites intruding Silurian-Permian metamorphic rocks) in the west of the Kualakurun area. Diagenetic processes identified in the sandstones are compaction, mineral authigenic and secondary porosity formations. The diagenesis regime is categorized as "mesogenesis mature A", that is equal to mudrock stage II, having a paleo-temperature of 80° up to 95° C, and the burial depth ranging from 2 to 3 kilometers.

Keyword: provenance, sandstone, diagenesis, Tanjung Formation, Kualakurun

SARI

Daerah Kualakurun terletak di tepi barat Cekungan Tersier Barito. Cekungan ini terisi oleh Formasi Tanjung berumur Eosen dan tersusun oleh konglomerat dan batupasir di bagian bawah, batulumpur dengan sisipan batubara di bagian tengah, dan batu pasir di bagian atas. Batupasir ini terdiri atas subarkose, sublitarenite, dan felspar litarenit. Kerangka butiran dikuasai oleh butiran kuarsa dengan sedikit fragmen batuan dan felspar. Mineral tambahan adalah muskovit dan mineral opak.

Provenan klastika batupasir Formasi Tanjung berasal dari Blok Benua (Craton Interior) dan Orogenesis terdaur ulang (Kuarsa terdaur ulang), yang sangat mungkin berasal dari batuan Pratersier Pegunungan Schwaner (batuan granit dan tonalit yang menerobos batuan malihan berumur Silurian-Permian) di sebelah barat daerah Kualakurun. Proses diagenesis yang teramati dalam batupasir adalah kompaksi, pembentukan mineral autigenik, dan pembentukan porositas sekunder. Tingkat digenesisnya termasuk kategori "mesogenesis matang A", yang ekuivalen dengan mudrock tingkat II dengan paleo-temperatur berkisar antara 80° sampai dengan 95° C, dengan kedalaman timbunan antara 2 sampai 3 kilometer.

Kata kunci: Provenan, batupasir, diagenesis, Formasi Tanjung, Kualakurun

INTRODUCTION

Kualakurun is the capital city of the Gunung Mas Regency, Central Kalimantan. The area is located in the western part of the Barito Basin (Figure 1). Physiographically, the Barito Basin is bounded by Schwaner High in the west and the Meratus High in the east. To the north the basin extends to the West Kutai Basin, and to the south it is bounded by the Java Sea. The development of the basin is elongated north - south direction parallel with the Barito River. The Schwaner High is occupied by the Cretaceous granites and tonalities intruding Palaeozoic metamorphic rocks. The Meratus High is formed by pre-Tertiary ophiolite, metamorphic, granitic, and sedimentary rocks (Supriatna *et al*., 1994).

The fieldwork was done in 2006, as a part of the research in sedimentological and tectonic processes of the Barito Basin, one of the research programme of the Geological Survey Institute. Petrography and Scanning Electron Microscope were used in order to reconstruct orginal sandstone composition and to identify the diagenetic process. The methods of data analyses followed those outlined by Dickinson and Suczek (1979), Ingersol and Suczek (1979), and

Dickinson *et al*. (1983). The diagenetic stage methods, however, followed those outlined by Schmidt and McDonald (1979), and also Burley *et al*. (1987).

GEOLOGICAL SETTING

Geological map and the stratigraphic column of the Kualakurun area are presented in the Figure 2. The oldest rock in the area is Paleozoic metamorphic rock which is cropped out in the western part (Schwaner Mountain). The metamorphic rock was intruded by Cretaceous granitic and tonalitic rocks. The oldest sedimentary rock unit is the Eocene Tanjung Formation. The Tanjung Formation in Kualakurun area comprises well bedded conglomerate and coarse grained quartz sandstone, with bedding thickness ranging from 50 to 200 cm (Photo 1) in the lower part. In the middle part, the formation consists of a mudstone with intercalations of coal seams and some fine-grained sandstone beds, with 30 to 150 cm thick. A sequence of well bedded fine-medium grained sandstone with some interbedded brownish mudstones (50-150 cm thick) is found in the upper part of the formation (Figure 3).

The Tanjung Formation is overlain by the Oligocene volcanic of the Malasan Formation. In the other part of the researched area, the Tanjung Formation is also covered by the Oligocene-Miocene Montalat Formation, which consist of mudstone with some intercalation of sandstone beds and limestone lenses. In the eastern part of the Barito Basin, the formation can be correlated with limestone dominated unit of the Berai Formation. The Miocene Warukin Formation comprises intercalation of sandstone, mudstone and some coal seams. The Plio-Pleistocene Dahor Formation is unconformable above these formations.

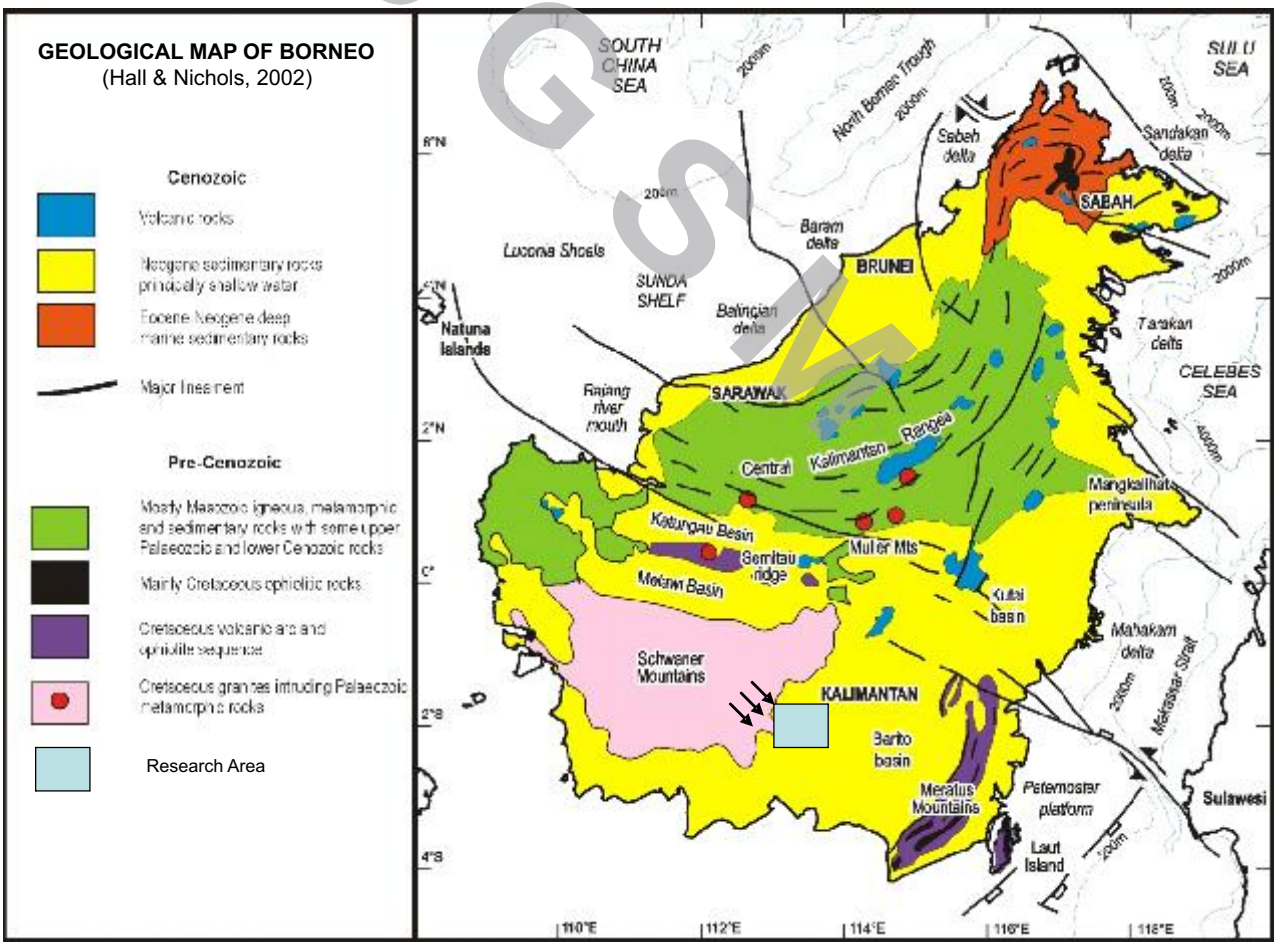

Figure 1. The geological map of Borneo (Hall & Nichols, 2002) and the location of the research area. The arrow indicates that the Schwaner Mountains acted as a provenance of the Tanjung Formation sandstones.

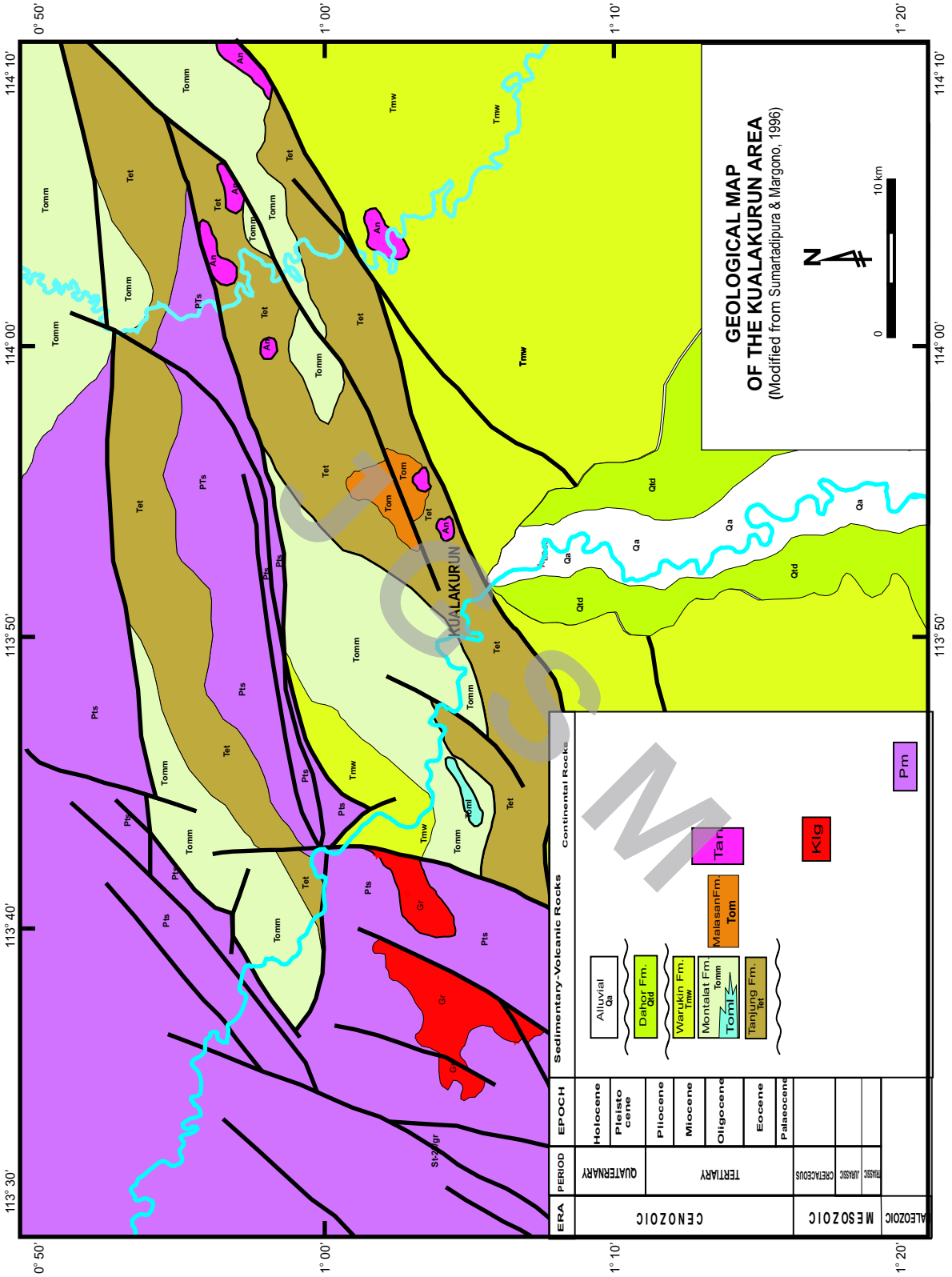

Figure 2. Geological Map of the Kualakurun Area (modified from Sumartadipura & Margono, 1996)

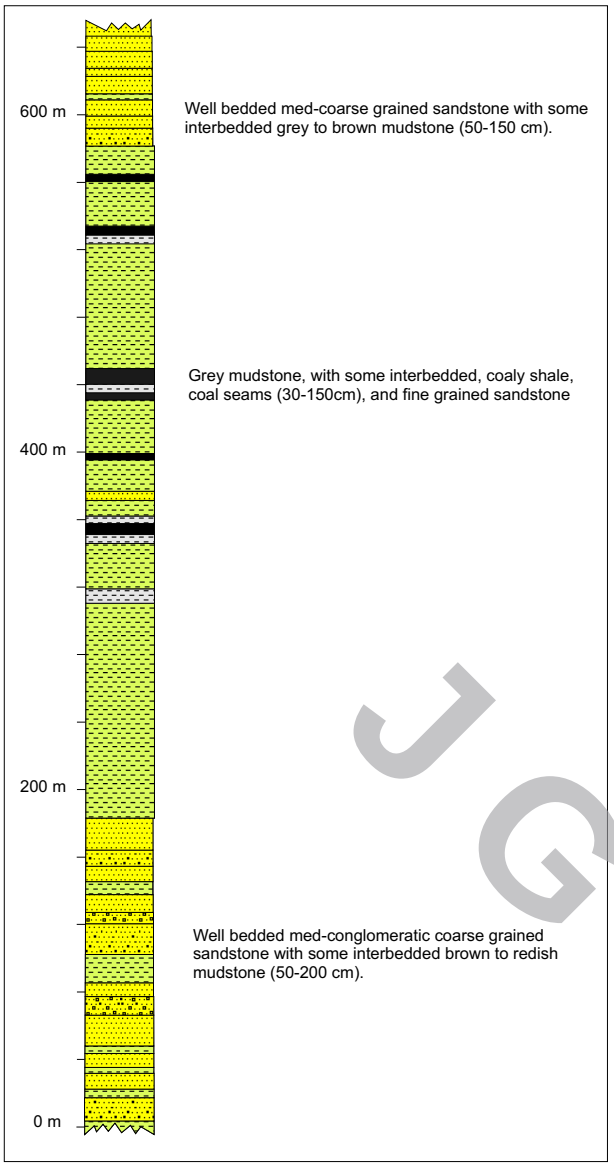

Figure 3. General stratigraphic column of the Tanjung Formation in the Kualakurun Area.

PROVENANCE

Petrographic analysis data of the Tanjung Formation sandstones are tabulated in Table 1. These data show that the majority of Tanjung Formation sandstones are white to grey in colour, composed of 75 to 99 % framework grains. Grain size of the sandstone ranges from 0.3 to 1.9 mm, ranging from subangular to subrounded and are generally moderately sorted. Framework grains consist of 20.3-80.3% quartz, 3-13% composite quartz, 3-9.7% feldspar and 1.6-14.0% lithic fragments. Accessory minerals are muscouvite (0-2.67%), and laumontite (0-1.3%), and opaque mineral (0-2.3%). The sandstone matrix is composed of clay mineral and silica. Spary calcite is also present as cement within some samples. Most of the quartz grains show as straight extinction and some of them show as undulose extinction. Composite quartz grains present as an irregular contact of unfoliated crystal and some foliated crystals. Feldspar grains consist of K feldspar (3.0-9.67%) and plagioclase (0-1.33%). Rock fragments within the Tanjung Formation sandstones are sedimentary rocks (1.33-12%), metamorphic rocks (0.33-3.67), and volcanic rocks (0-2%).

According to the QFR (Q: quartz; F: feldspar; R: rock fragments) sandstone classification diagram of Folk (1980; Figure 4), the Tanjung Formation sandstones in the Kualakurun area is composed of eight samples of subarkose (76.6-94.3% Q, 3.7-15.2% F, 2-9.8% R), as shown in Photo 2, followed by five samples of feldspathic litharenite (53.2-74.1% Q, 8.5-14.2% F, 14-32.6% R), and the last two samples of sublitharenite (80.6-87.1% Q, 5.3-9.2% F, 7.6-10.2% R).

The presence of abundant quartz grains with straight extinction indicates that granitic rockcs was influenced in the source area (Photo 3). Quartz grains with undulose extinction and/or inclusions are indicated to derive from metamorphic source area. Semicomposite and composite quartz grains are probably the first cycle derived from a gneissic or granitic terrain, whereas the composite quartz with foliated structure indicates that these grains were derived from a metamorphic source area (Photo 4). Fragments K-feldspar and plagioclase indicate that igneous rock was present in the source area. The sedimentary and metamorphic fragments indicate that metasediment and metamorphic were exist in the source area (Photos 3 & 4).

Based on the QFL (Q: total quartzose grains = monocrystalline quartz/Qm + polycrystalline quartz/Qp; F : Feldspar; L: total unstable lithic fragments = volcanic and metavolcanic fragments/Lv + sedimentary and metasedimentary fragments/Ls) and QmFLt (Qm: monocrystalline quartz; F: Feldspar; Lt: Total lithic fragment = L + Qp) diagrams of Dickinson et al. (1983), the Tanjung Formation sandstone was derived from recycled (quartzose recycled) orogenic and craton interior provenances (Figure 4). The area occupied by granitic, tonalith and metamorphic rocks is the Schwaner High located in the west of Kualakurun area. Therefore, the suitable area for the provenance of the Tanjung Formation sandstone in the Kualakurun area is the Schwaner High in the west of the researched area (Figure 1).

Photo 1. Outcrop of thelower part of the Tanjung Formation in the east of Kualakurun Village, consisting of well bedded med-conglomeratic coarse- grained sandstone with some interbedded brown to redish mudstone (50-200 cm).

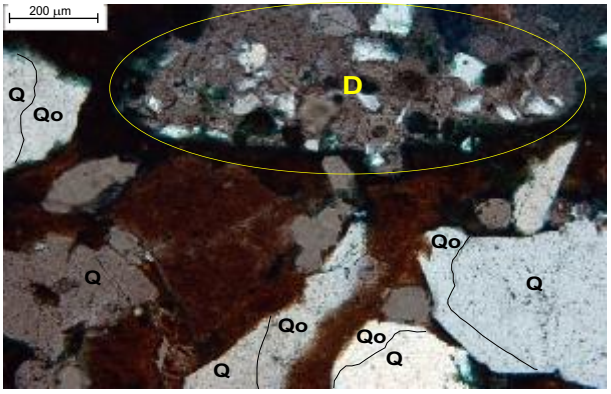

Photo 3. A microphotograph of the sandstone which shows a sedimetary rock fragment (D) and several quartz grains (Q),which have already overgrowth (Qo) Sample No. 06ED04B (X nicol).

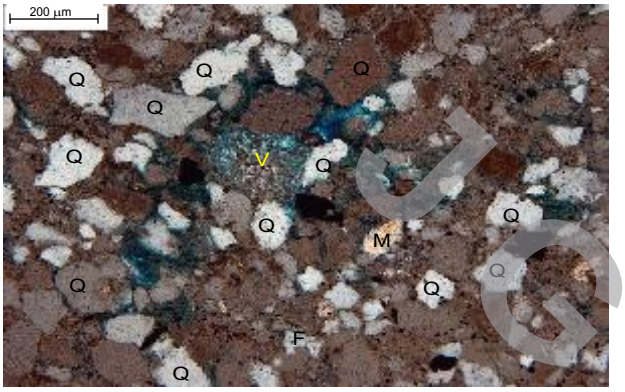

Photo 2. Microphotograph of the sandstone which shows a typical of the Tanjung Formation sandstone (subarkose), dominanted by quartz (Q) with some feldspar (F) and volcanic fragments (V), and also mica (M). Sample No, 06UM03C (X nicol).

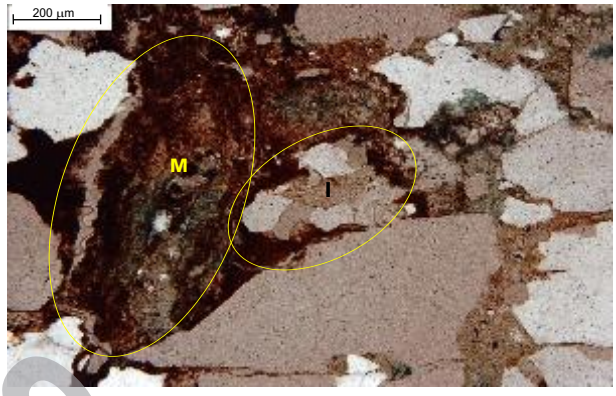

Photo 4. Thin section microphotograph of the sandstone which shows a metamorphic (M) and igneous rock fragments (I). Sample No. 06ED25 (X nicol).

Tabel 1. Petrographic Description of the Tanjung Sandstone Samples from the Kualakurun Area

No Samples / Description	06 ED 03	06 UM 06 A	06 UM 06 C	06 UM 05 A	06 ED 04B	06 ED 11 C	06 ED 16 A	06 ED 20	06 ED 22 B	06 ED 24 A	06 ED 24 B	06 ED 25 A	06 ED 26 A	06 ED 39B	06 ED 40B
Sorting	poor	Med	Mod	Med	Mod	Poor	Poor	Med	Mod	Well	Poor	Med	Poor	Mod	Poor
Fabric	closed	closed	closed	closed	closed	closed	closed	closed	closed	closed	closed	closed	closed	closed	closed
Grain size (mm)	.03-1.2	.05-1,9	03-0.5	.05-1,4	0,1-1.8	0,1-1,8	.03-0,8	.03- 0.2	.05-1.8	0.2-1,5	.03-0,8	.05-1,8	.03-0,8	.05-1.8	.03-1.2
Roucness	A SR	SA SR	SR	SA SR	SR	SA SR	SA SR	SR	SA SR	SA SR	SA SR	SA SR	SA	SA SR	SA SR
Grain contact	Pt-Lg	Pt-Lg	Pt-Lg	Pt-Lg	Pt-Lg	Pt	Pt-Lg	Pt-Lg	Pt-Lg	Pt-Lg	Pt-Pt	Pt-Lg	Pt-Pt	Pt-Lg	Pt-Lg
Mono Quartz	57,00	31,3	55.33	56,33	60,33	50.33	34.0	40.33	45,67	54,33	48,00	47,67	20,33	63.33	55.67
Poly Quartz	7,3	5,3	4,00	3,00	3,67	6,67	6,00	9.33	9.33	4,67	4,67	7.00	4,67	13.00	4.67
K-Feldspar	4,0	6,30	6,67	5,33	7,67	7,33	6,33	6.33	9.33	6,33	6,00	9.67	6,33	9.00	3.00
Plagioclase	0,6	0.67	0,67	0.33	0,33	-	1,33	0.67	1.00	-	-	-	1,33	-	0.67
Volcanic Frag	0,6	-	-	-	0,67	-	1,67	0.67	0.67	-	-	0.67	2,00	-	-
Sedimen Frag	8,3	1.67	5,00	1.33	5,33	2,00	12,00	13.33	5.67	3,33	6,33	5,33	11,33	1.33	4.00
Metamorph Frag.	3,0	1.00	0,67	0,67	0,67	1,67	1,33	2.33	3.67	2,00	1,33	1.00	2,00	0.33	1.33
Muscovite	0,3	1.00	1,67	1,67			2,67	-	0.67		1,00	0.33	0,67		2.33
Opak Min.	1,6	0.67	1,33	0,67	-	2,00	2,33	0.67	0.67	-	0,67	1.33	1,33	0.67	1.67
Leumenite	1,0	-	-	-	-	-	-	-	-	-	-	1,33	-	-	1.00
Clay Min	3,3	2.67	3,33	1.33	-	-	20.0	1.33	5.33	2.33	11.3	6.0	10,0	-	5
Carbonate	-	32,33	0,67	2.33	-	-	-	1.33	-	-	-	-	-	8.33	1.00
Iron Oxide	3,6	2.33	2,33	3,2	18,00	-	1,67	16,0	2.67	17,20	13,00	4.67	6,67	1.33	5.00
Silica	5.7	3.33	4.6	2.00	-	-	-	-	4.6						
Pseudomatrix	21.3	-	4.6	-	-	-	6,00	4.00	3.3	1.0-2,0	45.0	3.00-3.0	/32,67	2,33-	-
Pore	1.3	16,33	5.3	11.6	5.3	0	4,3	5.0	4.2	7	1	9	2.67	8,33	3.67
SS Class.	F.Litharnit	Subarkose	Subarkose	Subarkose	Subakose	S.Arkose	F.litharnit	F.litharnit	F.litharnit	S.Arkose	Subfeldsarenite	Subakose	F.litharnit	Subarkose	Subfeldsarenite
Q	71.1	79.2	82.8	90.1	81.4	88.8	63.8	68.1	74.1	83.5	80.6	76.6	53.2	94.3	87.1
F	8.5	15.2	9.7	7.3	10.2	7.5	12.3	9.6	11.9	8.9	9.2	13.6	14.2	3.7	5.3
L	19.4	5.6	7.5	2.6	8.4	3.7	23.9	22.3	14	7.6	10.2	9.8	32.6	2	7.6
Qm	89.3	67.7	77.4	88.2	76.7	81.9	64.2	55.2	32.1	76.9	73.5	66.8	43.3	78.2	80.3
F	8.5	15.2	9.7	7.3	10.2	7.5	12.3	9.6	11.9	8.9	9.2	13.6	14.2	3.7	5.3
Lt	31.2	17.1	12.9	6.5	13.1	10.6	33.5	35.2	26	14.2	17.3	19.6	42.5	18.1	14.4

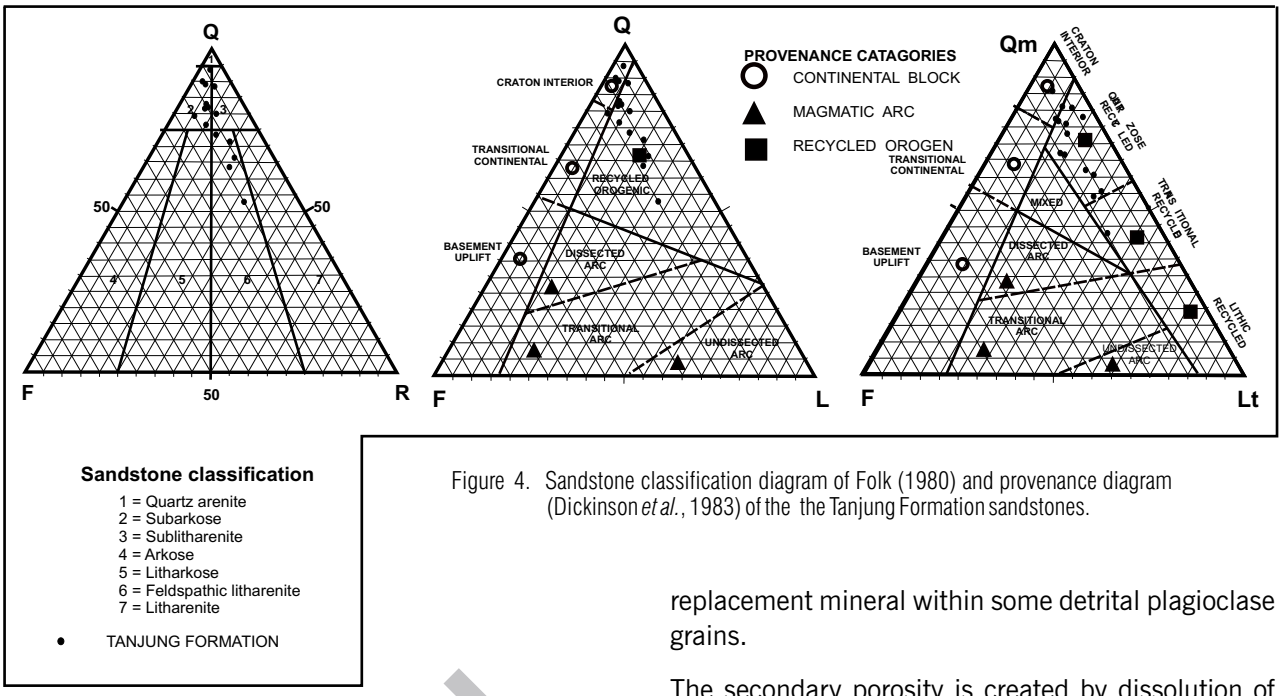

Figure 4. Sandstone classification diagram of Folk (1980) and provenance diagram (Dickinson *et al.*, 1983) of the the Tanjung Formation sandstones.

DIAGENESIS

Based on the petrographic and Scanning Electron Microscopic studies on the Tanjung Formation, the sandstone shows a variety of diagenetic feature as a result of diagenetic processes, such as compaction and the formation of authigenic minerals and secondary porosities.

Compaction effects were illustrated by grain supported fabrics with only minimal porosity preserved. Most of grain supported fabrics within the Tanjung Formation sandstones are point to long grain contacts. Compaction can also be recorded by the deformation of the grains. This process occurred in a detritus of mica flakes which exhibit flat to a slightly bent, and some of them occurred as a truly bent (Photo 5).

Authigenic mineral within the Tanjung Formation sandstone are quartz, clay minerals, rutile and laumontite. Authigenic quartz includes quartz overgrowths which occur to form to develop, and they attached to quartz grain (Photos 3 & 6). Authigenic quartz is small crystal which occurred within the pore together with authigenic clay minerals. Clay minerals consist of kaolinite, chlorite, smectite (montmorollonite), and illite (Photos 7 & 8). They appear as cement filling pores in between the sandstone. Authigenic rutile present as small crystal filling pores. Laumontite occurs as patches of cement interstitial to the framework grains, and also a replacement mineral within some detrital plagioclase grains.

The secondary porosity is created by dissolution of feldspar (Photo 8) and volcanic fragments (Photo 2). The secondary porosity in the sandstone consists of partial dissolution pores, elongated pores corroded and a few completely dissolved grains. The dissolution of various framework grains occurred after initial compaction and has resulted in an increase in porosity for some sandstone samples.

Based on the diagenetic cycle of Schmidt and McDonald (1979), the Tanjung Formation sandstone can be equated to the mesogenetic mature "A" stage of diagenesis, whereas based on the diagenetic scheme for mudrock (Burley *et al*., 1987), that would be included into mudrock stage II, with temperature in the range from 80° C to 95° C, and the depth of burial ranging from 2000 m up to 3000 m.

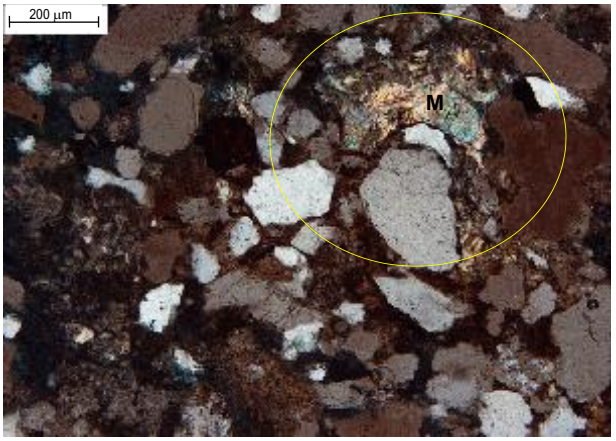

Photo 5. Thin section microphotograph of the sandstone which show a long grain contact fabric and a deformation of mica flakes (M). Samole No. 06ED40B (X nicol).

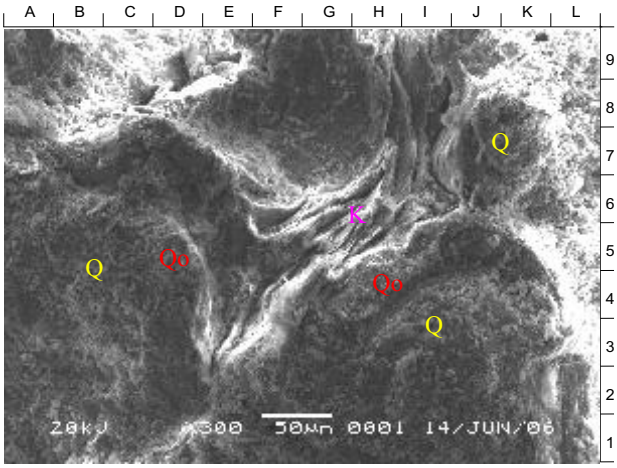

Photo 6. SEM microphotograph of the sandstone which shows a quartz overgrowth (Qo) on quartz grain (Q). Sample No. 06ED40B.

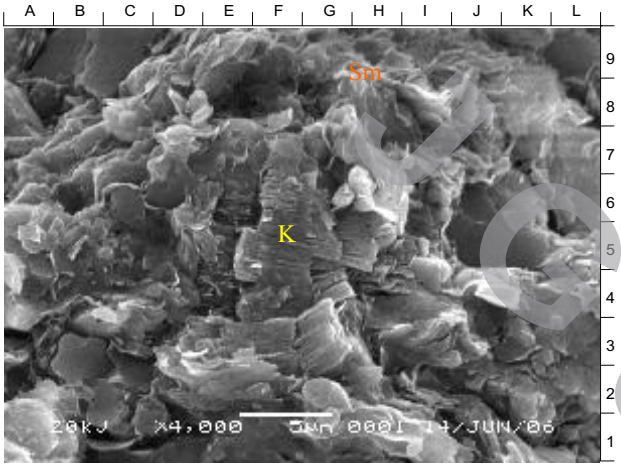

Photo 7. SEM microphotograph which shows an authigenic clay minerals such as kaolinite (K) and smectite (SM). Sample 06 ED 39A.

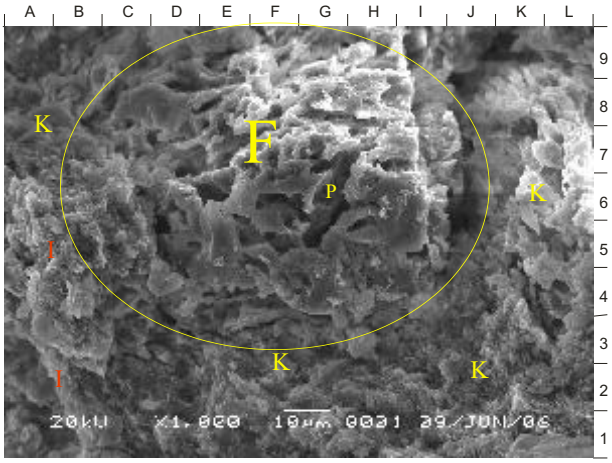

Photo 8. SEM microphotograph of the sandstone which shows a secondary Porosity (P), as a product of the dissolution of feldspar (F), surounding by kaolinite (K) and illite (I). Sample No. 06ED24B.

DISCUSSION

The framework grain of the Eocene Tanjung Formation consists of dominantly quartz with some feldspar and lithic fragments. Monocrystalline quartz grain can be divided into a single grain with a straight extinction and single grain with undulose extinction. Polycrystalline quartz grains can also be divided into unfoliated and foliated structures. These data indicate that the quartz grains within the Eocene Tanjung Sandstone were derived from granitic and metamorphic rock source area. The lithic fragments consist of metasediment and metamorphic rock fragments, with some volcanic fragment. These indicate that metasediment and metamorphic, also volcanic rocks exist in the source area.

The Schwaner Mountains, located in the west of the Barito Basin, comprise tonalite, granodiortite and granitic rocks associated with regional metamorphic rocks (Hall & Nichols, 2002). Intermediate to basic volcanic rocks are also present (Ammirudin and Trail, 1987; Supriatna *et al*., 1994). The plutonic and metamorphic and associated volcanic rocks in the Schwaner Mountains are the most suitable source for the Tanjung Formation sandstone.

The Eocene Tanjung Formation sandstone shows evidence of features, compaction, the formation of authigenic mineral and secondary porosity. These features indicate that the Tanjung Formation sandstone can be equated to the mesogenetic mature "A" stage of diagenesis (Schmidt and McDonald, 1979), that would be included into mudrock stage II (diagenetic scheme for mudrock of Burley *et al*., 1987), with temperature in the range from 80° C to 95° C, and the depth of burial ranging from 2000 m up to 3000 m.

These diagenetic features can be related to the stratigraphic position of the Tanjung Formation in the Tertiary Barito Basin. The Tanjung Formation is the oldest Tertiary sediment in Barito Basin. It is overlain by Malasan, Montalat, Warukin, and Dahor Formations. The depth and temperature attained during the burial can be estimated reliably using the diagenetic stages defined by Burley *et al*. (1987).

CONCLUSIONS

The Tanjung Formation sandstone in the Kualakurun area is composed of subarkose, feldspathic litharenite, and sublitharenite. The framework grains were derived from recycled (quartzose recycled) orogenic and craton interior provenances from the Schwaner High which occupied by granitic, tonalith and metamorphic rocks, to west of the researched area.

The diagenetic processes occurring in the Tanjung Formation sandstone are compaction, the formations of authigenic minerals and secondary porosity, that can be equated to the mesogenetic mature "A" stage of diagenesis, and would be included into mudrock stage II, with temperature in the range from 80° C to 95° C, and the depth of burial ranging from 2000 m up to 3000 m.

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