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Study on Garnet From Meratus Complex, South Kalimantan and Its Usefulness on Diamond Source Tracking

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ABSTRAK

Batuan metamorfik mengandung garnet pada Komplek Meratus, Kalimantan Selatan memperlihatkan dua karakter yang berbeda. Yang pertama adalah metapelit berfasies sekisbiru yang berasosiasi dengan batuan berfasies sekis hijau - epidot amfibolit lainnya yang mengalami retrogresif dari pengaruh tekanan tinggi ke rendah. Di dalamnya didapati garnet berukuran halus (Ø ~ 0.145 mm). Garnet hadir sebagai spesartin dan grosularit-almandine dengan komposisi masing-masing adalah $Alm_{9.1-27.3}Prp_{0.9-2.5}Grs_{14.8-20.6}Adr_{0-4.5}Sps_{51.9-70.5}$. dan $Alm_{27.4-45.7}Prp_{0.8-2.8}Grs_{27.3-52.7}Adr_{1.9-3.4}Sps_{15.5-35.8}$. Batuan-batuan tersebut tersingkap di bagian Barat-daya komplek, tepatnya di sekitar Aranio-Pelaihari yang berdekatan dengan tambang intan plaser Cempaka, sebelah selatan Banjarbaru. Yang kedua adalah granulite garnet (fasies granulit tekanan tinggi) yang berasosiasi dan terdapat di antara ofiolit Manjam. Batuan ini terdapat di lereng timur komplek ini dan berjarak lebih jauh dari lokasi penambangan plaser intan. Kandungan garnetnya (Ø ~ 3.06 mm) berupa pirop-almandin dengan komposisi $Alm_{39.5-42}Prp_{28.8-46.3}Grs_{7.7-31}Adr_{0-8.7}Sps_{1-2}$. Pada beberapa contoh bagian inti kristal garnet mengandung pirop lebih banyak dibandingkan almandinnya, meski pada bagian tepi kristalnya selalu sedikit lebih kecil. Beberapa sampel mengandung molekul Cr sejumlah 0.002-0.007. Pirop merupakan garnet kaya Mg yang terbentuk pada tekanan tinggi. Pada umumnya terdapat pada eklogit dan pada kimberlit, dua batuan yang memungkinkan mengandung intan. Kehadiran pirop terutama yang mengandung Cr merupakan mineral pelacak bagi keberadaan batuan yang terbentuk pada tekanan tinggi seperti pada kimberlit. Studi ini merupakan pendekatan awal dilakukan dalam pelacakan tersebut.

Kata kunci: *garnet, metapelite, spessartine, grossular, almandine, pirope, eclogite dan kimberlite*

ABSTRACT

Garnet bearing metamorphic rocks of the Meratus Complex, South Kalimantan show two different characters. The first is blueschist metapelite, associated with other greenschist - epidote amphibolite facies rocks which suffered retrogression from high to low pressure influence. They contain fine-grain garnet (Ø ~ 0.145 mm) in their assemblage. Garnet presents as spessartine and grossular-almandine with composition of $Alm_{9.1-27.3}Prp_{0.9-2.5}Grs_{14.8-20.6}Adr_{0-4.5}Sps_{51.9-70.5}$ *and* $Alm_{27.4-45.7}Prp_{0.8-2.8}Grs_{27.3-52.7}Adr_{1.9-3.4}Sps_{15.5-35.8}$ *respectively. Rocks are exposed in the South-West part of the complex, precisely in the vicinity of Aranio-Pelaihari, adjacent to the diamond placer mines at Cempaka village, south of Banjarbaru. The second is garnet-granulite (high pressure granulite) which are associated and windowed inside the Manjam ophiolites. These rocks are located on the eastern slope of the complex and is further away from diamond placer mining locations. Its garnet is pyrope-almandine (Ø ~ 3.06 mm) with composition of*

$Alm_{39.5-42}Prp_{28.8-46.3}Grs_{7.7-31}Adr_{0-8.7}Sps_{1-2}$. In some samples, its core has more pyrope molecule instead of the almandine, while in the rim, the pirope molecule are always slightly smaller. Some samples contain Cr molecule of some 0.002 – 0.007. Pyrope is Mg-rich garnet formed at high pressure environment. Generally its existence are in eclogite and in kimberlite, both which enables contain diamonds. Pyrope is tracer mineral for high pressure rock formation, and knorringite is typical species in kimberlite. This study represents an initial approach done in such tracing.

Keywords: *garnet, metapelite, spessartine, grossular, almandine, pirope, eclogite and kimberlite*

1. INTRODUCTION

Garnet is particular characteristic of metamorphic rocks but also found in some igneous and as detrital grain in sedimentary rocks. This group is subdivided into two series: pyralspite (pyrope-almandine-spessartite) and ugrandite (uvarovite, grossularite, andradite). The unit cell of garnet contains eight $X_3Y_2Z_3O_{12}$ formula units. The structure contains alternating ZO_4 tetrahedra and YO_6 octahedra which share corner to form the three-dimensional network (Dear et al, 1992). The X site is usually uccupied by Fe^{2+}, Mg^{2+}, Mn^{2+} and Ca^{2+}, the Y site by Al^{3+}, Fe^{3+} and Cr^{3+}. Garnets are almost found in dodecahedral crystal habit and sometime trapezohedral.

From the composition of X and Y sites, garnets are subdivided into at least 6 common natural species and some 16 other experimental garnets. Almandine ($Fe_3Al_2Si_3O_{12}$) is the most common species in the garnet group. Almandine generally contains appreciable amount of both the pyrope and spessartine molecules and may have amounts of grossular molecule. Pyrope ($Mg_3Al_2Si_3O_{12}$) is Mg rich garnet which is sometime the Y site substituted with Cr^{3+} to form Knorringite. Pyrope is one of the most diagnostic tracer garnet used in prospecting for kimberlite. Spessartine ($Mn_3Al_2Si_3O_{12}$) is Mn rich garnet while grossular ($Ca_3Al_2Si_3O_{12}$) is CaAl garnet which if the Y side is occupied by Fe ussualy named andradite. Uvarovite ($Ca_3Cr_2Si_3O_{12}$)is member of ugrandite which is rich Cr molecule in the Y side. Hardness of this group is about 6.5 – 7.5 in Mohs scale and usually used as abrasive and the beautiful one as gemstone(Dear et al, 1992).

Like many other diamond placer localities in Kalimantan, Cempaka mining site is diamond placer site located in the Meratus Complex. It is situated in the flat topography of the Quaternary alluvial deposits south of Martapuera. Debate on the source rocks of diamond have been highlighted during some decades which still put down some controversions. Kimberlite pipe or eclogite, two possible rocks which may supply diamond have not been indicated yet in adjacent regions. The Pamali breccias located near by the Riam Kanan reservoir is supposed to be boulder conglomeratic source of the (of course) redepositing diamond (Bergman et al., 1987) while later they coincide minette dykes in the Central Kalimantan diamondiferous region. Although non-diamondiferous, the primitive high Mg#, elevated Ni and Cr led them to suggest that as yet undiscovered related alkaline intrusives such as lamproite could be the local source of the diamonds (Bergman et al. 1988).

Occurences of alluvial diamonds located within relatively young geological terrains without an obvious primary source are normally found over the world (Smith et al, 2009). Some efforts have been done for approaching to find the diamond source. This study will concern on variety of garnet contained by metamorphic rocks in SE Kalimantan which might be correlated to the occurrence of the primary source of the diamond source, as kimberlite and eclogite contain garnet.

2. GEOLOGY OF THE MERATUS COMPLEX

Meratus Complex is situated in the southeast Kalimantan Island (formerly Borneo), Indonesia (figure 1.1). It is ridges and mountainous region extends NNE-SSW trend, started from southern end of Pelaihari Peninsula to the south to near Balikpapan to the north. The complex was Jurassic Cretaceous subduction zone which has [illegible] been correlated to the Luk Ulo Melange Complex in Central Java, and currently extended to contemporaneous age complex exposed in Bantimala, South Sulawesi (formerly Celebes) Asikin, 1973; Katili, 1978; Sikumbang, 1986, Parkinson et al, 1998, Wakita et al, 1998). Besides that it is interesting since its occurrences of oil basin and diamond finding that has been an enigma of its sources.

Rock assemblage in the Meratus Complex can be subdivided into the crystalline basements which consist of plutonic, metamorphic and ophiolite rocks and sedimentary overlies of Late cretaceous volcanic and turbidites of Manunggul and Alino Formation and Tertiary shelf sediments.

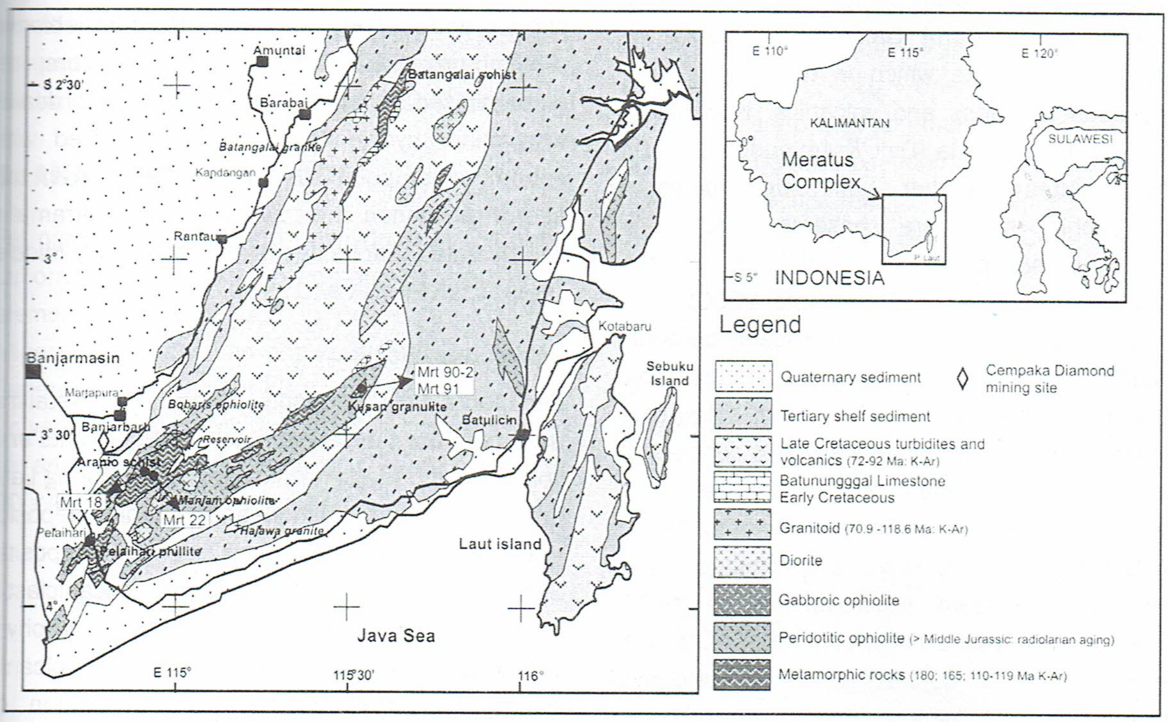

Figure 1. Geologic map of the Meratus area, Southeast Kalimantan compiled and modified from Heryanto and Sanyoto, 2007; Rustandi et al, 1995; Heryanto et al, 2007; Sikumbang and Heryanto, 1994, K-Ar age data taken from Wakita et al, 1998

Crystalline basements

Paleozoic and Mesozoic geology of the Meratus Complex are dominated by crystalline rocks. Outcrops of Late Paleozoic up to Early Mesozoic are plutonic rocks. The Late Carboniferous-Early Permian Lumo, S-type granite of syn-COLLG granite, located at east of Buntok City in northwestern part the Meratus complex is the oldest rock outcrop of the complex. K-Ar ages are 319 ± 1,7 Ma and 260 ± 1,66 Ma (Dirk & Aminuddin, 2000). To the east of this granite there is Late Jurassic Purui Dalam plagiogranite or oceanic trondhjemite which is overlaid by Late Cretaceous turbidites and volcanics. K-Ar dating age is yielded 155 Ma (Dirk & Aminuddin, 2000). Both granites together with high pressure metamorphic rock are basement to Late Cretaceous sediments and volcanics in the complex (Sikumbang, 1986; Heryanto, 2000).

Early – Middle Jurassic and probably continue to Early Cretaceous high pressure metamorphic rocks are another crystalline basement below Late Cretaceous turbidites and volcanics. It consists of Hauran schist, Pelaihari phillites to the south (Sikumbang, 1986; Sikumbang & Heryanto, 1994) and Batangalai schist, Kusan amphibolites to the north and northeast (Rustandi et al, 1995; Heryanto & Sanyoto, 1994; Heryanto et al, 2007). The Hauran schist consists of muscovite-quartz schist, micaceous meta-quartzite, biotite-epidote schist, peidmontite schist, glaucophane schist, and barroisite-epidote schist. Kyanite bearing quartz schist were also found in the Hauran schist, close to Martapuera. Its mineralogy exhibits greenschist up to epidote amphibolite facies (Parkinson et al, 1998). Mica in schists near Aranio, north of Riam Kanan River shows K-Ar age of 180 ± 9 Ma and 165 ± 8 Ma while south of the Riam Kanan River yielded ages of 119 ± 6 and 110 ± 6 Ma(Wakita et al, 1998).The data consistent with the previous K-Ar dating done by Sikumbang & Heryanto, 1994 that yielded 119 and 108 Ma.

Huge Alkali-Calk Alkali granitoid of Volcanic Arc Granite and gabbro are found in the main body of the Meratus Complex. They consist of trondhjemite, granite, tonalite, diorite and subordinate gabbro. They are cropped out at Riam Andungan, Hajawa in eastern flank and at Batangalai to the centre of the complex. K-Ar ages are 118. 61 ± 1.45 Ma and 101 ± 2.6 Ma while Hajawa granitoid are 70.96 ± 0.49 Ma up to 87.184 ± 1.04 Ma (Dirk & Aminuddin, 2000) . With exception to Hajawa granite, the plutons were basement for the Late Cretaceous sediments and volcanics.

Ophiolite out crops in the Meratus Complex represent oceanic plate stratigraphy. It is found in incomplete slices that consist of ultramafic rocks, pillow basalt, limestone, chert, silicious shale, shale and sandstone as tectonic blocks (Sikumbang, 1982). The ultramafic rocks comprise serpentinized peridotite, harzburgite and dunite with minor pyroxenite and are associated with gabbro and amphibolite (Suparka, 1988). From the age of radiolarian chert overlaid on the ultramafic can be dated that its age is older than early Middle Jurassic (Wakita, et al, 1998).

Sedimentary Rocks

Sediments unconformably overlie the crystalline basement are the Late Cretaceous Sediments and volcanics and the Cenozoic sediments. During Late Cretaceous time, traction and turbidite deposits interfingered with volcanics derived deposits. Shallow intrusive, lava and volcaniclastic deposition of dolerite, basalt and porphyry andesite, andesitic lava intercalated with volcanic breccias occurred together with deposition of clastic limestone, polymict conglomerates and turbidite sediments (Sikumbang, 1986). It construct formations of Batununggal, Paniungan, Pudak, Kintap, Keramaian, Manunggul and Alino which are group as Manunggul and Alino group to the south (Yuwono et al, 1988; Sikumbang & Heryanto, 1999) and are popularized as Heruyan and Pitap groups to the north (Sikumbang, 1986; Heryanto & Sanyoto, 2007; Heryanto et al, 2007). Geochemistry analysis and K-Ar dating of some volcanic rocks of Alino and Manunggul Formations exhibit orogenic Calc Alkali rocks of 92 – 72 Ma (Yuwono et al, 1988).

Pre Tertiary rocks in Meratus Complex are unconformably overlain by Tertiary System shelf sediments. It comprises Tanjung, Berai, Warukin and Dahor Formations. The oldest formation

Tanjung was deposited in Eocene, followed by Berai and Pamaluan, Warukin and Dahor respectively up to Pleistocene. To the east Berai Formation interfingers with Pamaluan Formation. Sediments deposited during Tertiary show alternating of various siliciclastic rocks that sometime inserted by lignite and coal with carbonate clastic and bioclastic. They deposited in paralic up to neritic marine environment. Quartz component specifically constructs Tanjung, Warukin and Dahor Formations that usually also together with lignite or coal layer (Sikumbang & Heryanto, 1994; Heryanto& Sanyoto, 1994; Rustandi et al, 1995, Heryanto et al, 2007).

3. ANALITICAL METHODS

Petrography analysis had been done at Petrology Laboratory ITB while trace elements and rare earth elements were analyzed in Acme Lab Canada. Mineral chemistry was analyzed by using a JEOL Superprobe JXA-8900R electron microprobe at the University of Kiel. The Acceleration potential used for analyses was 15-20 kV for a beam current of 20 nA. The raw data were corrected by using the CITZAF method (Amstrong, 1995) and some others by using the Minpet for Windows Version 2.02 application by Richard, L.R., 1988.

4. RESULTS

Petrography of garnet bearing metamorphic rocks

Two different characters are displayed by garnet bearing metamorphic rocks in Meratus Complex. The first is an assemblage of blueschist, greenschists and quartzites. Those rocks are outcropped in Apukan and Riam Kanan Rivers east of Banjarbaru, South Kalimantan. Blueschist contains Qz + Ms + Ep + Opq + (Cs-Gl) ± Grt ± Cal ± Zo ± Bt ± Ab and commonly the glaucophane-crossite bodys have pseudomorphed to be Chl + Ep + Act. Greenschist has Qz + Pl + Ep + Chl + Act + Ttn ± Ttn ± Ms ± Bt ± Bt ± Zo ± Cal ± Opq ±Grt while quartzite has variety of Chl + Ms; Grt + Ms and Grt + Chl quartzites. They contain more than 80 % bulk quartz and are composed of Qz + Opq + Ms ± Pl + Bt + Ep + Opq + Ttn + Grt. Usually its appearances are schistoses, porphyroblastic and poikiloblastic textures.

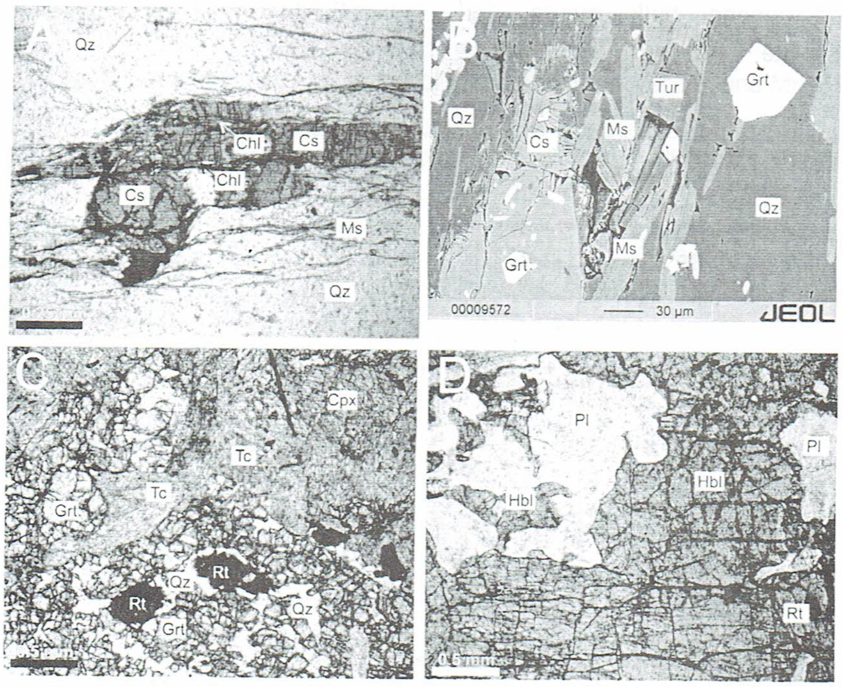

Figure 2. Crossite bearing quartz rich metapelite (quartzite) that is embedded among quartz and muscovite (A). Micro inclusion of garnet sometime exist inside crossite but usually spessartine is embedded inside quartz (B). Grt granulite contains grt, Tc, Rt,Qz and CPx (C) and Hbl and Pl (D).

The second garnet bearing metamorphic rocks are granulites which are out-cropped at Kusan River west of Batulicin. They are located among or windowed inside ultramafic rocks. Its relation to the ultramafic rocks is tectonic contact. The assemblage are tipical high pressure granulite which consist of Grt + CPx + Hbl + Zo ± KFs ± Tc ± Zo ± Qz ± Rt ± Ilm ± Pl. The assemblage are tipical high pressure granulite which suffered about 9 - 12 KBar and temperature 675 - 900°C during regional metamorphism process.

Garnet in metamorphic rocks

Garnet contained in sample number Mrt 13 and Mrt 18 that was taken from Apukan River display high concentration ratio of XSps and X Grs. Garnet of Mrt 13 has formula as $Alm_{9.6-30.9}Prp_{0.3-1.1}Grs_{24.8-36.2}Adr_{0-2.6}Sps_{40.9-62.9}$. Its core has higher Spessartine than its rim while its almandine content is higher in the rim. The garnet is 0.14 mm in diameter. Garnet of Mrt 18 has no regular pattern. Its XSps is high up to 0.7 which makes other contents are slightly low even in some part has no pyrope content. Garnet of Mrt 18 present as inclusion inside crossite-glaucophane and as matrix embedded among bulk quartz and subordinate muscovite of quartz rich schist. Garnet inclusion is about < 0.05 mm while the matrix are < 0.11 mm big. The composistion is $Alm_{8.7-19.5}Prp_{0.9-1.8}Grs_{15.1-20.8}Adr_{0.2-5}Sps_{57.5-69.9}$.

Unlike previous garnets, garnet contained in garnet-granulite of Kusan Region display different character. It appears as pyrope-almandine garnet with composition of $Alm_{39.5-41.9}Prp_{34.4-40.8}Grs_{15.5-22.2}Adr_{0-2.6}Sps_{1.4-1.9}$. Their cores have similar almandine pyrope content and alternating or substitute each other but in its rim almandine tend to be higher than its pyrope (figure 3 below). Some of garnets crystallize in a bit big size up to 4 mm. Many inclusions found inside of these garnets consists of hornblende, augite, zoisite, rutile and quartz. Other mineral assemblage beside garnet in sample number Mrt 91 are:

Assemblage 1:

Tc + Grt + CPx + Hbl + Zo + Rt + Qz

Assemblage 2:

KFs + Grt + CPx + Hbl + Rt + Pl

Assemblage 3:

KFs + Grt + CPx + Hbl + Ilm + Pl

Those assemblages represent garnets generated in high pressure high temperature environment which suffered pressure of about 9 - 12 KBar and temperature 675 – 900°C.

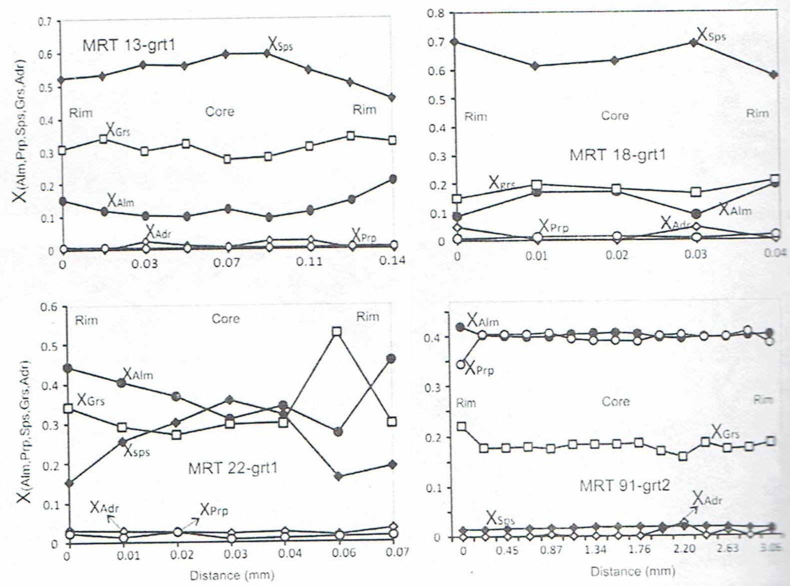

Figure 3. Kinds of garnet found in garnet bearing metamorphic rocks in Meratus Complex. Sample [illegible] 18 contain spessartine with sub ordinate grossularite while Mrt 22 contains almandine and [illegible] Mrt-91 is garnet granulite that contains pyrope and almandine in almost similar amount, even [illegible] higher amount of pyrope content.

Tabel 1a. Mineral chemistry of Garnet of sample number Mrt 13; Mrt 22

Sample	Mrt 13 grt-1									Mrt 22 grt-1						
Expl.	rim				core				rim	rim			core			rim
SiO_2	37.65	37.49	37.12	37.14	37.05	36.81	36.91	37.66	38.08	39.31	38.11	37.16	38.1	37.99	34.97	38
TiO_2	0.201	0.229	0.196	0.379	0.284	0.279	0.295	0.346	0.144	0.181	0.173	0.083	0.243	0	13.54	0.158
Al_2O_3	21.38	21	20.86	21.18	21.13	21.02	20.84	21.09	21.35	21.45	21.35	20.97	21.39	21.31	14.23	21.3
FeO	6.983	5.443	4.679	4.546	5.467	4.276	5.155	6.68	9.3	19.399	17.794	16.103	13.775	15.077	11.552	20.264
Fe_2O_3	0.275	0.052	0.856	0.404	0.171	0.86	0.862	0	0	1.134	1.04	0.942	0.805	0.882	0.675	1.185
MnO	23.42	23.73	24.9	24.8	26.17	26.02	23.92	22.59	20.24	6.71	11.13	13.09	15.68	14	6.83	8.39
MgO	0.127	0.117	0.104	0.069	0.132	0.096	0.102	0.118	0.147	0.587	0.363	0.677	0.217	0.283	0.341	0.43
CaO	11.21	12.05	11.37	11.75	9.71	10.58	11.65	12.07	11.43	12.84	11.11	10.26	11.17	11.23	17.99	11.53
Total	101.246	100.111	100.085	100.268	100.114	99.941	99.734	100.554	100.691	101.61	101.07	99.285	101.38	100.77	100.13	101.26
TSi	2.98	2.994	2.975	2.966	2.975	2.959	2.967	2.995	3.025	3.08	3.021	2.997	3.013	3.019	2.865	3.006
TAl	0.02	0.006	0.025	0.034	0.025	0.041	0.033	0.005	0	0	0	0.003	0	0	0.135	0
Sum_T	3	3	3	3	3	3	3	3	3.025	3.08	3.021	3	3.013	3.019	3	3.006
Al^{VI}	1.973	1.969	1.944	1.958	1.974	1.949	1.939	1.971	1.997	1.979	1.993	1.989	1.992	1.994	1.238	1.984
Fe^{3+}	0.016	0.003	0.052	0.024	0.01	0.052	0.052	0	0	0.067	0.062	0.057	0.048	0.053	0.042	0.07
Ti	0.012	0.014	0.012	0.023	0.017	0.017	0.018	0.021	0.009	0.011	0.01	0.005	0.014	0	0.834	0.009
Sum_A	2.002	1.986	2.007	2.005	2.001	2.018	2.009	1.991	2.006	2.057	2.065	2.051	2.054	2.047	2.114	2.064
Fe^{2+}	0.462	0.364	0.314	0.304	0.367	0.287	0.347	0.444	0.618	1.271	1.18	1.086	0.911	1.002	0.791	1.34
Mg	0.015	0.014	0.012	0.008	0.016	0.012	0.012	0.014	0.017	0.069	0.043	0.081	0.026	0.034	0.042	0.051
Mn	1.57	1.605	1.69	1.678	1.78	1.772	1.629	1.522	1.362	0.445	0.747	0.894	1.05	0.942	0.474	0.562
Ca	0.951	1.031	0.976	1.005	0.836	0.911	1.003	1.029	0.973	1.078	0.944	0.887	0.946	0.956	1.579	0.977
Sum_B	2.998	3.014	2.993	2.995	2.999	2.982	2.991	3.009	2.97	2.863	2.913	2.949	2.933	2.934	2.886	2.93
Sum cation	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Alm	15.418	12.062	10.48	10.138	12.244	9.641	11.587	14.768	20.803	44.4	40.489	36.838	31.058	34.15	27.423	45.742
And	0.817	0.159	2.573	1.212	0.515	2.578	2.594	0	0	3.249	3.002	2.783	2.331	2.573	1.968	3.414
Gross	30.892	34.054	30.051	32.359	27.348	27.981	30.955	34.186	32.756	34.402	29.386	27.288	29.934	30.016	52.745	29.932
Pyrope	0.5	0.462	0.415	0.274	0.527	0.386	0.409	0.465	0.586	2.395	1.472	2.761	0.872	1.143	1.443	1.73
Spess	52.373	53.263	56.481	56.016	59.366	59.414	54.456	50.581	45.855	15.555	25.651	30.33	35.806	32.118	16.421	19.182
XCagnt	0.317	0.342	0.326	0.336	0.279	0.305	0.335	0.342	0.328	0.377	0.324	0.301	0.323	0.326	0.547	0.333
XFegnt	0.154	0.121	0.105	0.102	0.122	0.096	0.116	0.148	0.208	0.444	0.405	0.368	0.311	0.342	0.274	0.457
XMggnt	0.005	0.005	0.004	0.003	0.005	0.004	0.004	0.005	0.006	0.024	0.015	0.027	0.009	0.012	0.015	0.017
Fe_Mggnt	30.8	26	26.167	38	22.938	23.917	28.917	31.714	36.353	18.42	27.442	13.407	35.038	29.471	18.833	26.275

Tabel 1b. Mineral chemistry of Garnet of sample number Mrt 18; and Mrt 91

Sample	Mrt 18 grt-1					Mrt 91 grt 2															
Expl.	rim		core		rim	rim							core							rim	
SiO_2	36.78	37.7	37.61	37.07	37.52	40.50	40.24	40.56	40.46	40.17	40.43	40.48	40.35	40.52	40.02	40.03	40.17	39.90	40.14	39.93	40.17
TiO_2	0.178	0.134	0.095	0.26	0.182	0.02	0.12	0.04	0.03	0.04	0.05	0.19	0.09	0.12	0.08	0.10	0.00	0.15	0.16	0.05	0.08
Al_2O_3	19.96	20.22	20.25	20.03	20.44	22.59	22.41	22.40	22.45	22.45	22.28	22.44	22.32	22.44	22.26	22.28	22.37	22.10	22.36	22.18	22.24
FeO	3.891	7.763	7.773	4.003	8.791	20.25	19.31	19.15	19.02	19.28	19.43	19.31	19.55	19.44	19.47	19.81	18.68	19.41	19.22	19.58	19.58
Fe_2O_3	1.654	0.152	0.074	1.508	0.122	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.46	0.93	0.00	0.39	0.00	0.38	0.00
MnO	30.56	27.42	28.04	30.35	25.6	0.65	0.66	0.72	0.77	0.81	0.82	0.90	0.89	0.91	0.89	0.88	0.87	0.88	0.79	0.78	0.65
MgO	0.246	0.346	0.404	0.23	0.456	9.31	10.87	10.85	10.83	10.97	10.61	10.44	10.55	10.46	10.78	10.84	10.41	10.71	11.01	10.32	10.53
CaO	6.98	7.13	6.44	7.41	7.48	8.37	6.66	6.68	6.74	6.72	6.91	6.88	6.95	7.00	6.90	6.92	6.84	6.94	6.59	7.38	6.73
Total	100.25	100.87	100.69	100.86	100.59	101.7	100.3	100.4	100.3	100.6	100.5	100.6	100.7	100.9	100.9	101.8	99.3	100.5	100.3	100.6	100.0
TSi	2.983	3.028	3.029	2.986	3.015	3.02	3.02	3.04	3.03	3.00	3.03	3.03	3.02	3.03	3.00	2.99	3.04	3.00	3.01	3.00	3.02
TAl	0.017	0	0	0.014	0	0	0	0	0	0	0	0	0	0	0.002	0.013	0	0	0	0	0
Sum_T	3	3.028	3.029	3	3.015	3.02	3.02	3.04	3.03	3.00	3.03	3.03	3.02	3.03	3.00	3.00	3.04	3.00	3.01	3.00	3.02
Al^{VI}	1.889	1.913	1.921	1.886	1.934	1.98	1.98	1.97	1.98	1.98	1.96	1.98	1.97	1.97	1.96	1.94	1.99	1.96	1.97	1.96	1.97
Fe^{3+}	0.101	0.009	0.005	0.091	0.007	0	0	0	0	0.006	0	0	0	0	0.026	0.052	0	0.022	0	0.021	0
Ti	0.011	0.008	0.006	0.016	0.011	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.00	0.01
Sum_A	2.001	1.93	1.931	1.993	1.953	1.98	1.98	1.98	1.98	1.99	1.97	1.99	1.97	1.98	1.99	2.00	1.99	1.99	1.98	1.99	1.98
Fe^{2+}	0.264	0.521	0.524	0.27	0.591	1.26	1.21	1.20	1.19	1.20	1.22	1.21	1.22	1.21	1.19	1.18	1.18	1.20	1.20	1.21	1.23
Mg	0.03	0.041	0.049	0.028	0.055	1.03	1.21	1.21	1.21	1.22	1.18	1.17	1.18	1.16	1.20	1.21	1.17	1.20	1.23	1.16	1.18
Mn	2.099	1.865	1.913	2.071	1.743	0.04	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.04
Ca	0.606	0.614	0.556	0.639	0.644	0.67	0.54	0.54	0.54	0.54	0.55	0.55	0.56	0.56	0.55	0.55	0.56	0.56	0.53	0.59	0.54
Sum_B	2.999	3.042	3.04	3.007	3.032	3.00	3.00	2.99	2.99	3.01	3.01	2.98	3.01	3.00	3.01	3.00	2.97	3.01	3.01	3.01	3.00
Sum cation	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Alm	8.799	17.142	17.219	8.965	19.485	41.993	40.322	40.084	39.842	39.82	40.453	40.53	40.591	40.525	39.689	39.482	39.844	39.761	39.971	40.186	41.108
And	5.046	0.477	0.234	4.588	0.376	0	0	0	0	0.32	0	0	0	0	1.30	2.62	0	1.11	0	1.066	0
Gross	15.175	19.694	18.043	16.676	20.865	22.24	17.82	17.91	18.09	17.56	18.43	18.50	18.49	18.70	17.11	15.83	18.69	17.44	17.56	18.68	17.84
Pyrope	0.992	1.362	1.595	0.918	1.802	34.42	40.46	40.48	40.44	40.60	39.38	39.06	39.05	38.87	40.02	40.22	39.58	39.83	40.82	38.42	39.41
Spess	69.988	61.325	62.91	68.852	57.472	1.36	1.40	1.52	1.63	1.70	1.74	1.91	1.88	1.91	1.88	1.85	1.88	1.86	1.66	1.65	1.38
XCagnt	0.202	0.202	0.183	0.212	0.212	0.22	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.18	0.18	0.19	0.19	0.18	0.20	0.18
XFegnt	0.088	0.171	0.172	0.09	0.195	0.42	0.40	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.41
XMggnt	0.01	0.013	0.016	0.009	0.018	0.34	0.41	0.41	0.40	0.41	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.41	0.38	0.39
Fe_Mggnt	8.8	12.707	10.694	9.643	10.745	1.22	1.00	0.99	0.99	0.98	1.03	1.04	1.04	1.04	0.99	0.98	1.01	1.00	0.98	1.05	1.04

Table 1c. Mineral chemistry of Garnet of sample number Mrt 91(continued)

Sample	Mrt 91			
Mineral	grt 1	grt 3	grt 4	grt 5
SiO_2	39.55	39.95	39.95	39.65
TiO_2	0.072	0.052	0.074	0.108
Al_2O_3	21.86	22.18	22.12	22.05
Cr_2O_3	0.069	0.041	0.072	0.122
FeO	20.01	19.85	20.02	18.95
Fe_2O_3	0.358	0	0.046	0
MnO	0.522	0.596	0.641	0.585
MgO	9.47	9.56	9.66	8.59
CaO	8.08	8.05	7.87	9.9
Total	99.991	100.279	100.453	99.955
TSi	3.003	3.012	3.009	3.005
Sum_T	3.003	3.012	3.009	3.005
AlVI	1.955	1.969	1.962	1.968
Fe^3	0.02	0	0.003	0
Ti	0.004	0.003	0.004	0.006
Cr	0.004	0.002	0.004	0.007
Sum_A	1.984	1.974	1.973	1.982
Fe^2	1.25	1.251	1.258	1.201
Mg	1.072	1.074	1.084	0.971
Mn	0.034	0.038	0.041	0.038
Ca	0.657	0.65	0.635	0.804
Sum_B	3.013	3.014	3.019	3.013
Sum_cat	8	8	8	8
Alm	41.492	41.52	41.683	39.863
And	1.032	0	0.132	0
Gross	20.576	21.448	20.687	26.312
Pyrope	35.577	35.645	35.927	32.211
Spess	1.114	1.263	1.354	1.246
XCagnt	0.218	0.216	0.21	0.267
XFegnt	0.415	0.415	0.417	0.398
XMggnt	0.356	0.356	0.359	0.322
Fe_Mggnt	1.166	1.165	1.161	1.237

Origin of garnet containing rocks and its tectonic environment

Garnet containing rocks are subdivided to be two groups. Spessartine, spessartine-grossular and grossular almandine containing rocks of Mrt 13, Mrt 18 and Mrt 22 are low grade metamorphic rocks of shelf sediment protolith. It was blueschist of high pressure rock and retrograded to be greenschist with chlorite-epidote-actinolite assemblage (figure 2a). That imply subduction related metamorphism influence and then had been followed by post subduction metamorphism.

The second group is garnet granulite. Garnet granulite of Mrt 90-2 show REE diagram pattern of Continental Flood Basalt type or Active Continental Margin type which displays about 20 time REE enrichment. Another garnet granulite of Mrt 91 displays a normal MORB like pattern (figure 4). It was a NMORB that was subducted in an active continental margin of Sundaland under high pressure condition and then followed by emplaced in situation of a condition which enables it to suffer high pressure high temperature metamorphism: 9 - 12 KBar and temperature 675 - 900°C. It supposed occurred when tectonic environment changed from subduction toward collision. The rock assemblages of Active Continental Margin and MORB protolith support an idea of metamorphism in Active Continental Margin.

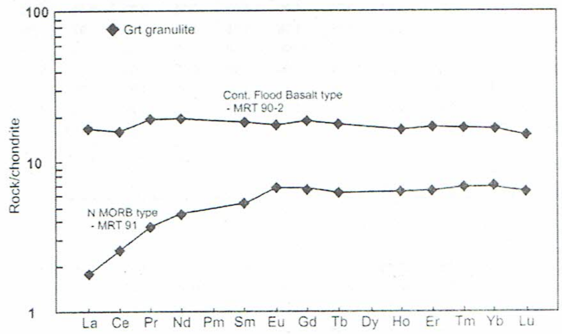

Figure 4. REE diagram of garnet granulite taken from Kusan area, South Kalimantan. Its protolith show Normal MORB like pattern and Continental Flood Basalt like type. Normalizing value based on Sun And Mc Donough, 1989.

5. DISCUSSION

Diamond found in west, central, east and south of Kalimantan Island (Smith et al, 2009). The Cempaka alluvial diamond mining site is the most popular since the largest diamond ever found in Kalimantan: 166 carat that was named as Trisakti diamond. Smith et al, 2009 indicates that Kalimantan diamond has olivin, ortho pyroxene, rutile, kyanite, chromite, clino pyroxene, garnet inclusions. It characterize the occurrence of peridotitic and eclogitic paragenesis of source rock, Themobarometry of 930 to 1250°C; > 4.2 Gpa and Archean Re-Os sulphite inclusion which was extensive re-working of diamond from multiple primary sources via a formerly buried sediment of palaeo-container.

Although pyrope almandine garnet of the garnet granulite Mrt 91 from Meratus Complex has molecule Cr of some 0.002-0.007 (table 1c), but it is not fit with chemistry of garnet found as inclusion in Kalimantan diamond which indicates knorringite species. In the other hand REE diagram of garnet granulite Mrt 90-2 resemble with Continental Flood Basalt or Active Continental Margin Calk Alkali. It open an argument that there is still enable another possibility to correlate it with some possibility of mantle source come during ancient continental rifting which supposedly related with some opinion of the occurrence of Paternoster continental platform or the diamonds was just xenocrystic /detrital minerals contained by later container rocks of further geological events.

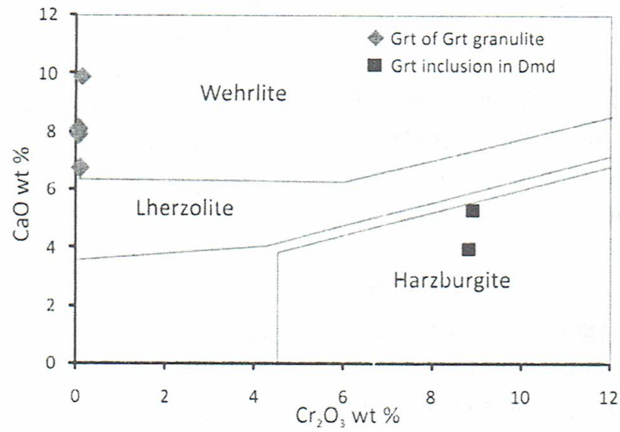

Figure 5. Plot of Cr_2O_3 content of garnet taken from garnet granulite (Mrt-91) of current study and from inclusion inside diamond done by Smith et al, 2009. Field of harzburgite, lherzolite and wehrlite from Sobolew, 1974 as cited in Smith et al, 2009.

6. CONCLUSION

Garnet found in the Meratus Complex varies from spessartine, spessartine grossular, grossular almandine and pyrope almandine garnet. They are contained inside crossite/glaucophane bearing and other quart rich schist or garnet granulites. Mg rich garnet only present in garnet granulite. Some pyrope- almandine garnet contains molecule Cr but in a very poor amount which does not indicate knorringite character and its Cr2O3 content does not fit with its garnet inclusion composition inside diamond found in Cempaka placer mining site.

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Tema 6

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Tema 7

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Tema 8

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