Mineral Identification on Sediments of Pergau Dam Intakes

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Mineral Identification on Sediments of Pergau Dam Intakes

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Abstract. Pergau Dam as the largest hydroelectrical generation station in Peninsular Malaysia within a mountainous region; is supplied by many flowing river as its intakes. Previous researches within Pergau area mostly focused on biodiversity while this research was to carry out baseline investigation on the minerals present in the intakes sediment of Pergau Dam through surface sampling. Through stereoscopic observation, assemblages of quartz, plagioclase, feldspar, muscovite,and biotite minerals in sediments implies a granitoid source rock. By computing X-ray Fluorescence (XRF) chemical compositional data of sediments into chemical weathering indices, overall weathering condition of Pergau Dam intakes area are unweathered to low chemical weathering intensity. Through Combination of XRF data and X-ray Diffraction (XRD) patterns of mineral phases, detailed mineralogy of plagioclases, K-feldspars, sericites, chlorites and accessory minerals such as epidotes, zircon and monazite were identified. Mineral assemblage and Streckeisen Diagram plots indicate the granitoid source rocks of the sediments are quartz monzorite and quartz monzodiorite.

1. Introduction

Mineral is the basic unit of rocks. Weathering and erosion separate a mineral from its source rock; it is then transported away by fluid medium and deposited as sediments [1]. Minerals are distinctive by its physical and chemical characteristics thus a mineral conventionally can be identified by direct observation of with the aid of tools such as hand-lenses or stereoscope. Progressively, a mineral phase due to its crystal structure can be identified through its diffraction pattern under X-ray diffraction (XRD) [2] and its chemical constituents can be identified by employing X-Ray Fluorescence (XRF) method [3]. Combining data from both X-ray methods can confirm the mineral identification.

Pergau Dam is the largest hydroelectrical generation station in Peninsular Malaysia, located within a mountainous region with abundant flowing water as its intake sources. Biological and geological studies had been carried out around Pergau area [4] to study its natural diversity, or occasionally act as one of the sampling point in regional study [5] yet no detailed sediment study of the Pergau Dam specifically on its intakes sediment data had been carried out. Thus this research was performed to fill research gap in mineral identification on sediments of Pergau Dam Intakes in order to identify the source rocks and the weathering conditions.

2. Materials and Methods

2.1 Sample Collection, Preparation and Stereoscopic Observation

Seven surface sediment samples were collected manually by using plastic scoop with depth not more than 10cm from seven localities of the Pergau area then named on which intake they were collected, as shown in Table 1 and Figure 1.

Table 1. The Seven Sediment Sampling Points.

Sampling Point	Coordinate		
	Latitude	Longitude	Elevation
Terang	5.443667	101.8018	596
Suda	5.477067	101.7988	673
Renyok 1	5.550028	101.7675	686
Renyok 2	5.526944	101.7703	673
Renyok 3	5.519306	101.7822	663
Long 1	5.59955	101.7295	823
Long 2	5.586617	101.7396	734

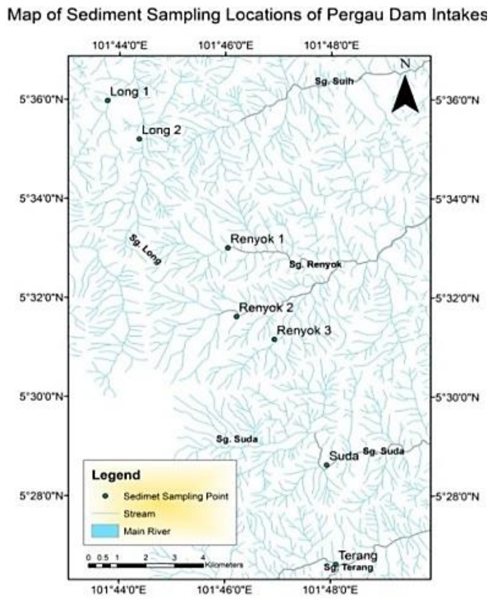

Figure 1. The Sediment Sampling Locations.

Samples were collected at the upstream of the artificial dam structures to avoid collecting minerals that are possible eroded from the artificial building. Prior to stereoscopic observation, samples were dried in an oven at 100 ºC for 24 hours. To carry out XRF and XRD analysis, the sediment samples were then sieved on a Vibratory Sieve Shaker AS 200 at magnitude 90 for 15 minutes to obtain sediment with particle size less than 63 μm.

2.2 X-Ray Fluorescence Method (XRF)

XRF analysis was performed using Energy Dispersion XRF (EDXRF) which outfitted with a rhodium (Rh) x-ray tube operates at a voltage of 40 kV, and a current of 30 μA for integration times ranging from 60-600 sec. A filter composed of 0.001” Ti and 0.012” Al was used to optimize the excitation conditions for elements ranging from titanium to silver (Ti-Ag). A collimated elliptical x-ray beam, ~

10 mm x 7 mm, was emitted at 53° onto the samples, which were positioned on an automated sample changer. The EDXRF spectra were collected using Bruker's software (S1PXRF 3.8).

2.3 X-Ray Diffraction Method
XRD analysis was performed using Bruker D2 Phaser diffractometer with voltage and current source of 40 kV and 40 mA, respectively. The diffractometer was equipped with Cu-Kα radiation ($\lambda = 0.154$ nm) and scanning was conducted at step size of 0.0340, with scanning range (2θ degree) of 10º - 90º. The output of the XRD analysis was diffraction pattern graph with peak's intensity versus 2θ degree. Chemical weathering indices were used to predict the mineral present prior to a mineral phase identification which was analysed using DIFFRAC EVA 3.2 software by comparing experimental XRD pattern obtained from sediment sample with theoretical XRD pattern from Crystallography Open Database (COD).

3. Results and Discussion

3.1 Stereoscopic Results
All localities from Terang Pump House to Long 1 were mainly constituted by felsic minerals such as quartz, feldspar and muscovite and some mafic mineral, biotite based on stereoscopic observation. The abundant mineral in Pergau sediments, quartz hard mineral ranging from transparent to translucent to opaque depending on the binding elements. It is the main constituent of felsic rock. Quartz is the Earth continental crust second most abundant minerals after feldspar [6]. Its ubiquities is due to its resistance towards all form of weathering as a result of the strong bonding of continuous silicon-oxygen tetrahedral framework. It is the most stable mineral in Goldich Stability Series of Resistance to Weathering [7].

Feldspar consist of K-feldspar and plagioclase feldspar, is another mineral abundant in the sediment samples of this region which is distinguishable from quartz by its thin parallel lines on cleavage face due to its crystal structure. Mica is the group name for muscovite and biotite. Both of them are ready to split into thin sheets at one perfect cleavage plane. To distinguish them, muscovite sheets are clear transparent and look mostly silvery or sometimes light yellow to light brown under sunlight whereas biotite sheets are usually of dark brown to black colour. Muscovite is a felsic mica while biotite is considered as a mafic mica.

Each sediment samples were observed by naked eye on site and also under stereoscope after drying to observe the minerals in higher details for a better mineral quantitative estimation as shown in Figure 2. To provide a detailed mineralogy, X-Ray methods: fluorescence (XRF) and diffraction (XRD) were used to identify the elements and oxides; and mineral phases respectively. The XRF data were used to infer the mineral present in the sediments which are also needed to cross-validate with the mineral found by XRD.

3.2 XRF Results
Based on the XRF data on Pergau Dam Intakes sediment as shown in Table 1, silica (SiO_2) ranges between 58.3 to 64wt% while alumina (Al_2O_3) ranges between 15.6 to 19.2wt%. Potassium oxide (K_2O) ranges between 11.8 to 15.5wt%. These three oxides made up the highest concentration in each of the sediment are the main constituents of quartz (SiO_2), potassium feldspar ($KAlSi_3O_8$) and muscovite ($(KF)_2(Al_2O_3)_3(SiO_2)_6(H_2O)$). Sodium oxide ($Na_2O$) and calcium oxide (CaO) meanwhile are the building components of plagioclase ($NaAlSi_3O_8$ to $CaAlSi_3O_8$).

Iron oxide (Fe_2O_3) and magnesium oxide (MgO) build up mafic mineral, biotite ($K(Mg,Fe)_3 AlSi_3$). Titanium oxide (TiO_2) represents titanite or sphene ($CaTi(SiO_4)O$). Zirconium oxide (ZrO_2) is the building material of zircon ($ZrSiO_4$) which is a typical primary accessory mineral in granitic rocks. The presences of phosphorus oxide (P_2O_5) together with calcium oxide (CaO) indicate the presence of apatite ($Ca_5(PO_4)_3(Cl,F,OH)$). The combinational presences of P_2O_5 and lanthanum oxide (La_2O_3) whereas indicate the presence of monazite ($LaPO_4$).

3.2.1 Weathering Indices.

With the data obtained from the XRF methods as shown in Table 2, weathering intensity of the source rock can be calculated by several weathering indices. There are several ratios such as $^{230}Th/^{232}Th$ and $^{234}U/^{238}U$ to calculate the source of minerals and elements [8]. Index of Compositional Variability (ICV) = [Fe_2O_3 + K_2O + Na_2O + CaO + MgO + MnO + TiO_2] / Al_2O_3 measures the abundances of aluminium oxide or alumina relative to other major cations of the rock [9]. ICVs of all the Pergau Dam intake sediments collected ranging from 1.24 to 1.07 were higher than 1 showing there are more non-clay minerals than the clay minerals in the source rocks or sedimentologically indicates a first cycle sediment deposit. Due to the dominance of feldspars in upper crust of earth, Chemical Index of Alteration (CIA) is used to evaluate the clay minerals formation from plagioclase and potassium feldspars. CIA= [Al_2O_3 / (Al_2O_3+ CaO*+Na_2O+K_2O)] ×100 where oxides are expressed in molar proportions. CaO* is the CaO in silicate fraction thus if the CaO is more than Na_2O, the reading computed into this formula should be the molar proportion of Na_2O as had been done to calculation all the Pergau Dam Intake sediments [10]. All the rock sources of sediments in the study area are considered as slightly weathered rock ranging from 50.22 to 56.97 as unaltered plagioclase and K-feldspar values approximately equal to 50 whereas complete conversion of these minerals into clay minerals is 100.

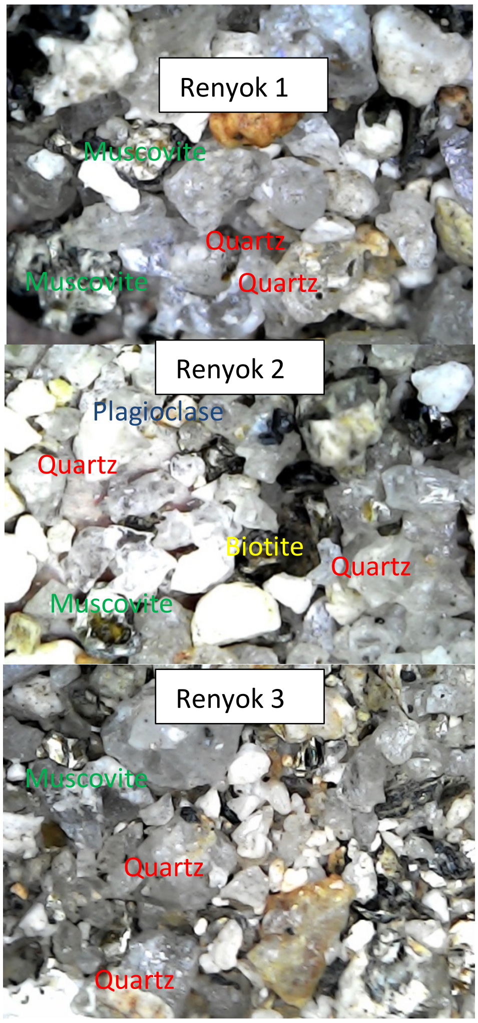

Figure 2. Sediments Minerals from Renyok 1, 2 and 3 Intakes under 80 Times Magnification.

Table 2. The Chemical Composition of Pergau Dam Intake Sediment in Wt% and The Values of Their Chemical Indices of Weathering

Pergau Dam Intake Sediment							
Oxides	**Long 1**	**Long 2**	**Renyok 1**	**Renyok 2**	**Renyok 3**	**Suda**	**Terang**
Al_2O_3	17	19.20	18.50	18.60	17.90	18.60	15.60
BaO	0.32	0.26	0.34	0.28	0.32	0.31	0.23
CaO	1.03	1.33	1.52	1.88	1.32	0.88	1.60
Fe_2O_3	2.80	4.00	2.14	3.80	2.37	2.48	2.39
K_2O	14.20	12.20	13.60	11.80	15.00	15.50	12.90
La_2O_3	0.11	0.11	0.11	0.11		0.11	
MgO	0.815	1.02	0.869	0.983	0.69	0.728	0.632
Na_2O	0.648	1.15	0.736	1.25	0.599	0.763	1.28
P_2O_5			0.243		0.173		
SiO_2	61.2	58.3	60.2	59.4	60.4	59.1	64
SO_3		0.161		0.107			
TiO_2	1.12	0.89	1.14	0.97	0.68	0.72	0.59
ZrO_2	0.24	0.61	0.15	0.29	0.11	0.18	0.19
SUM	99.49	99.23	99.56	99.47	99.56	99.38	99.41
ICV: Index of Compositional Variability	1.21	1.07	1.08	1.11	1.15	1.13	1.24
CIA: Chemical Index of Alteration	52.31	56.97	55.11	56.53	52.50	52.21	50.23
PIA: Plagioclase Index of Alteration	68.35	75.27	76.90	73.12	70.77	67.01	51.33
CIW: Chemical Index of Weathering	92.91	89.30	92.63	88.15	93.73	92.42	85.90
WIP: Weathering Index of Parker	11913.4	10694.76	11502.27	10442.08	12504.52	13025.89	11304.51
RR: Ruxton Ratio	3.60	3.04	3.25	3.19	3.37	3.18	4.10
IOL: Index of Laterization	24.44	28.47	28.47	25.53	27.38	25.13	26.29
VRI: Vogt's Residual Index	12.52	8.97	10.27	7.39	12.61	14.36	8.12
STI: Silica-Titania Index	93.82	95.56	94.20	95.04	96.33	96.27	96.39

As used to monitor the plagioclase weathering, Plagioclase Index of Alteration (PIA)=[(Al_2O_3 - K_2O)/ (Al_2O_3+ CaO*+Na_2O-K_2O)]×100, same CaO*correction in CIA was also used to evaluate the sediments [11], obtaining values between 51.33 to 76.89 suggest a slight to moderate plagioclase weathering in Pergau Dam intakes.

Since potassium (K) can be remobilized through leaching and residual accumulation, Harnois [12] measures chemical weathering intensity by Chemical Index of Weathering (CIW)= [Al_2O_3 / (Al_2O_3+ CaO*+Na_2O)] ×100 by considering immobility of Al_2O_3 and mobilization of CaO* and Na_2O. CaO* requires same correction as in CIA. Excluding K_2O had made CIW values much higher than CIA, ranging from 85.90 to 93.73, indicating a moderate weathering in term of CIW.

Weathering Index of Parker [13] or WIP = [(2Na_2O/0.35) + (MgO/0.9) + (2K_2O/0.25) + (CaO/0.7)] ×100. This index is not suitable for strongly weathered rocks or sediment as the formula involves the most mobile major elements i.e. sodium, magnesium, potassium and calcium [14]. The same properties make it the best tool to access hydrolytic chemical weathering [15]. On the basis of WIP, the analysed samples are considered fresh or unweathered as the values are all larger than 100 ranging from 10442.08 to 13025.89.

Ruxton Ratio or RR= (SiO_2/Al_2O_3) shows the total element loss relative to the immobility if aluminium in weathering which correlated well under his world-wide test on humid region acid to intermediate igneous rock and metamorphic rock. The dam intake sediments valued from 3.04 to 4.10 indicate moderately weathered as the optimum weathered value is 0 and fresh value is larger than 10.

Index of Lacterization (IOL) is used to measure the degree of lacterization or bauxitization in extreme weathering conditions where quartz and kaolinite dissolute and iron enrich [16]. IOL= [(Al_2O_3 +Fe_2O_3) / (Al_2O_3+ Fe_2O_3+ SiO_2)] ×100. The computation of the analysed XRF data shows the sediments IOL values are between 21.94 to 28.47 indicating a low silica dissolution or slightly weathered.

Vogt's Residual Index [17] or VRI = [(Al_2O_3 +K_2O)/ (Na_2O+CaO+ MgO)]×100. Upper quotients are considered as immobile cations and lower quotients as mobile cations to define the maturity of the residual sediments [18]. By applying VRI, sediments of the study area values are from 8.12 to 12.61 which are larger than 1 indicating weathering happens but in a low intensity.

Silica-Titania Index (STI) was proposed from a tropical region study in Sri Lanka on silicate rocks [19]. STI= {(SiO_2 /TiO_2)/[(SiO_2/TiO_2) × (Al_2O_3 /TiO_2) × (SiO_2/Al_2O_3)]}×100. By applying this formula, the dam intakes sediments have values all larger than 90 indicating a fresh, unweathered source.

Combining the information getting from the various chemical indices of weathering, the sediments are from a fresh or slightly weathered source rock where the minerals are still mostly constituted by primary minerals which indicate an igneous rock source or bedrock. After interpretation on XRF data, the source of sediments should from a granitoid rock. To obtain the more accurate and detailed mineralogy, diffraction pattern graphs generated by XRD had been used to identify the mineral phase.

3.3 Minerals Identified by XRD Results

By inputting elements present from XRF data into XRD software to identify each possible minerals in the sediment, mineral candidates had then been selected and the Crystallography Open Database number of each selected candidates is recorded for the mineral phase identification on the other sediment samples. The COD numbers and quantity of minerals present in sediments were tabulated in Table 3.

XRD data showed that the most abundant minerals in the collected fluvial sediments in the study area are plagioclases, 28 to 42.1wt% Plagioclase is a group of primary mineral with chemical formulae of $NaAlSi_3O_8$ to $CaAlSi_3O_8$. $NaAlSi_3O_8$, the sodium end member of plagioclase is albite, following by oligoclase, andesine, labradorite, bytownite to $CaAlSi_3O_8$ the calcium Ca-end member of plagioclase, anorthite with COD number of COD 9009663, COD 9011423, COD 9001030, COD 9000748, COD 9011201and COD 9001258 respectively The composition of members in the plagioclase group does not vary much but bytownite, 5.5 to 7.8wt% is the most abundant within other plagioclases.

The second abundant minerals in the intake sediments are K-feldspars or potassium feldspars 18.2 to 24.4wt% with chemical formulae of $KAlSi_3O_8$. K-feldspars group are primary minerals made up of orthoclase (COD 9000162), microcline (COD 9000189) and sanidine (COD 9000303). Microcline is the largest portion of K-feldspar in every analysed sample followed by orthoclase and sanidine.

The third abundant mineral is a primary mineral namely muscovite, 7.8 to 9.5wt% with chemical formula of $(KF)_2(Al_2O_3)_3(SiO_2)_6(H_2O)$ and COD number of COD 9004409.
The abundance was then followed by chlorite group, sericite group, quartz, sphene or titanite, aluminium minerals, clinozoisite, biotite, epidote, tourmaline, iron minerals, zircon and monazite. Apatite, $Ca_5(PO_4)_3$(Cl, F, OH) of COD 9011098 only present in Renyok 1, 2 and 3 sediments.

Chlorites group, 5.4 to 10.1wt% with chemical formulae of ((Mg, Fe)$_3$(Si, Al)$_4O_{10}(OH)_2$ (Mg, Fe)-$_3$)$(OH)_6$ consists of clinochlore, Mg_5Al $(AlSi_3O_{10})(OH)$, COD 9013852; chamosite, (Fe^{2+}, Mg, Al, Fe^{3+})$_3$ (Si, Al)$_4O_{10}$(OH, O)$_8$ COD 9009233 ; and penninite, $Mg_5Al(AlSi_3O_{10})(OH)_8$ COD 9000766, a variety of clinochlore.

Sericites group, 6.6 to 9wt% with chemical formulae of KAl_2 $(AlSi_3O_{10})$ $(OH)_2$ consists of illite, $K_{0.65}Al_{2.0}$ $(Al_{0.65}Si_{3.35}O_{10})$ $(OH)_2$ COD 9013721 and paragonite, $NaAl_2$ $(AlSi_3O_{10})$ $(OH)_2$ COD

9000905. Quartz, SiO_2 of COD 9009666 makes up 3.2 to 6.7wt%. Sphene or titanite, $CaTi(SiO_4)O$ of COD 9001327 makes up 2 to 3.6 wt%.

Aluminium minerals, 2 to 3.5wt% are made up of gibbsite, $Al(OH)_3$of COD 9015976; and diaspore, AlO(OH) of COD 9014565. Clinozoisite, $(Ca_2)(Al_3)(Si_2O_7)(SiO_4)O(OH)$ of COD 9001799 makes up 2 to 2.8wt%. Epidote, $(Ca_2)(Al_3Fe^{3+})$ $(Si_2O_7)(SiO_4)O(OH)$ of COD 9000038 constitutes 1.3 to 2wt%.

Iron minerals, 0.8 to 1wt% are made up of goethite $\alpha - Fe^{3+}O(OH)$of COD 9011412; hematite $Fe_2O_3$of COD 9016457; magnetite $Fe^{2+}Fe^{3+}{}_2O_4$ of COD 9009768; and ilmenite $Fe^{2+}TiO_4$of COD 9000913. Zircon, $ZrSiO_4$ of COD 9002556 makes up 0.4 to 1wt%. Monazite, $LaPO_4$ of COD 9001647 makes up 0.4 to 0.7wt%.

Table 3. The Results from X-Ray Diffraction Analysis on Minerals Present In Pergau Dam Intake Sediment of the Fraction Less Than 63 μm. *COD abbreviates for Crystallography Open Database Number*

Pergau Dam Intake Sediment								
Mineral	**COD**	**Long 1**	**Long 2**	**Renyok 1**	**Renyok 2**	**Renyok 3**	**Suda**	**Terang**
Quartz	**9009666**	**6.4**	**6**	**4**	**3.3**	**3.2**	**4.6**	**6.7**
K-Feldspar		**24.4**	**20.2**	**22.1**	**18.9**	**20.6**	**22.7**	**18.2**
Orthoclase	9000162	6.6	5.1	6.2	5.1	5	5.3	4.2
Microcline	9000189	12.7	10.2	11.3	10.1	11.3	12.9	10.8
Sanidine	9000303	5.1	4.9	4.6	3.7	4.3	4.5	3.2
Plagioclase		**28**	**31.5**	**38.1**	**42.1**	**40.2**	**32.3**	**41.4**
Albite	9009663	3.6	3.9	6.2	7.2	6.3	3.6	6.5
Oligoclase	9011423	4.4	5.3	6.6	7.2	6.6	4.2	7.4
Andesine	9001030	4.8	5.2	6	6.4	6.2	5.5	7
Labradorite	9000748	4.8	5.5	6	6.8	6.7	5.9	6.8
Bytownite	9011201	5.5	5.9	7.6	7.8	7.8	6.1	7.7
Anorthite	9001258	4.9	5.7	5.7	6.7	6.6	7	6
Biotite	**9001265**	**2.5**	**2.5**	**1.8**	**1.8**	**2.1**	**2.4**	**2.1**
Muscovite	**9004409**	**8.9**	**9.5**	**7.9**	**7.8**	**8**	**8.1**	**8.5**
Sphene/Titanite	**9001327**	**2.3**	**2**	**2.7**	**2.7**	**2.8**	**3.6**	**2.4**
Apatite	**9011098**			**0.3**	**0.4**	**0.5**		
Zircon	**9002556**	**1**	**0.8**	**0.7**	**0.5**	**0.5**	**0.6**	**0.4**
Epidote	**9000038**	**2**	**1.3**	**1.6**	**1.7**	**1.7**	**1.9**	**1.8**
Tourmaline (foitite)	**9001571**	**1.3**	**1.8**	**1.8**	**1.4**	**1.1**	**1.4**	**1**
Clinozoisite	**9001799**	**2.4**	**2.4**	**2**	**1.7**	**2.4**	**2.8**	**2.1**
Monazite	**9001647**	**0.7**	**0.6**	**0.5**	**0.5**	**0.4**	**0.6**	**0.4**
Chlorite		**8.8**	**10.1**	**6.2**	**7**	**5.9**	**5.6**	**5.4**
Clinochore	9013852	3.7	4	2.6	2.7	2.3	2.2	2.3
Chamosite	9009233	1.2	1.9	0.9	1.2	1	1	0.8
Penninite	9000766	3.9	4.2	2.7	3.1	2.6	2.4	2.3
Sericite		**7.8**	**8**	**7.2**	**7.2**	**7.3**	**9**	**6.6**
Illite	9013721	3.6	3.2	2.5	2.4	2.1	2.9	2.4
Paragonite	9000905	4.2	4.8	4.7	4.8	5.2	6.1	4.2
Iron Minerals		**0.9**	**0.8**	**0.8**	**1**	**0.8**	**0.9**	**0.8**

Pergau Dam Intake Sediment								
Goethite	9011412	0.4	0.3	0.3	0.2	0.3	0.4	0.2
Hematite	9016457	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Magnetite	9009768	0.2	0.2	0.2	0.3	0.2	0.2	0.2
Ilmenite	9000913	0.2	0.2	0.2	0.3	0.2	0.2	0.3
Aluminium Minerals		**2.6**	**2.5**	**2.3**	**2**	**2.5**	**3.5**	**2.2**
Gibbsite	9015976	1.9	1.7	1.6	1.7	1.8	2.7	1.8
Diaspore	9014565	0.7	0.8	0.7	0.3	0.7	0.8	0.4
	TOTAL	100	100	100	100	100	100	100

3.4 Source Rock of Pergau Dam Sediments

Due to the unweathered or low chemical weathering intensity calculated using chemical indices of weathering, thus the sediment minerals are very similar to the parent rocks and are considered as a reliable material and could represent the original composition of the source rock.

Combining the stereoscopic observation, XRF and XRD results, the mineral assemblages showed a granitoid rock source. Thus the mineral assemblage of quartz, K-feldspar also known as alkali feldspar, and plagioclase was normalized and plotted on the 1967 Streckeisen Ternary Diagram to name the granitoid or plutonic source rock as shown in Figure 3. According to the plotting of the mineral assemblages, the sediment mineral compositions thus the granitoid source rock fall in quartz monzonite and quartz monzodiorite.

Granitoid rock as a type of igneous rock is very hard in nature and the collection and processing of its fresh sample can be time, energy and cost consuming. The direct usage of in-situ or near to the granitoid source rock sediments is thus an alternative for the identification of source rock.

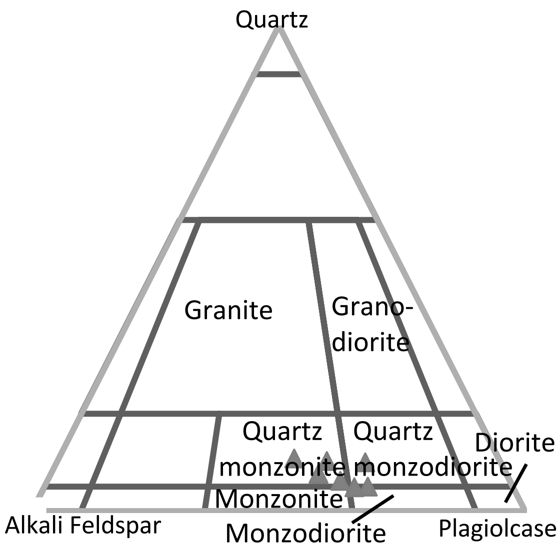

Figure 3. The Plotting of Pergau Dam Intakes Sediments based on The Abundance of Quartz, Alkali Feldspar and Plagioclase in QAP Diagram [20].

4. Conclusion

In conclusion, the minerals identified from the Pergau Dam Intakes sediment are plagioclases, K-feldspars, muscovite, chlorites, sericites, quartz, sphene, aluminium minerals, clinozoisite, biotite, epidote, tourmaline, iron minerals, zircon and monazite in all intakes while apatite was only found in Renyok 1, 2 and 3 intakes. Chemical weathering indices collectively show an unweathered to low

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chemical weathering intensity. From the mineral assemblages in all seven localities sediments under 1967 Streckeisen plutonic rock classification system, the rock types in Pergau Dam Intake area are quartz monzonite and quartz monzodiorite. Further correlational and comparative studies are still needed to validate the usage of in-situ or near fluvial sediments to represent the granitoid source rock.

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