A study on the relevance of geology and sediment discharge in mountain watershed of Shimanto accretionary complex

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Abstract

Recently, comprehensive sediment management is necessary to solve sediment problem in whole river basin. However, sediment discharge in river has been measured in only dam reservoirs, and sediment production from tributary and factors on sediment transport are not clearly in most cases.

In this study, we conducted sampling of sediment in Nanatsuyamakawa River, to clarify the relationship of sediment chemical composition and the geology. Nanatsuyamakawa River is one of the tributaries that supplies more sediment to mainstream than other tributaries in Mimikawa River Basin of Miyazaki Prefecture. It is also necessary mission to clarify sediment volume from tributary.

First, we analyzed landform of the study area by GIS to select sampling locations in which sediment will be trapped due to the morphology of river-bed such as knickpoint, steps and pools etc. Chemical compositions of the sediment were revealed by XRF, and were analyzed statistically. As a result, the chemical composition has been classified into two components: one is characterized by SiO_2, Na_2O, Sr, and S, and the other is characterized by Fe_2O_3, Al_2O_3, and etc. Then, the sediment samples can be explained mix of these components, and the ratio of these components have relation to geology of slope, that consist of sandstone and mudstone of Shimanto Supergroup affect sediment transportation. The ratio of these components has related to area ratio of Shimanto Supergroup sandstone and mudstone. Consequently, the formula is defined to estimate sediment discharge ratio of Nanatsuyamakawa River according to the area ratio of sandstone and mudstone.

Keywords: sediment discharge, XRF, mudstone

1. Introduction

In recent years, with frequent occurrence of landslides and slope failures, preventing sediment disaster is getting more and more attention. Among all the disaster, controlling sediment transportation is an important issue especially in dam management (Wang, 2014). Sediment increases the river-bed and the risk of flooding in the reservoir. On the other hand, the decrease of sediment has bad influence on stability of bridge pier and ecosystem in downstream of the dam (Nishida, 2011). Not only sediment management in dam reservoirs but also comprehensive sediment management in whole basin is necessary to solve such a sediment problem (Takahashi, 2006).

For this reason, it is important to measure the amount of moving sediment in a river and it is also a significant issue in Mimikawa Basin. Although there is a method for measuring moving sediment such as sediment measuring device and river-bed fluctuation simulation, moving sediment in the river couldn't be completely measured. In addition, since tributaries of Mimikawa Basin are unlike alluvial river, measure is more complicated.

Nanatsuyamakawa River has complex river shape because of bedrock and torrent. Nanatsuyamakawa River is the biggest tributary of Mimikawa Basin. Except conventional method it is highly required to apply different ways which make the result more perfect. However, it is easy to grasp the river-bed situation before and after the flood. So far, a river-bed sediment survey in Nanatsuyamakawa River is conducted to get information about river-bed, then the sediment transportation considered as a result. Moreover, sediment in the site where steep slope changes to gentle slope is found and related with the movement of sediment.

In this study, sampling survey is implemented where steep slope changes to gentle slope. The survey sites are selected by GIS. Moreover, XRF is conducted to clarify the chemical composition of the sediment, and the relation between surface geology and sediment

in Nanatsuyamakawa River is statistically examined.

2. Geological setting

Study area is a part of Mimikawa Basin in Miyazaki Prefecture. As shown in Fig.1, study area contains five branches such as Nanatsuyamakawa River, Yanabarugawa River, Masutanigawa River, etc. Shimanto Supergroup mainly composes surface geology of the area and it is different between north and south, in south side the geological age is younger. Furthermore, Shimanto Supergroup distributes from the northeast to the southwest, strata repeatedly exists because of much strike fault.

In Nanatsuyamakawa Basin, surface geology mainly consists of N.Shimanto Supergroup sandstone and slightly N.Shimanto Supergroup mudstone. Generally, sandstone and mudstone are affecting sediment production. Shimanto Supergroup sandstone is a rock containing much SiO_2. The chemical composition of Shimanto Supergroup is clarified in the research of Teraoka (2004). In Teraoka's research, compared to sandstone, Shimanto Supergroup mudstone is lack of SiO_2, yet rich of Al_2O_3, Fe_2O_3 and MgO. Therefore, as a mixture of sandstone and mudstone, sediment sample in the river is expected to be assessed by the ratio of two geology types.

3. Site selection by GIS and river-bed sediment survey

The measurement of river-bed structure and the river-bed sediment survey was conducted in Nanatsuyamakawa River. The survey was carried out to clarify river-bed shape and sediment situation. As a result, significant deposition has been confirmed in the sites where steep slope changes to gentle slope. Also, the sediment was confirmed in the partial deposition fields such as behind of large rock, it is considered to be deposited by sediment transport during floods. As a result of examining the grain size in these sites, it was around 2 mm. It is possible that sediment in the site where steep slope changes to gentle slope can be said as moving sediment.

The site of five branches in Mimikawa River was selected by GIS. Then, the sediment samples were trapped in selected site of each branch. Before the sampling survey, not only selected site but also surface geology, river divergence, and sediment caused by topographic condition are parameters for site investigation. Moreover, survey site was limited because investigation happened to be during typhoon. The number of trapped sediment samples was twenty two throughout five branches. Fig.1 is the map of selected site by GIS and investigated site of five branches.

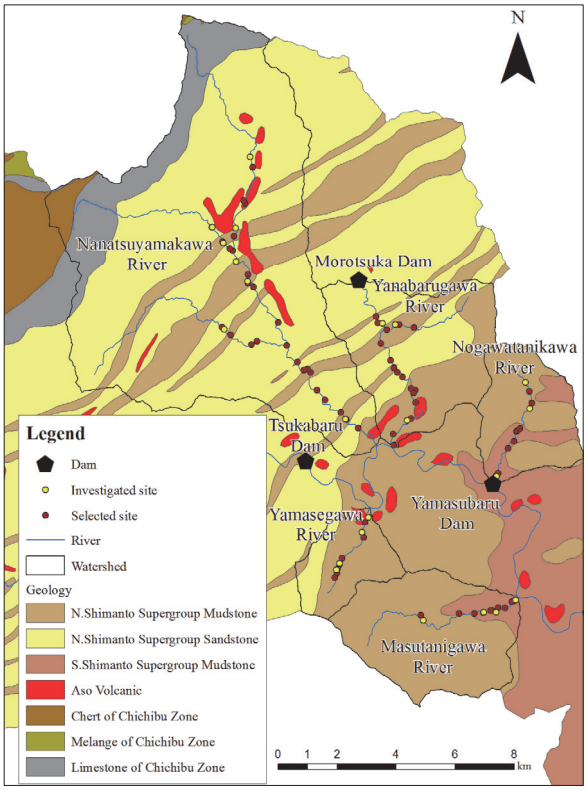

Fig. 1 Map of selected site by GIS and investigated site of five branches

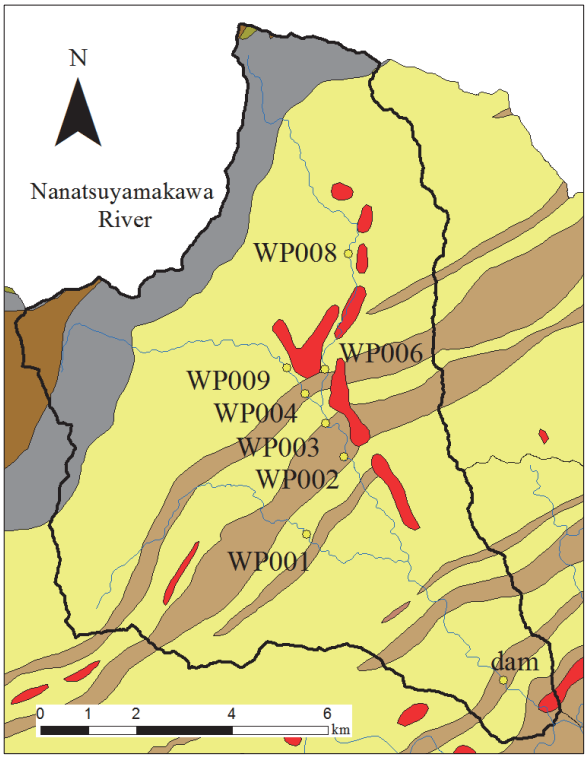

Fig. 2 The site of trapped sediment samples for XRF (Legend is same as Fig.1)

4. Analysis results of surface geology and sediment

4.1 X-ray Fluorescence Analysis (XRF Analysis)

The chemical composition of eight samples in Nanatsuyamakawa River are clarified by XRF. XRF is the method to identify element types and content of element by observing the wavelength of the fluorescent X-rays emitted from the sample when irradiating the sample with X-rays. It is found that sediment contains exactly thirty chemical elements. Fig.2 shows the site of trapped sediment samples for XRF.

4.2 Principal Component Analysis (PCA)

Each chemical element is characterized by PCA. PCA is one of statistical analysis, the method for elucidating characteristic of target factor. Fig.3 is the result of PCA, direction and length of arrows explain the chemical composition trend and strength in all samples. Considering the major components such as SiO_2 and Fe_2O_3, Al_2O_3, each sample is represented as the mixture of other components and SiO_2. Therefore, relation between SiO_2 and nine other major components are compared. A comparison results between SiO_2 with Fe_2O_3, Al_2O_3, MgO are shown in Fig.4 through Fig.6. MgO has the highest correlation with SiO_2, followed by Fe_2O_3 and Al_2O_3. Generally, among chemical elements of rock, alkaline metal (Na, K) and alkali earth metal (Ca, Mg) are easy to dissolve (Kimiya, 1991). Consequently, correlation coefficient of SiO_2 with Na_2O, K_2O, CaO is considered to have low value.

5. Estimation of sediment discharge ratio

5.1 Relation between sediment and surface geology in Nanatsuyamakawa Basin

On the basis of geological chemical composition, it is necessary to indicate the relation between the sediment and surface geology. Considering that each sample is the mixture of Shimanto Supergroup sandstone and mudstone, WP008 sample must not contain Shimanto Supergroup mudstone because mudstone doesn't exist in the upper stream. Although there is little mudstone in the upper stream of WP009, obviously, it has an influence on WP009 from the existence of mudstone in the vicinity. Each sample is evaluated by the ratio of Shimanto Supergroup sandstone on the basis of WP008. Like Fig.7 shows, the area ratio of Shimanto Supergroup sandstone is related to the ratio of Shimanto Supergroup sandstone in river-bed sediment. Except WP001, other samples have high correlation with surface geology. It is considered the sediment comes from Shimanto Super group mudstone because SiO_2 ratio of sediment sample in site

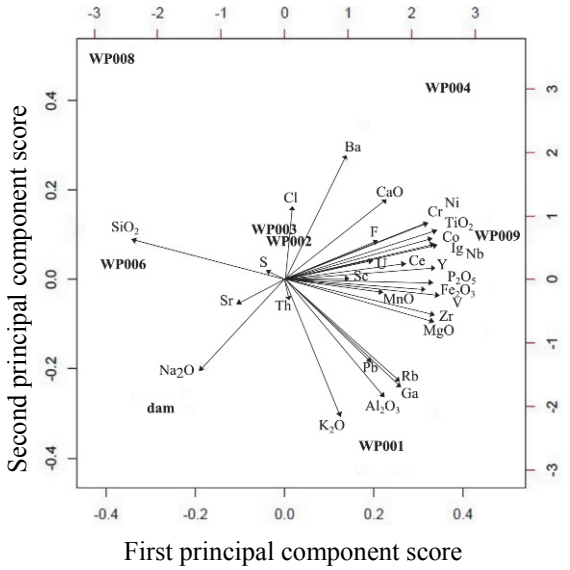

Fig. 3 The result of principal component analysis

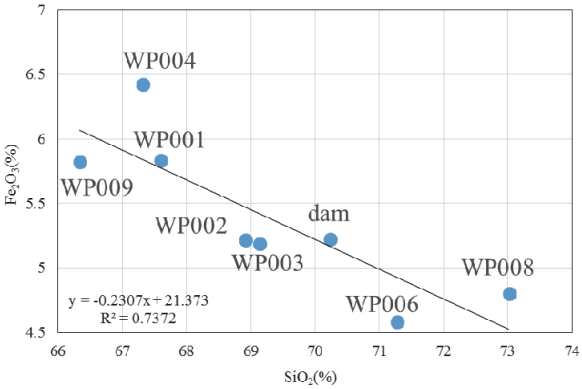

Fig. 4 The correlation between SiO_2 and Fe_2O_3

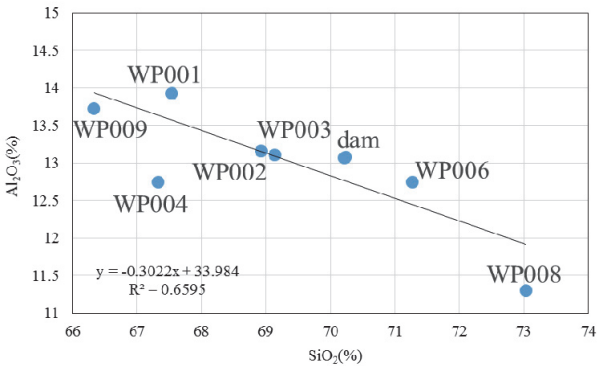

Fig. 5 The correlation between SiO_2 and Al_2O_3

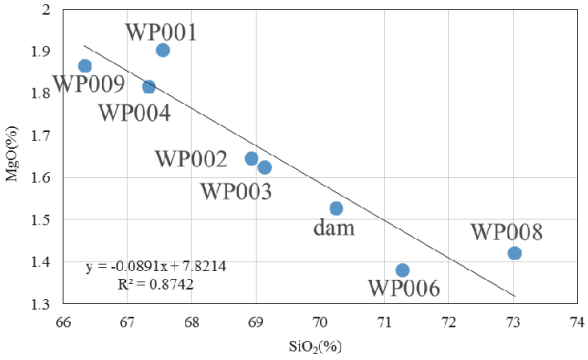

Fig. 6 The correlation between SiO_2 and MgO

WP001 is lower than other samples. Therefore, sample WP001 doesn't follow the correlation of Fig.7.

5.2 Formulation of sediment discharge

According to Fig.7, in the case that about 65% area is sandstone, the percentage of sandstone in sediment is around 50%, so compared to sandstone, mudstone plays a major role. The following model equation (1) is defined to calculate contribution of basin for river-bed sediment, since the chemical composition suggests quantitative relation between surface geology and river-bed sediment.

(Sediment discharge)
= (Ratio of A in sediment) × (Area of A)
+ (Ratio of B in sediment) × (Area of B) (1)
A: Shimanto Supergroup sandstone
B: Shimanto Supergroup mudstone

As a result of calculation, the area Group1 obviously including mudstone was identified as a significant sediment discharge area like shown in the Fig.8.

6. Conclusions

In this study, river-bed sediment survey was conducted in the site of significant sedimentation, chemical composition of the sediment was clarified by XRF. As a result of XRF, the sediment was evaluated as mixture of sandstone and mudstone. Moreover, the chemical composition of sediment was related to the chemical composition of surface geology in Nanatsuyamakawa Basin. Particularly, the area ratio of Shimanto Supergroup sandstone in the watershed interrelates with the percentage of Shimanto Supergroup sandstone in sediment. The area of significant sediment discharge in the basin was identified by the relation. The result of this study signified that mudstone plays a vital role in sediment discharge. Additionally, it was suspected that moving sediment was closely related to the sediment of the site where steep slope changes to gentle slope.

Acknowledgements

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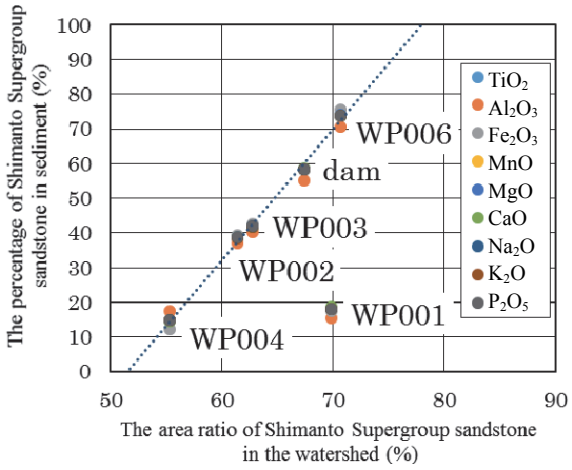

Fig. 7 The correlation between sandstone of river-bed sediment and sandstone of surface geology

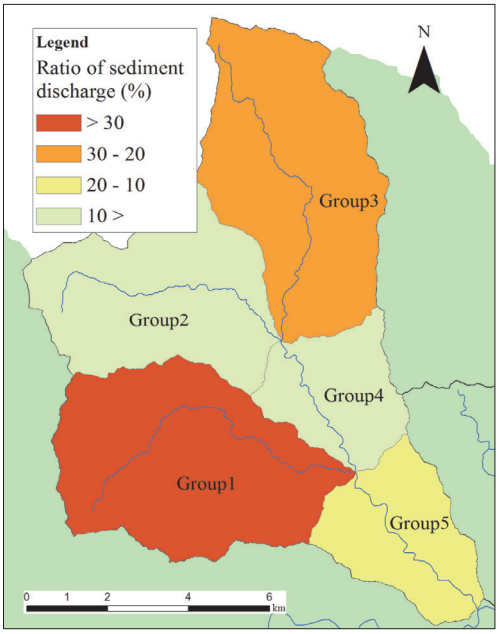

Fig. 8 Sediment discharge ratio

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