

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/239540253>

SOME PROPERTIES AND PROBLEMS OF SMECTITE MINERALS IN JAVA SOILS

Article · January 2005

CITATIONS

4

READS

447

1 author:



[Mohammad Nurcholis](#)

Universitas Pembangunan Nasional "Veteran" Yogyakarta Indonesia

13 PUBLICATIONS 13 CITATIONS

SEE PROFILE

Some of the authors of this publication are also working on these related projects:



Variation of the Soil Layers Developed on the Past Depositional Series on Merbabu Volcano [View project](#)

SOME PROPERTIES AND PROBLEMS OF SMECTITE MINERALS IN JAVA SOILS

M Nurcholis

Dept. of Soil Science, University of Pembangunan Nasional "Veteran" Yogyakarta.
email: nurch2003@yahoo.com

INTISARI

Keberadaan mineral smektit sangat penting dalam menentukan sifat fisik dan kimia dalam tanah atau bahan dari sumberdaya alam lainnya. Mineral smektit mempunyai kemampuan mengembang sebagai hasil dari sifat mineral ini yang dapat mengabsorpsi air dan kation-kation ke dalam ruang interlayer antar lembaran struktur kristal tetrahedral-oktahedral-tetrahedral. Sifat ini juga dapat berpengaruh terhadap kemudahan berubah menjadi mineral lain. Kajian ini bertujuan untuk memberikan informasi permasalahan yang ada dalam hubungannya dengan mineral smektit dalam tanah dan bentonit. Untuk memberikan informasi tersebut, dikumpulkan contoh tanah yang mengandung mineral smektit dari profil tanah di Semin dan Ngargosari serta bentonit Nanggulan. Fraksi lempung dipisahkan dari tanah dengan analisis mekanik, sedang mineralogi lempung dianalisis dan ditetapkan menggunakan difraksi sinar-X. Perbandingan intensitas puncak smektit antar sampel dalam satu lokasi dipergunakan untuk mengetahui perubahan yang terjadi dalam mineral smektit yang disebabkan oleh pelapukan. Hasil analisis menunjukkan bahwa mineral smektit yang berasal dari Vertisol Semin mengandung *hydroxy interlayered smectite* (HIS) dan *kaolin/smectite mixed layer minerals*. Distribusi mineral smektit dari profil tanah di Semin menunjukkan adanya perusakan mineral smektit di per lapisan tanah bagian atas sebagai hasil proses pelapukan. Mineral smektit yang ditemukan di lapisan bawah profil tanah di Ngargosari sebagai penyebab terjadinya *landslide*. Ada kecenderungan perubahan mineral smektit menjadi pirofilit di profil tanah Nanggulan yang berkembang di atas bentonit.

INTRODUCTION

We, the community of the earth sciences, already understand that smectite minerals are parts of important minerals in soils. Attentions have been given to these minerals because the properties of soils are significantly influenced by the presence of them. Many reports show that there are much variability in properties and behavior of the smectite minerals. There were reports of hydroxy interlayer in expansible silicates (Rich, 1968); chlorite-like intergrade minerals (Weed and Nelson, 1962), and many others regarding the smectite minerals in soils. Then Nurcholis and Tokashiki (1998) reported the kaolin/smectite mixed

layer minerals in Paleudults of Java Island.

The important case of water adsorbed by smectite is which water - cation surface interaction is significant. The smectite mineral structure is always somewhat unbalanced, resulting in negative charge. The negative charge is balanced by exchangeable cations that are absorbed around the edge of the fine clay particles. Such cation absorbance and the associated cation exchange capacity are important inherent property of many types of clay. Further processes of cation absorption might change properties of smectite minerals, and even alter smectite minerals to other type. As an example when the smectite mineral

are heated in air, the interlayer water is driven off, thereby causing the collapse of the structure around the spontaneously in nature during burial metamorphism, leading to water expulsions and layer collapse thereby transforming the smectite mineral structure to an illite-like structure.

According to AIPEA (Association Internationale Pour l'Etude des Argiles), smectite has been accepted as the group of name for clay minerals with charge between 0.2 and 0.6 per formula unit (Bailey, 1980). This decision was made as there was confusion between montmorillonite and saponite. As we already know that montmorillonite is dioctahedral type of expandable 2:1 type mineral, and saponite is trioctahedral type one.

The smectite mineral, have ability to swell as a result of the incorporation of water molecules between t-o-t sheets, in association with the interlayer captions, Na^+ and Ca^{2+} . At slightly higher relative humidity the interlayer cations became hydrated, causing a stepwise expansion of the interlayer spacing. Further adsorption and/or the filling of external micro pores. However, monovalent and bivalent exchange forms behave rather differently. The Na^+ -exchanged clay represents a series of hydration states. As an increasing in humidity, the molecule of water in the interlayer space also increase that resulting in the basal spacing expansion of clay lattice. Then the immersion of sodium smectite may result in unlimited swelling to large interlayer spacing. In contrast, in the case of Ca^{2+} -exchanged clay, there are higher hydration energy needed for calcium ion and the stability of the octahedral $\text{Ca}(\text{H}_2\text{O})_6^{2+}$ solvation complex causes initial expansion to bilayer complex and latter a three layers complex. The presence of water and kinds of cation in the interlayer space of smectite

minerals influence to the use and problem regarding to the smectite minerals.

Smectite minerals are the major component of bentonite which is a soft, plastic; light colored rocked that also contains some colloidal silica. It is the result of devitrification and accompanying chemical alteration of glassy igneous rock material, usually tuff or volcanic ash. Commercial applications of the bentonite are already wide use in petroleum exploration and other drilling activities. It is needed attention in bentonite for the other purpose such as in soil remediation, and in the fertilization of soils.

Studies of the smectite minerals in detail may find variability in properties of these minerals. In this paper, there is little information in regarding the smectite minerals in soil and underlying material that presence in Java soils. Many problems may appear as an effect of the presence of the smectite minerals in soils, and even the use of material containing smectite minerals. But in here, only some properties and problems that can be reported according to some collected researches in clay minerals.

DATA COLLECTION AND ANALYSIS

This paper was prepared by collecting any separated research in mineralogical studies of Java soils. There were there locations that smectite minerals collected. The first smectite minerals from Semin were collected from Alfisol that developed in calcareous environment with parent material of marl (Wibowo, 2000). Soil profile was made and the soil of each horizon was sampled. Clay fraction was separated from all soil samples and then determination of the clay mineral was performed using X-ray diffraction (XRD).

The second location was Ngargosari village Samigaluh sub district Kulonprogo. This village has a steep slope surface, and generally the soil surface is covered by dense annual trees. Landslides often occur at the start of rainy season. Study on the landslide was conducted by Suparman (2005) to explain how the landslide happens. In this study, soil profile was made and the soil morphology was examined. Soil samples of each horizon and underlying material were collected. The clay mineralogy of all samples, as a part of all analysis, was determined using XRD.

Third location was Nanggulan Kulonprogo. Exploitation of bentonite was done in this location by using the open pit mining method. The overlying soil depth is relatively shallow, but the soil texture is clay. To extract the bentonite, it was done by excavating the coverage soil and removed to the side place. After the mining activity finish, there are some large holes on the soil surface. Investigation on the prospect of bentonite was conducted by Buntoro *et al.* (2003). In this study there were bentonite and overlying soil were sampled. For mineralogical study, the clay fraction was collected as same as the above two locations others.

The XRD analysis was performed on the parallel oriented clay of the Mg^{2+} and K^+ saturated clay samples. The Mg^{2+} saturated clay was treated with the XRD in the air dry and glycerol salvation. The K^+ saturated clay was in the air dry and heating until $550^{\circ}C$. The diffraction was conducted in the range from 30° to 4° .

RESULT AND DISCUSSION

XRD pattern of the clay in Semin soil

In this study it was selected a clay sample from Vertisol at Semin that showed specific minerals (Fig. 1). There were two peaks that showed by X-ray diffraction. X-ray diffraction on the parallel oriented sample of the Mg saturated clay resulted a broad peak of 17.55 \AA . Glycerol solvation on the Mg-clay shifted the peak, also to be a broad peak and the highest part was 18.35 \AA . Potassium saturation on the clay sample resulted in broader peak forming shoulder over 12.61 \AA until 14.72 \AA . The typical smectite minerals give a sharp peak of 12.5 \AA on the K-saturated clay. As the peak is higher than 12.5 \AA , there are some materials in the interlayer space. There are hydroxy-Al polymers that commonly develop in this space, however it is still weak and it needs long period to develop chlorite (Rich, 1968). This mineral is generally termed as Hydroxy-Al Interlayered Smectite (HIS) or Smectite-chlorite Intergrade minerals. These minerals were already reported by several researches as the alteration of mineral that occur in nature. Dahlgreen *et al.* (1997) reported the formation of HIS in the weathering process of the Mt. ST. Helen tephra.

Heating the K-saturated clay until $550^{\circ}C$ caused a completely shift the peak to 10.05 \AA . Generally, smectite minerals that are saturated with Mg at air dry condition give peak not more than 15.2 \AA (Post *at al.*, 1997). But smectie mineral on several soils that developed in Java, also in this sample, showed peak that higher than that commonly found (Nurcholis, 1998).

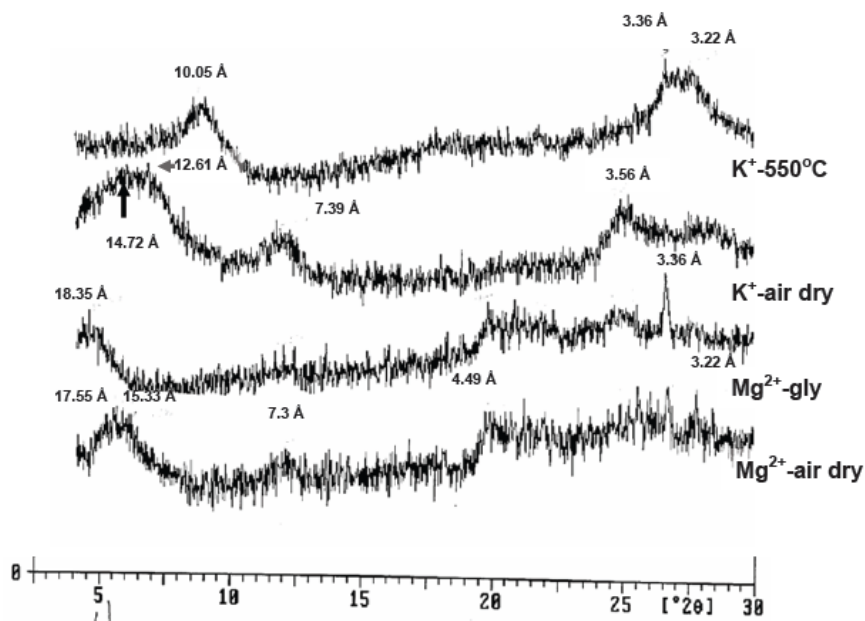


Figure 1. X-ray diffraction pattern of the parallel oriented clay specimen of the Vertisol from Semin.

The sample also showed a broad peak of 7.76 Å on the Mg-saturated clay, and it is interpreted as a 7 Å halloysite. Glycerol solvation caused lowering and broadening the peak, and it is interpreted as an irregular expansion of the sheet layer. Some portion of glycerol may enter the interlayer space between clay lattice of halloysite, but it was not in the same. The K-saturated clay showed a peak of 7.39 Å which sharper than that resulted on the Mg-saturated clay. It indicates that potassium may reduce the basal spacing of halloysite. Further heating to 550°C resulted in completely collapse the peak of 7.39 Å.

There were several broad peaks between 7.39 Å and 14.72 Å shown on the K-saturated clay. This appearance may provide strong support for the presence of kaolin/smectite mixed layer mineral. This type of the mineral was also reported by Nurcholis and Tokashiki (1998) on the Paleudult at Bogor, West Java.

Distribution of the smectite minerals in the soil profile

Further analysis of the result of the XRD data of all layers in soil profile are shown as intensity of peak of the smectite minerals (Figure 2). The intensity of the peak of the smectite minerals was measured as a high of the 15-16Å peaks of the Mg-saturated clay specimen. This method was already used by Harris *et al.* (1989) to study pedon distribution in coastal plain Paleudult. Such semi quantitative analysis was done to compare the relative content of the smectite minerals in every soil layer. According to the result in the Figure 2, it can be said that there was a significantly decrease in the intensity of the peak of smectite minerals from lower to upper layer in the soil profile. The similar phenomenon was reported by Nurcholis and Prastistho (2000) in Paleosol that developed between two layers of tertiary Semilir and Wonosari

Formations in Gunungpanggung Gunungkidul Yogyakarta Special Region. It was suggested that there was an alteration of the structure of the mineral lattice resulted in broken of the mineral crystal. This process might be resulted by the intensively weathering in the upper parts of the soil profile.

Landslide in Ngargosari Village

Problem that may occur in relation with smectite mineral is landslide. As an example, a soil in Ngargosari Kulonprogo district develops overlying clay material that rich with smectite mineral.

Prastistho and Paripurno (2002) reported that the underlying clay material was as one of several causes the occurrence of landslide in this area. There was an extremely difference in the porosity between soil and underlying material. Permeability of the soil was also relatively high so that water from rainfall was infiltrated to the soil body. As the slope of the surface soil was relatively steep causing water flow in the soil is laterally distributed and running along the interface between soil body and underlying clay material. This condition may cause the surface of the clay material to be slippery. Then the weight force of the upper soil mass that is saturated with water increases, causing the attraction forces among soil particle can not hold the soil body

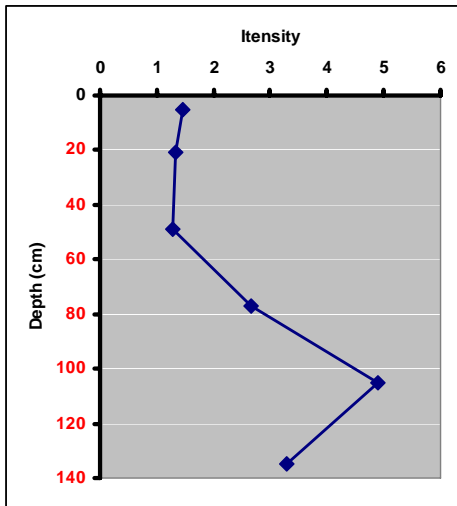


Figure 2. Relative intensity of the peak of smectite mineral under Mg saturation clay at Semin soil

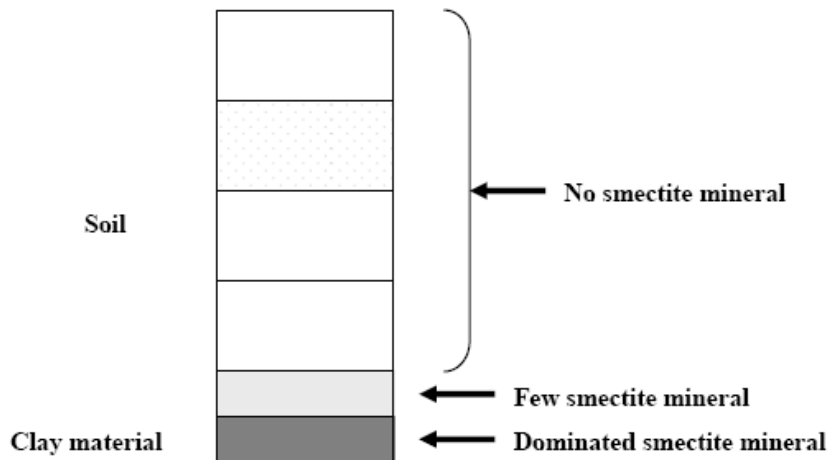


Figure 3. Sketch of the soil profile that occurring landslide

over the slippery surface and it moves downward along the slope direction as landslide.

Additions there are many annual trees growing over the surface soil that add the weight of soil. Landslides in this location generally occur at the early of the rainy season. It can be thought that there is a process of swelling of materials, especially the smectite mineral, when the starting point of the rainy season. The process of the swelling clay particles results in pressures among them in many directions. As a result there is decreasing in attraction among soil particles.

Bentonite and Overlying Soil at Nanggulan

Actually bentonite has a higher economic value if it meets requirement in engineering purpose, especially in drilling project. For this purpose, bentonite that is usually used is Na-bentonite. Bentonite that develop in Tanjungharjo village Nanggulan sub district is dominated by Ca-smectite (Buntoro *et al.*, 2003). Activation using NaOH did not increasing the quality of the bentonite. Studying the soil in Nanggulan that developed over bentonite (Fig. 4) showed that the dominant mineral in clay particle of the soil also smectite.

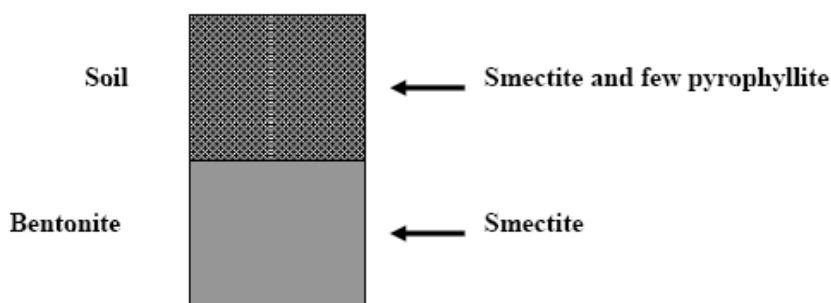


Figure 4. the sketch of the soil profile and underlying bentonite

There was an interesting on the clay mineral in the soil, that small peak of 9 A was also present. The peak of 9 A is probably pyrophyllite or talc. According to AIPEA, both minerals are included in the 2:1 type minerals that have not negative charge. Actually, pyrophyllite and talc are included in the group of pyrophyllite-talc, but they are separated into sub group, but still in dual names (Bailey, 1980). The pyrophyllite is a rare mineral and it is formed in some environments which are characterized by high magnesium (Wilson, 1987). Formation of pyrophyllite requires environment that has silica-alumina ratio of more than 4

and high content of Ca and Mg and high temperature (Grim, 1968). The presence of this mineral in the natural environment, especially in the soil with lower temperature, needs more attention to explain the formation process of mineral. As for the abundant of SiO₂ and Ca and Mg cations in this environment are obviously defined because the underlying material is bentonite. So that it can be thought that pyrophyllite-talc minerals formation in this soils are resulted from a long period process of crystal growth of aluminosilicate that rich in Ca and Mg cations and high value of silica-alumina ratio, or it might be as a transformation smectite.

Further studies are needed to explain what kind process that resulted in this mineral and to determine the name of the mineral, i.e. pyrophyllite or talc. Transformation of smectite to illite in the laboratory experiment was successfully done by Drief *et al.* (2002). They immersed the clay containing smectite mineral in the sea water that enriched with KOH at 50°C and basic pH for 30 days.

Closing Remarks

There is still little information, regarding the smectite minerals in Java soils, that has been reported in this paper. The smectite minerals may give advantages in specific uses if we understand the properties of them. We can modify the smectite minerals in what kinds of cation that saturate the interlayer space. Other methods to make higher value of these minerals might be done by combining with other materials. But in other cases, the swelling properties may cause problems in our live. Ones again, more understanding in the properties of the smectite minerals are needed.

REFERENCES

- Bailey, S.W. 1980. Summary of recommendation of AIPEA nomenclature committee on clay minerals. *American Mineralogist*. 65:1-7.
- Buntoro, A., M Nurcholis, and D.R. Ratnaningsih. 2003. Penelitian pemanfaatan deposit bentonite Kulonprogo sebagai bahan dasar Lumpur yang diperlukan pada proses pemboran minyak dan gas bumi. Kerjasama PSTM LPPM UPNVY-Bappeda Kab Kulonprogo. Unpublished.
- Dahlgreen, R.A., J.P. Dragon, and F.C. Ugolini. 1997. Weathering of Mt. St. Helens Tephra under a Cryic-Udic climatic regime. *Soil Sci. Soc. Am. J.* 61:1519-1525.
- Drief, A., F. Martinez-Ruiz, F. Nietc, and Velilla Sanchez. 2002. Transmission electron microscopy evidence for experimental illitization of smectite in K-enriched seawater solution at 50°C and basic pH. *Clays and Clay Minerals*. 50: 746-756.
- Grim, R.E. 1968. *Clay mineralogy*. 2nd edition. McGraw-Hill. New York.
- Harris, W.G., K.A. Hollien, V.W. Carlisle. 1989. Pedon distribution in coastal plain Paleudult. *Soil Sci. Soc. Am. J.* 47:158-163.
- Nurcholis, M. 1998. "Unique" mixed layer and Mn-oxide minerals and exchangeable Al of Acidic soils in Java Island. Ph.D. dissertation. Kagoshima University. Japan. Unpublished.
- Nurcholis, M. and B. Prastistho. 2000. Pewatakan tanah yang berkembang di antara perlapisan formasi Semilir dan Wonosari di daerah Gunung Panggung Gunungkidul. Hasil penelitian UPNVY. LPPM. Yogyakarta 11:1-13.
- Nurcholis, M and Y. Tokashiki. 1998. Characterization of kaolin/smectite mixed layer mineral in Paleudult of Java Island. *Clay Science*. 10: 291-302.
- Post, J.L., B.L. Cupp, and F.T. Madsen. 1997. Beidellite and associated clays from De Lamar mine and Florida mountain area, Idaho. *Clays and Clay Minerals*. 45: 240-250.
- Prastistho, B. and E.T. Paripurno. 2002. Kali Trayu, Ngargosari, Kulonprogo: Gerakan tanah. Prosiding symposium nasional pencegahan bencana alam sediment. ISDM Project. Yogyakarta. p. 482-486.

- Rich, C.I. 1968. Hydroxy interlayer in expansible layer silicate. *Clays and Clay Minerals*. 16:15-30.
- Suparman. 2005. Kajian fisik tanah berpotensi longsor di desa Ngargosari kecamatan Samigaluh Kabupaten Kulonprogo. Skripsi S-1. unpublished.
- Weed, S.B. and L.A. Nelson. 1962. Occurrence of chlorite-like intergrade clay minerals in Coastal Plain, Piedmont, and Mountain Soils of North Carolina. *Soil Sci. Soc. Proc.* 26:393-398.
- Wibowo, D.A. 2000. Pewatakan kimia, fisika dan mineralogy dua pedon yang berdekatan di daerah Semin Gunungkidul. Skripsi S-1. Unpublished.
- Wilson M.J. 1987. *A handbook of determinative methods in clay mineralogy*. Chapman and Hall. New York.