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Geology, Characterization and Usability for Drilling of Seyitgazi-Eskişehir Clays

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ABSTRACT

In this study, geological properties and characterization evaluations of Seyitgazi-Eskişehir region bentonites were investigated. Also, usability for drilling the bentonites was investigated according to the American Petroleum Institute (API) standards. Bentonite samples were collected from different locations and named ES-1A, ES-1B, ES-1C, ES-2A, ES-2B, and ES-3 for analysis. The geological evaluations were examined with formations and occurring mechanisms. Characterization of the samples were examined through XRF, XRD, Rietveld, FT-IR, and optical microscope analysis. Also, the suspensions made with the samples investigated flow properties with a rotary viscometer and filter press. With the results of the mud flow analysis, suitabilities for drilling operations were determined.

1. Introduction

Drilling operations for the oil and gas industry are critical. Drilling mud is the main task in drilling operations. A large proportion of oil field chemicals are consumed constitutes annually for drilling mud. The cost of importing mud fluids for drilling operations is a very big amount of dollars per year and affects the economic conditions of the country. Also, research for oil and gas reserves in fields especially drilling occuries of huge costs. The cost of the drilling operation is also influenced by the performance of the drilling fluid (Ozyurtkan et al., 2022; Ozdemir et al., 2021, 2022; Güllü et al., 2021). Therefore, the geological properties, reserve, chemical properties, and rheological properties of the bentonite mine should be investigated well. Bentonites are used in all of operations such as natural gas, oil, and geothermal drilling as additive materials of drilling fluids. Also, bentonite-added drilling fluids have important duties such as removing the cuttings from bottom to surface, cooling and lubricating bit and drill pipes, provide wellbore stability, controlling and balancing formation pressure, preventing corrosion and suspending cuttings when non-circulation times (Chilingar and Vorabutr, 1983; Caenn and Chillingar, 1996; Abdou and Ahmed, 2011; Erdoğan and Kök, 2019a,b; Kök et al., 2019; Erdoğan and Kök, 2020; Kök et al., 2023).

The world's most important bentonite reserves are located in the United States, Russia, Greece, Germany, Japan, Italy, Spain and England. The total bentonite reserves in the world are estimated to be 1700 million tons (USGS). Turkey has approximately 20% of the world's bentonite reserves. Important bentonite deposits in Turkey; It is located in the provinces of Tokat, Ordu, Çankırı, Balıkesir, Çanakkale, Giresun, Kütahya and Eskişehir. Bentonites extracted from the deposits operated in Turkey are mostly sold abroad as raw bentonite. According to the data of the General Directorate of Mining Affairs, there are 164 million tons of visible

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bentonite reserves (Gandhi et al., 2022; Stary et al., 2021; Kadir et al., 2021; Afolabi et al., 2018).

Bentonites are clays that are formed by the chemical decomposition of glassy volcanic materials such as volcanic ash or tuff and can be dispersed in water as particles smaller than 2 μm. The instability of the glassy material causes it to turn into montmorillonite by hydrolysis. The mineral montmorillonite is dominant in bentonite. They are porous industrial raw materials of different colors that can be dispersed colloidally in liquids due to smectites, which are the main clay minerals and can be shaped when they become mud. The density of dry bentonite varies between 2.7-2.8 g/cm³. In powdered bentonites, the compressed bulk densities show a significant decrease and go down to 0.8-1.1 g/cm³.

Colloidal clays have many different colors. Bentonites can be slightly yellow, beige, or greenish. In determining the usage areas of bentonites, their physical properties are more important than their chemical composition. Bentonite has many uses due to its colloidal properties when mixed with water, swelling in volume in water and some organic media, and high plasticity. One of the most important properties of bentonite is that it swells in water and forms a gel-like structure. For clay to be qualified as bentonite, it must swell at least five times its volume. Quality bentonites can swell 10-20 times their volume, and high-quality bentonites can swell 25 or even 30 times. The most important distinguishing feature of bentonites is their ability to hold water in their structures.

Siyahi et al. (1996) stated that the swelling deformations and swelling pressures of the compressed clay soil decreased as a result of repeated wet/dry cycles at different initial water contents of bentonite. However, this decrease was more in the first cycles, and it was stabilized at the end of the fourth cycle. Kök (2004) investigated the rheological and thermal properties of bentonites for water-based test fluids and determined that there was a 2% mass loss on heating in bentonite samples. Önal et al. (2005) in their study on non-clay minerals found in clays, examined many X-ray diffraction (XRD) patterns and determined non-clay minerals and determined that these are zeolite, feldspar, carbonate, sulfate, sulfide, phosphate, hydroxide, oxide and silica polyforms. Önal and Sarıkaya (2007), the mineralogical composition of Kütahya bentonite; was determined by using chemical analysis, X-ray diffraction (XRD), and thermal analysis (TG-DTA) methods and was composed of 60% calcium-rich smectite (CaS), 30% opal-CT, a small amount of illite and it was determined that there were some non-clay impurities.

In this study, geological properties and characterization evaluations of Seyitgazi-Eskişehir region bentonites were investigated. The bentonite reserve of Seyitgazi (Eskişehir) has been estimated to be above 40 million tons (MTA, 2018a). Despite this situation, the drilling industry does not yet fully enable the use of locally sourced bentonite, as there are few studies on the use of local bentonite for drilling. The properties of the drilling muds that have been added local bentonite and its suitability for drillings in the drilling industry investigated, up to the present. This situation has brought about increased research into the use of local bentonites for drilling applications.

Previous works on the use of Seyitgazi bentonite as an additive material in drilling fluids have shown that not enough for the American Petroleum Institute (API) standard due to the low quality of bentonite. These bentonites in their raw form exhibit low rheological and filtration properties hence the need for development. The physicochemical characterization of the Seyitgazi bentonites has been developed and improving techniques have been employed to meet the API standard. With the rising demand for bentonites as oil and gas exploration shifts to deep offshore, there is a growing need to enhance the properties of Seyitgazi bentonite clays to meet the API standard. Firstly, In the geological studies carried out in the area covering the Seyitgazi (Eskişehir) region, the fields that can form bentonite suitable for swellable were examined.

According to the examination and the studies carried out in the area, the region was distinguished into three groups Afyon metamorphites, Bozkır Birliği, and cover units. Secondly, characterization studies of the samples were made with XRF, XRD, Rietveld, FT-IR and optical microscopy analyses. The potential economic effects of the Seyitgazi bentonite reserve make a compelling case for more extensive research in improving the quality of these clay deposits in Turkey.

2. Geological Setting of the Study Area

In the geological studies carried out in the area covering Seyitgazi (Eskisehir) region, the fields that can form bentonite suitable for swellable were examined. According to the examination and the studies carried out in the area, the region was distinguished into three groups Afyon metamorphites, Bozkır Birliği, and cover units.

In this study, the Precambrian Ihsaniye Formation, which consists of micaschists, schists, orthogneiss, metariolites and metabasites as Afyon Metamorphites; Late Permian aged Iscehisar Formation consisting of quartzite, meta-conglomerate, quartzist, calcschist and marble; Early-Middle Triassic aged Kiyir formation consisting of metaconglomerate, quartzite, schist and recrystallized dolomitic limestones; the Middle-Late Triassic Şaphane Dağ Formation consisting of recrystallized dolomite and recrystallized dolomitic limestone; the Jurassic-Cretaceous aged Budagan Formation consisting of metaconglomerate, recrystallized limestone, recrystallized dolomitic limestone and cherty recrystallized limestones; It is stated that it is composed of Late Cretaceous aged Kayı Formation, which consists of metaclastic, calcschist, recrystallized limestone and various rock types (MTA, 2018a; MTA, 2009).

In the Bozkır Birliği area is represented by the Middle-Late Triassic aged Çiğdemli Formation consisting of Late Cretaceous aged Dağardı mélange and Triassic-Cretaceous aged Domuzdağ nappe limestones.

At the base of the cover units, there is the Late Paleocene-Middle Eocene aged marine Hanköy Formation, which consists of conglomerate, sandstone, mudstone, siltstone, nodular limestone, clayey limestone and limestone towards the top. It is unconformably overlain by the Early Miocene aged Seyitler ignimbrite, the İdrisyayla volcanite consisting of rhyolite, rhyodacite and dacite, and the Sarıkaya Formation, which was deposited in a lacustrine environment consisting of borate zones and clayey limestone, limestone, claystone, siltstone, marl and sandstones with local tuff levels. The Middle Miocene is represented by the Kesenler Volcanite consisting of basalt lavas and the Late Miocene by the Uruş Formation consisting of marl, limestone, gypsum, conglomerate and sandstone.

It is determined that the cover units continue with the Pliocene aged Kıran Formation consisting of conglomerate and the Early Pleistocene aged Pörnek Formation consisting of sandstone, loosely attached conglomerate, siltstone and claystone, and end with Quaternary-aged alluvium.

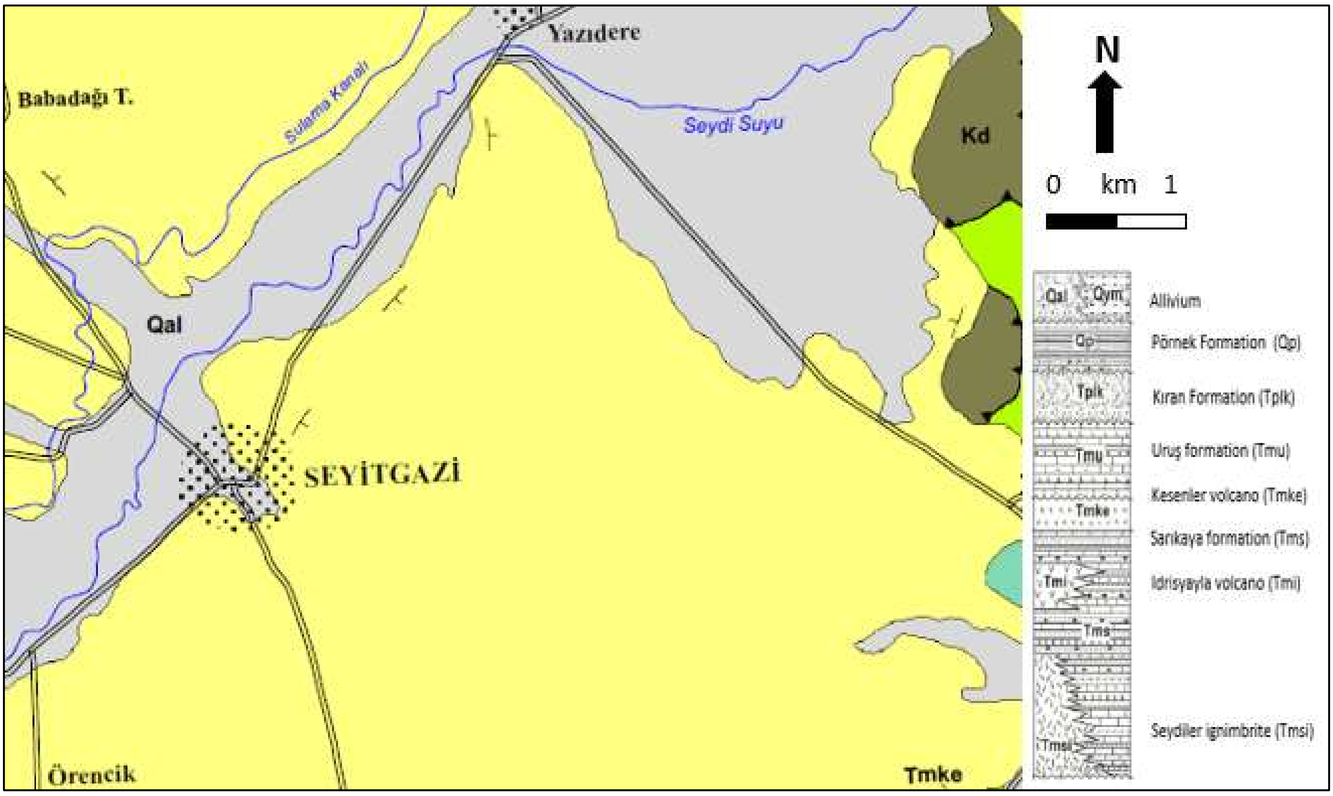

Fig. 1. The geology of Seyitgazi Region (modified from MTA, 2018b)

Table 1. XRF results of the samples

	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	Na_2O	K_2O	Others	LOI	MR
ES-1A	55.44	16.22	5.32	3.74	2.34	0.41	0.80	0.81	14.92	0.13
ES-1B	57.82	15.79	5.58	2.82	2.10	0.93	0.67	0.99	13.30	0.19
ES-1C	53.97	16.31	4.64	3.17	2.51	0.88	1.01	1.00	16.51	0.24
ES-2A	58.15	12.89	4.79	4.00	3.03	0.75	0.95	1.27	14.17	0.19
ES-2B	56.66	15.13	4.84	3.63	2.98	0.69	0.73	1.46	13.88	0.16
ES-3	55.58	15.99	4.17	3.59	2.87	0.98	0.97	1.26	14.59	0.25

Sarıkaya Formation (Tms), a cover unit, was investigated as the area that may form bentonite suitable for drilling mud. And the formation consisting of limestone, clayey limestone, siltstone, claystone and tuff intermediate levels, including borate formations in the central parts of Sarıkaya Formation, was named Sarıkaya Formation for the first time by Yalçın (1988). The unit, whose typical outcrops are located on Sarıkaya in the Eti Maden, is widely distributed around the villages of Üçsaray, Ayvalı, Gümüşbel, Seyitgazi district, Bardakçı, Çatoren villages, Kırka district, Karaören, Gökçekuyu, Gökbahçe, Ağlarca, Mallıca, Çukurkuyu and Eymir villages in the study area. The base of the formation begins with massive, medium-thick bedded limestones containing yellowish, thin-bedded claystone and tuff intermediate levels. Thin bedded clayey limestones are located above this level. It is overlain by a tuff intercalated, clayey carbonate borate zone containing pumice fragments from claystone, marl and limestone alternations.

The positions of the minerals in the borate zone in the field are generally massive and radial in structure and are observed alternately with carbonate and clayey levels. The main boron minerals identified in the macro samples are colemanite, ulexite and borax. These minerals show mineralogical zoning in the form of Na, Na/Ca and Ca-borate in the deposit. Overlying this zone, laminated claystone, clayey limestone alternation is yellowish, cream colored, medium-thick bedded. At the top, there are thick-bedded, locally cherty (nodular/banded) limestones with widespread dissolution gaps towards the top, forming the cover rock of the borate zone. Between these limestones, thin-bedded claystone, siltstone and sandstone are sparsely found in intermediate levels. The apparent thickness of the formation in the study area is around 450 m according to the drilling data.

In addition, the Uruş Formation (Tmu) is located among the bentonite deposits that may be suitable for drilling mud in the region. The Uruş Formation begins with an alternation of white-colored, medium-bedded marl, white-gray-colored, thin-medium-bedded, gastropodal limestone. There are occasional gypsum formations between these levels. The upper parts of the unit are composed of green, yellow and brown colored claystone, white colored marl and limestone intercalations, intercalations of conglomerate and sandstone and intercalations of gypsum. It gains a mottled appearance with this arrangement. The thickness of the unit is around 200 m.

In the eastern part of the study area, it is seen that the Kayı Formation, which is one of the Upper Cretaceous aged ophiolitic melange and metamorphic units, is also located. Alluvial materials were found along the Seydi Stream (Fig. 1).

3. Characterization Evaluations

Characterization evaluations of the samples were made with XRF, XRD, Rietveld, FT-IR and optical microscopy analysis. Also, suitability for drilling operations was investigated.

3.1. XRF Analysis Results

The chemical compositions of samples were detected through X-ray fluorescence (XRF) analysis with MINIPAL 4 and the results are given in Table 1.

According to XRF analysis, similar results were obtained from the samples and characterized with bentonite. Mass ratio (MR) values were calculated with $Na_2O+K_2O/CaO+MgO$ formulation (MR>1=Sodium type bentonite, 0.35<MR<1= Mix type bentonite MR<0.35= Calcium type bentonite). Results showed that all samples were Ca-Ben-type bentonite.

3.2. XRD Analysis Results

X-ray diffraction (XRD) spectrums of samples were obtained using Rigaku Miniflex (Cu Ka radiation in 2θ angle and range 5-90°) and results are given in Fig. 2.

According to the XRD spectrums, it was seen that there were montmorillonite (M) peaks at <20^0, feldspar (F) at between 20^0-25^0 for ES-2A, quartz (Q) at 25^0-30^0 and low montmorillonite at 55^0-65^0 for all samples. Also, a muscovite (Mu) peak was detected in ES-1C. Also, gypsum (G) peaks were seen in ES-1B and ES-3, respectively. Results showed that the samples were characterized with bentonite in general. In some samples (ES-1B and ES-3) non-clay mineral peaks were detected.

3.3. Rietveld Analysis Results

For the collected samples, Rietveld analysis was applied and results showed that montmorillonite, quartz, alkali feldspar, plagioclase feldspar, calcite, chlorite and muscovite had different ratios. These ratios were measured between from montmorillonite as 48-69%, quartz as 20-25%, alkali feldspar as 15-17%, plagioclase feldspar as 2-13%, calcite as 5-8%, chlorite as 3-6% and muscovite as 4-7%. As a result of the analysis, the samples were characterized with bentonite.

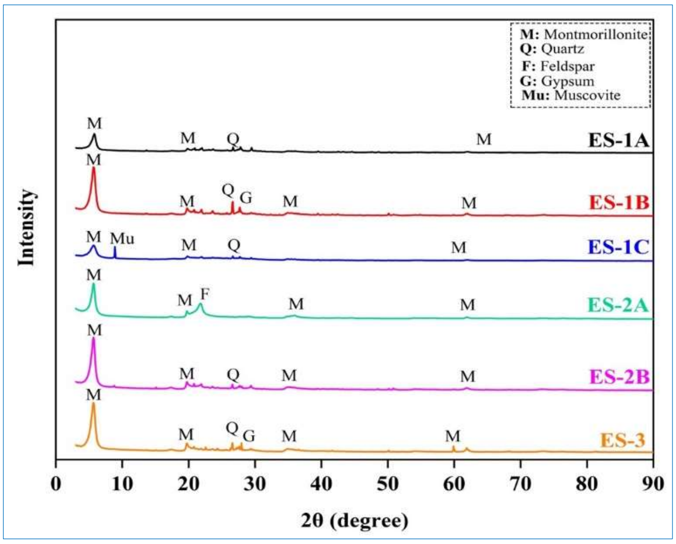

Fig. 2. XRD spectrums of the samples

3.4. FT-IR Analysis Results

Fourier Transform Infrared Spectroscopy (FT-IR) analyses were applied using JASCO FT/IR-6700. Spectrums were obtained range from 400-4000 cm^{-1} and results given in Fig. 3.

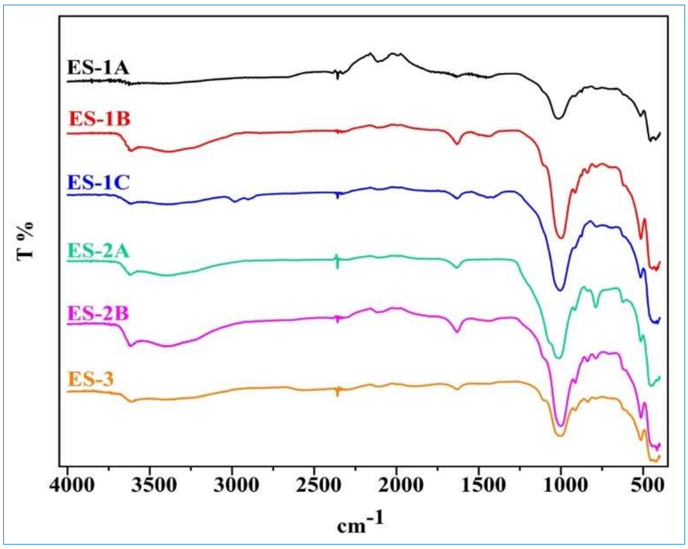

Fig. 3. FT-IR spectrums of the samples

FT-IR results of the samples showed that spectrums are similar to bentonites. In the octahedral layer in the range of 3500-3750 cm^{-1}, peaks occurred due to the stretching of structural hydroxyl groups such as Al-OH and Mg-OH. For the ES-1C sample, a peak was formed from the stretching of water molecules (H-O-H) at 2952,17 cm^{-1}. Peaks due to deformation of water molecules occurred in the range of 1 550-1650 cm^{-1}. In the range of 920-1150 cm^{-1}, impurities in the composition formed peaks due to Si-O and Si-O-Si stretching. As a result of the displacements in the octahedral layers in the range of 990-1000 cm^{-1}, the Al-Al-OH and Al-Mg-OH deformation bands are significantly formed.

As a result of impurities such as quartz and chloride, Si-O and Al-O-Si peaks were formed in the range of 700-850 cm^{-1}. A peak at 795.49 cm-1, is seen for the ES-2A coded sample. In the tetrahedral layer in the range of 400-550 cm^{-1}, Al-O-Si, Fe-O-Si and Si-O-Si bands are formed for all samples.

3.5. Optical Microscopy Analysis

The samples of bentonite were taken from Sarıkaya and Urus Formations. According to the optical microscopy (OM) results (Fig. 4), it was determined that the abundances of nonclay constituents vary from thirty to ten percent. Also, the samples show porphyritic tissue. Nonclay fragments are constituted Quartz, feldspar, biotite, muscovite, various rock fragments and fossils.

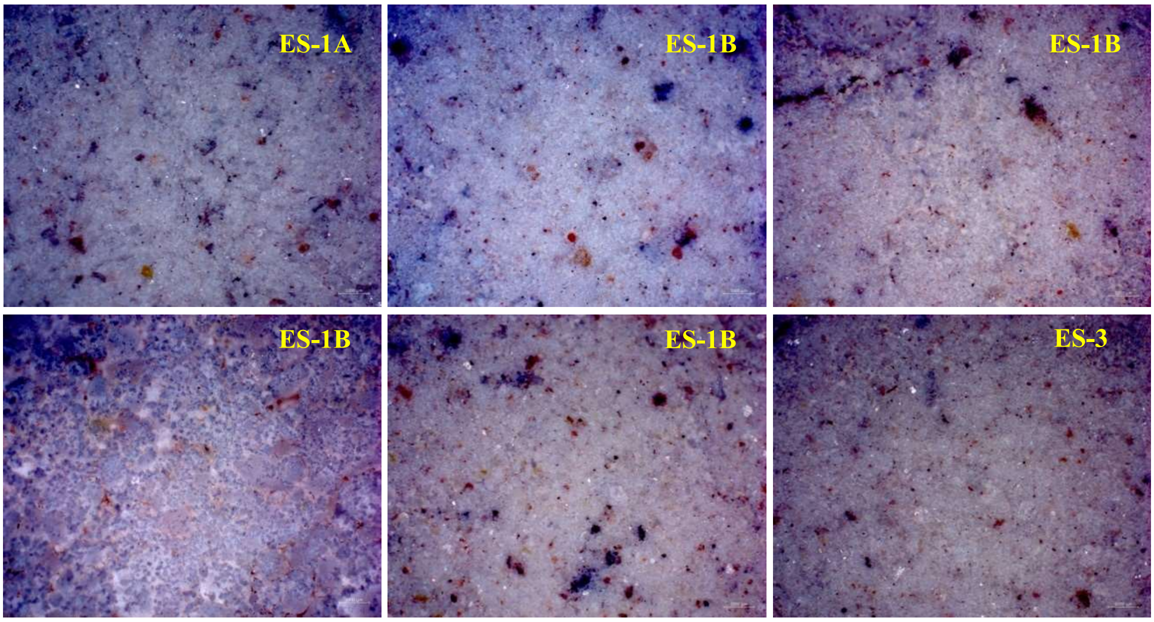

Fig. 4. OM images of the samples

Table 2. Flow properties of the samples

Sample	θ_{600}	θ_{300}	AV (cP)	PV (cP)	YP (lb/100ft^2)	Filtration (mL)
ES-1A	4	3	2	1	2	44
ES-1B	5	3	2.5	2	1	38
ES-1C	5	4	2.5	1	3	40
ES-2A	4	3	2	1	2	40
ES-2B	3	2	1.5	1	1	47
ES-3	5	3	2.5	2	1	41

θ_N: Dial reading at N rpm

3.6. Suitability for Drilling Operations

Suitability analyses for drilling applications were carried out according to the American Petroleum Institute (API) standards. Drilling muds/suspensions were prepared according to the API Spec. 13A and measured according to the API 13B-1 and results are given in Table 2.

According to the flow properties of suspensions prepared with the samples, results showed that none of the samples are suitable for the drilling industry. In AV analysis, the highest values were obtained from ES-1B, ES-1C and ES-3. In PV analysis, ES-1B and ES-3 showed higher than others. For YP results, the highest results were obtained from ES-1C. Also, in the filtration analysis, the lowest filtrate volume was obtained from ES-1B. Other filtrate volumes range from 40 mL and 47 mL.

According to the API 13A standard, bentonite suspensions must provide the standard specifications such as θ_{600} DR>30, YP/PV<3 and filtrate volume <15 mL. Results showed that ES-1B made more quality suspensions than the others, but any suspensions were not suitable for the drilling industry.

4. Results

In the geological studies carried out in the area covering Seyitgazi (Eskisehir) Region, the fields that can form bentonite suitable for swellable were examined. According to the examination and the studies carried out in the area, the region was distinguished into three groups Afyon metamorphites, Bozkır Birliği and cover units. The bentonite samples were taken from cover units which are Sarıkaya and Uruş Formations. Geological properties and drilling distingtion of formations in that area were investigated for reserve for drilling mud. The characterization analyses indicated that the collected samples were bentonite but contained impurities. Types of the bentonites were determined as calcium type. When used as pure clay, a purification process must be applied. Also, no samples provided API specifications and were not suitable for drilling operations. Thus, some activation processes such as alkali, organic and carboxymethyl cellulose activations should be applied for improved flow properties. However, in this region, bentonites can be used directly for the sectors that bentonites with low swelling properties are preferred such as casting, petroleum and natural gas refining, ceramic, drug, and cosmetics sectors.

5. Conclusion

In this study, it was aimed to investigate the clays of the Seyitgazi-Eskişehir region in detail. Its geological properties, characterization and usability for drilling operations were evaluated. As a result of the findings, results are beneficial for industry and scientific studies. New usage areas and improvement-development methods can be investigated for these clays.

References

Abdou, M.I., Ahmed, H.S., 2011. Effect of particle size of bentonite on rheological behavior of the drilling mud. Journal of Petroleum Science and Technology 29, 2220-2233.

Afolabi, R.O., Ogunkunle, T.F., Olabode, O.A., Yusuf, E.O., 2018. Dataset on the beneficiation of a Nigerian bentonite clay mineral for drilling mud formulation. Data in Brief,20, 234-241.

Caenn, R., Chilingar, G.V., 1996. Drilling fluids: State of the art. Journal of Petroleum Science and Engineering 14, 221-230.

Chilingar, G.V., Vorabutr, P., 1983. Drilling and drilling fluids (2nd Ed.). Elsevier. ISBN: 978-044-4421-77- 7.

Erdoğan, Y., Kök, O.E., 2020. Current Research in Engineering and Architecture Sciences. Flow Char- acteristics of Eldivan–Çankırı (Turkey) Bentonites Compared to Wyoming (USA) in Drilling Muds: An Experimental Approach (pp. 91-101). IVPE Publishing Group. ISBN: 978-9949-46-027-3.

Erdoğan, Y., Kök, O.E., 2019a. Production and characterization of nanobentonite from sodium bentonite with mechanical grinding. Fresenius Environmental Bulletin 28 (11), 8141- 8150.

Erdoğan, Y., Kök, O.E., 2019b. Usage of olivine as additive material in water-based drilling muds. Fresenius Environmental Bulletin 28 (7), 5559-5568.

Gandhi, D., Bandyopadhyay, R., Soni, B., 2022. Naturally occurring bentonite clay: Structural augmentation, characterization and application as catalyst. Materials Today: Proceedings 57, 194-201.

Geological Map of J-25 Layout (1/100.000), 2018b. Mineral Research and Exploration General Directorate (MTA), Ankara, Turkey.

Geological Report of J-25 Layout, 2018a. Mineral Research and Exploration General Directorate (MTA), Ankara, Turkey.

Geological Report of J-26 Layout, 2009. Mineral Research and Exploration General Directorate (MTA), Ankara, Turkey.

Kadir, S., Külah, T., Erkoyun, H., Uyanık, N.Ö., Eren, M., Elliott, W.C., 2021. Mineralogy, geochemistry, and genesis of bentonites in Upper Cretaceous pyroclastics of the Bereketli member of the Reşadiye Formation, Reşadiye (Tokat), Turkey. Applied Clay Science 204, 106024. https://doi.org/10.1016/j.clay.2021.106024.

Kök, M.V., 2004. Rheological and thermal analysis of bentonites for water base drilling fluids. Energy Sources 26, 145-151. https://doi.org/10.1080/00908310490258524.

Gullu, A., Ozdemir, A., Palabiyik, A., Yaşar, E., 2021. Türkiye kara alanlarındaki petrol ve doğalgaz kuyularında kullanılan sondaj akışkanı katkı maddeleri [Drilling fluid additives used in oil and gas wells drilled in onshore of Turkey]. European Journal of Science and Technology, 398-406, (in Turkish with English abstract). https://doi.org/10.31590/ejosat.954723.

Kök, E., Özdemir, A., Erdoğan, Y., 2023. Bentonitlerin Oluşumu, Sınıflandırılması ve Kullanım Alanları [Occurrence, Classification and Uses of Bentonites]. Bardak S. and Ayata, Ü. (Eds), Current Research in Engineering, Gece Publishing, 82-92, ISBN: 978-625-430-706-5 (in Turkish)

Ozdemir, A., Palabiyik, Y., Yasar, E., Gullu, A., 2022. A new approach to estimate drilling time, rate of penetration, and drillability of formations in oil and gas exploration and production basins of Turkey. Geomechanics and Geophysics for Geo-Energy and Geo-Resources 8 (3), 94, https://doi.org/10.1007/s40948-022-00405-2.

Ozdemir, A., Güllü, A., Yaşar, E., Palabiyik, Y., 2021. Drilling engineering assessment and cost analysis of oil and gas wells drilled in onshore of Turkey. International Journal of Earth Sciences Knowledge and Applications 3 (3), 235-243

Ozyurtkan, M.H., Arslan, M.S., Palabiyik, Y., Ozdemir, A., Erdoğan, Y., 2022. The application of borax as a fresh water-based drilling fluid additive for different temperature and clay contamination conditions. International Journal of Earth Sciences Knowledge and Applications 4 (3), 375-379.

Önal, M., Sarıkaya, Y., 2007. Thermal behavior of a bentonite. Journal of Thermal Analysis and Calorimetry 90 (1), 167-172.

Önal, M., Üstünışık, G., Noyan, H., Kahraman, S., Sarıkaya, Y., Bozdoğan, I., 2005. Killer İçinde Bulunan Kil Dışı Mineraller Give the title in English in parentheses, XII. Kil Sempozyumu, Yüzüncü Yıl Üniversitesi, Van, 5-9 Eylül 2005, pp. 46-56 (in Turkish).

Siyahi, B.G., Hekimoglu, S., Ansal, A.M., 1996. Sıkıştırılmış Kil Zeminin Tekrarlı-şişme Davranışı Give the title in English in parentheses, 6. Ulusal Zemin Mekaniği ve Temel Mühendisliği Kongresi, pp. 179-188 (in Turkish).

Starý, J., Jirasek, J., Pticen, F., Zahradnik, J., Sivek, M., 2021. Review of production, reserves, and processing of clays (including bentonite) in the Czech Republic. Applied Clay Science 205, 106049. https://doi.org/10.1016/j.clay.2021.106049.

Yalçın, H., 1988. Kırka (Eskişehir) Yöresi Volkanosedimanter Oluşumların Minerolojik-Petrografik ve Jeokimyasal İncelemesi (Give the title in English in parentheses). Doctoral Thesis, Hacettepe University, Institute of Natural Sciences, Ankara (In Turkish).