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IMPLICATIONS OF BEDROCK IN LANDSLIDE-PRONE AREAS BASED ON ROCK LAYERS IN ENREKANG DISTRICT, SOUTH SULAWESI

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Abstract

Events Landslides that occurred in the area Enrekang, especially because the topography is hilly steep. the bedrocks are composed of sediments rocks interbedded of calcareous sandstone and marl and calcareous siltstonr, there is *Globorotalia nana* BOLLI (N1-N2), and Oligocene-Early Miocene, the rocks layer dip > 45^{o}. The retrieval of research data is at an altitude of 518 meters above sea level. Objective study of the analyzes to connection of rock weathered base with content types of minerals in soil and value index plasticity soil and shrinkage limit of the frequent landslide event. Method research used to analysis micropaleontology, XRD method for determination types of minerals, and the Atterberg test for use to know value liquid limit, plastic limit, and index plasticity soil (19.24-25.07%) is in the value range medium, shrinkage limit in safe value. The results of the XRD analysis obtained Albite, Calcite, Phengite, Quartz, and montmorillonite minerals (1.3%) in percentage smallest. Those results in a manner general indicate that the influence of the main happening landslide is on rock quickly basics disintegrated, because the slope of the bedding plane is in the direction of the slope topografi slope.

Keywords: Rocks Sediments, XRD, Indices Plasticity

1. INTRODUCTION

Analysis of the stratigraphic conditions of an area can provide geological information that can be used as a basis for developing knowledge in other fields, such as geotechnical and mapping areas prone to ground movement disturbances. Understanding the lithology of an area, the nature and types of rocks [1], and the differences in the position of layers of sedimentary rocks and geological structures [2] It can be used as information to support plans in the broader field of development planning and coverage of environmental security against geological disasters.

Areas with steep topography and constituent rocks consist of alternating sedimentary rocks clastics as fine grain, which are susceptible to weathering so that the plane of the layers can become a slip plane at the dip rock layers in the direction of the topography slope. Areas with steep morphology tend to seek equilibrium with ground movement or denudational events that allow them to become flat.

Landslide events are ground movements in steep topography and can also occur in flat areas with soil composition on the earth's surface that is vulnerable due to several factors. Trigger factors that cause landslides are divided into internal and external factors. Internal factors can be triggered by geological conditions, especially the constituent rocks of an area, including namaly the stratigraphy consists of interbeded layers between rocks that are easily experienced weathering and lithology-type volcanic tuff. External factors are triggered by vibrations, rainfall intensity, and steep topographical slopes [3].

Several cases of landslide incidents and incidents occurred on October 9, 2022 [4] in twoares namely Maiwa Districts and Enrekang Districts. Data was obtained on the number of victims of 117 people who had to be evacuated and 124 people rehabilitated. Then ground movement occurred again on December 26, 2022, cutting off the road connecting Enrekang.Regencies and Tana Toraja Regencies. As a result, the roads that are crowded being passed by these travelers are closed and experience severe traffic jams for 5 Km [5]. Then disaster landslides and floods on February 26, 2023 [6], in Cemba and Karueng Villages, Enrekang District. The height bulk of proven rain triggered this with the incident of the flood that hit the area. On March 25, 2023, a landslide occurred in Deakaju Village, Kadingeh Village, Baraka District, causing the connecting road access to be cut off between the 2 sub-districts, the width of the avalanche that covered the road was about 10 meters [7]. The last landslide occurred on May 9, 2023. The road collapsed, resulting in a traffic jam so that the vehicles having to queue for up to 3 hours at km 242+400, the Trans Sulawesi route to be exact, in the Kulinjang area, Tuara Village, Enrekang District, which is a connecting road between Enrekang and Tanatoraja Regencies [8].

Landslide events in many places in Enrekang Regency provide an overview of the potential conditions of landslides in the area experiencing very active dynamics of landslide, so the identification of cause and possible evaluation and investigation needs to be done regionally. The determination factor triggers ground movement character can obtain accurate data to provide appropriate and practical information as the cause, use can be anticipated, and minimized the consequences of the landslide activity.

2. REGIONAL GEOLOGY

2.1 Geomorphology

Physiographically, the area of Enrekang Regency is a cluster of mountains, the average height is 200-1000 m, with the highest peak of Bulu Samauran at an altitude of 1348 m above the surface of sea level, that is consist of hills area, mountains area, and karst areas [9].

Mountains spread almost the entire area, extending to the west, in the middle part to the south, and are settlements 500 and 200 meters above sea level as the lowest area of Enrekang Regency. This mountain range is bounded to the west by the broad plains of Pinrang as a continuation of the plane to the south, which border Luwu Regency. The mountains in the east are relatively lower, with an average peak of 600-1300 meters above sea level, and the highest is 1022 meters above sea level, Luwu Regency bordering. The northern part of this mountain range has a karst topography whose partly conical surface connects Tana Toraja Regency.

2.2 Stratigraphy

According to Djuri [9], the rock constituents are primarily volcanic rocks and gray limestones. The youngest deposit in this area is Alluvium consisting of clay, silt, sand, and gravel. The Walanae Formation comprises conglomerates, sandstone glauconite, and shale; it contains Kokuina, Molluscs, and Foraminifera. The formation of Walanae member, found as a lens at the upper part of Walimbong Volcano Rocks, which indicates Pliocene age, deposited in a shallow marine environment.

Walimbong Volcano Rock is composed of lava, basalt to andesite, some pillow lava consist of: pyroxene andesite breccias, andesitic trachite breccias, containing feldspathoids in several places, deposited in marine environment of Miocene-Pliocene age, interfingers with Sekala Formation consists of green sandstone, marl, and pillow lava, some rocks characterized of turbidite of precipitate shallow marine environment.

Date formation consists of marl interbedded with calcareous siltstone and calcareous sandstone, outcrop thickness reaches 500-1000 m, foraminifera content indicates Middle Oligocene-Middle Miocene age with the shallow marine depositional environment, and according to Ratman and Atmawinata [10] this formation is referred to and described in the Mamuju Map sheet as the Riu Formation. Sekala Formation are composed of sandstones, conglomerates, shale, tuff, inserts andesite-basalt, partially characterized turbidites sediment, containing of foraminifera fossils of Middle Miocene to Pliocene aged with t shallow marine deposition environment. Salowajo Formation comprises marl and intercalated limestone, locally containing calcareous sandstone of gray-black color, conglomerates, and breccias, containing Foraminifera of Early Eocene to Late Middle Miocene age.

2.3 Structure Geology

Enrekang is located in the West Sulawesi Mandala zone, which is passed by two thrust fault belt direct of North–South and streched towards the west as well of normal faults belt Northwest-Southeast. In the eastern and western parts of the area, there is a transform fault of direction east-west, that is cross cutting of thrust fault. Bedding plane of rocks generally Northwest-Southeast strike, parallel with anticline and syncline folds, meanwhile dip of rock layers between 20^{O} – 70^{O}.

2.4 Soil Consistency

Rock weathering results in fine-grained soil, can be determined consistency limit for the Atterberg's method, namely it use soil properties for describe in general, if the high liquid limit usually will swelling potential and if reduced water level happen shrinkage potential, so influence characteristic technique resulted in the disturbance balance and strength will decrease.The determination of soil expansion based on plasticity limit has swelling and shrinkage potency [Table 1].

Table 1: Connection Index Plasticity to Shrinkage Potency [11]

Plasticity Index (%)	Shrinkage Potential
0-15	Low
15-35	Currently
20-55	Tall
>55	Very High

For determining category number percentage shrinkage and expansive soil [11] can see in Table 2. Each soil is a different ability to expand factor. The main factor is determined by the surrounding water and the type of clay minerals contained in the soil [12].

Table 2. Relationship of Percentage Expansive to the Level of Expansive [11]

Expansive Percentage (%)	Swelling Potential
100	Critical
50 - 100	Limit
50>	Safe

3. RESEARCH SIGNIFICANCE

The purpose of this study was to analyze factors related to the influence of the occurrence of ground motion from a review of the characteristics of the mineral compotition of the rocks and residual soil, and the types of minerals contained in the soil based on geological observations. Analyze relationships content types of minerals with characteristic plasticity soil with incident movement frequent land happens over and over again. Although has lot study about landslide but every area will give characteristics certain related to rock composition, residual soil, and topography as well as structure geology. With analyze matter can give information and innovation important in anticipation, so landslide no causing casualties and losses treasure object consequence incident.

4. MATERIALS AND METHODS

4.1 Materials

Field data collection method with take a sample of fresh rocks, namely in marl, and inserts calcareous sandstone for analyzed its micropaleontology, to knows the age and environment deposition rock at the base of the area.

For the determination content types of minerals in soil and determination mark Index plasticity using surface soil as a result of weathering of the bedrock, to the appearance outcrop arrangement stratigraphy rock composer in detail consists of alternating clastic calcareous medium sand and marl as well as limestone who have a dip layering 45^0 - 48^0 (Figure 1).

Research map (Fig. 2), an area taking sample located at a height of 51.8 meters above surface sea level at coordinates N-3 ˚ 29'1.7" - E-119 ° 47'39.7", Bambapuang Village Kotu Enrekang Regency, South Sulawesi Province, modification from the Topographic Map of the Information Agency Geospatial [13].

Figure 1: Outcrop with the position of the layers in the direction of the slope.

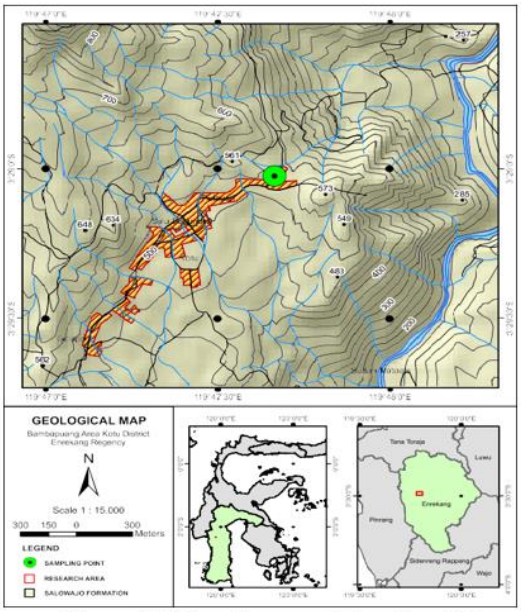


Figure 2: Map of research location [13]

4.2 Research Methods

4.2.1 Fossil Analysis

Micropaleontology analysis in the laboratory use binoculars microscope, to describe the content and abundance of planktonic and benthic foraminifera fossils used to identify the age and depositional environment of rocks. The sample was soaked then in the sieve and then in the oven for drying.

4.2.2 XRD Method

Soil samples were analyzed to identify the types of minerals resulting from weathering using the X-Ray Diffraction (XRD) analysis method, to determine the mineralogical characteristics contained in the residual soil. Mineral content testing aims to determine of the type and percentage of mineral contained in soil samples as a result of weathering of the bedrock. The output data of the XRD test is in the form of a diffractogram graph to determine phases (crystals) are contained in the test object. Phase identification is carried out by searching for peak positions and matching the phases in the database so that the type of mineral is obtained [14].

4.2.3 Atterberg Limit Testing

This test will be carried out on soil samples mixed with sand, with a mixture percentage of 5%, 10%, 15%, 20%, and 25% respectively.

Liquid limit test (LL) based on SNI 1967; 2008. The liquid limit is the water content when the soil properties at the limit from the liquid state become plastic. The water content in the soil should be expressed as the moisture content in percent of the weight of the oven-dried soil and should be calculated as follows:

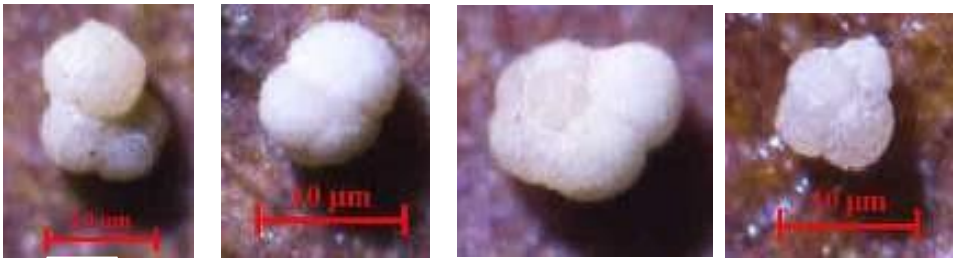
Percentage of moisture content = Weight of Water/Weight of oven Dry Soil x 100 % [15]

Plastic Limit Test (PL) based on SNI 1966: 2008. The plastic limit is the lowest limit for water content conditions when the soil is still in a plastic condition. The calculation of the plastic limit is expressed in percent as follows:

Plastic Limit = Weight of the Water Mass / Weight of the Soil Mass x 100% [16]

5. RESULTS AND DISCUSSION

Determination of the age of the bedrock to be analyzed is prepared soaked, washed and sifted, cleaned and then dried, then observed under a binocular microscope. Observable fossils in the description then determine of specified name, so age is known based on Postuma [17]. Fossils contained in marl from an excerpt taken for analysis (Figure 3), is on the layer part lower obtained *Globigerina ampliapertura* BOLLI (N1) and layers on obtained *Globigerinoides diminitus* BOLLI (N7-N8). Foraminifera fossils content found in the rocks that have been described show the Oligocene to Early Miocene aged.



1 2 3 4

Figure 3: Foraminifera plankton; Pl.1, *Globigerina ampliapertura*, Pl.2, *Globigerinoides dominions* Pl.3, *Globorotalia nana*, Pl.4, *Catapsydrax dissimilar*.

The results of X-ray diffraction analysis can be found in the identification of the different program peaks (Figure 3), then determined according to the type of mineral. Data on chemical composition as the main component of soil composition in Table 1. The composition shows that the mineral calcite is the component that has the largest percentage of all the minerals contained in the sample. Soil which is analyzed, as a character of sedimentary rocks that are carbonate. Albite are minerals that can form in volcanic areas, as inserts or results of alteration of plagioclase minerals with a smaller percentage of 30.6%. The mineral quartz is the most stable mineral among other minerals, commonly called silicon dioxide, the most abundant found on the surface of the earth, found in almost all rocks.

The mineral montmorillonite is a smectite mineral group, that is very easy to absorb water because broad surface. Its existence can influence characteristic flower shrink soil, because these minerals have payload negative and capacity swap high cation [18], so cause this mineral is very reactive to the environment, have percentage smallest of the minerals identified in weathering interbedded rocks between calcareous sandstone, marl, and limestone.

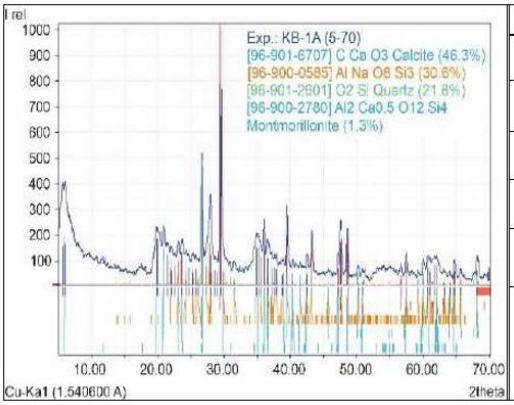


Table 1: Analisis XRD sampel KB 1A

Indekx	*Amount (%)*	*Name*	*Formula sum*
A	46.3	Calcite	C Ca O3
B	30.6	Albite	Al Na O8 Si3
C	21.8	Quartz	O2 Si
D	1.3	Montmorillonite	Al2 Ca0.5 O12 Si4
	9.3	*Unidentified peak area*	

Figure 3: The diffractogram of soil sample KB 1A

Analysis results from weathered insert calcareous sandstone with diffraction X-rays identified peak diffractogram (Fig. 4) then determined in accordance type the minerals. The composition of the minerals as components main preparation of soil can be seen in Table 2.

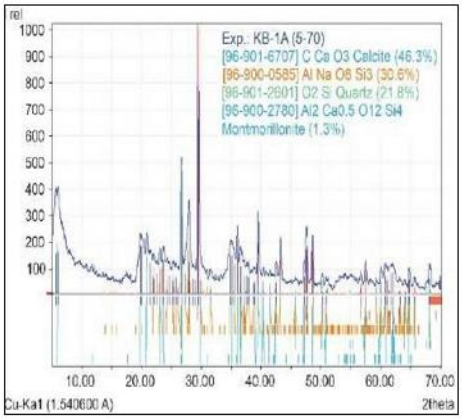


Table 2: Analisis XRD sampel TK 3B

Indekx	Amount (%)	Name	Formula sum
A	51.6	Albite	Al Na O8 Si3
B	18.2	Calcite	C Ca O3
C	16.8	Phengite	Al2.28 F0.04 Fe0.
			28 H1.96 K0.475 Mg0.2
			Na0.025 O11.96 Si3.24
D	12.1	Silicon oxide $-alpha	O2 Si
		Quartz low	
E	1.3	Montmorillonite	Al2 Ca0.5 O12 Si4
	14.9	*Unidentified peak area*	

Figure 4: The diffractogram of soil sample TK 3B

Albite including the group of alkali feldspar minerals, is the sodium end member of the easy solid solution plagioclase series modified, pure albite has the formula NaAlSi3O8 and is tectosilicate [19]. Composition shows that the mineral Albite has a percentage biggest between all the minerals contained within derived soil samples from calcareous sandstone.

Phengite is a muscovite mineral have the composition Fe, Al, and Mg, Fe, Mn which can each other substituted no limited, so high Fe content can easily oxidize.

Montmorillonite is a clay mineral that has characteristic crystals that can absorb water so at the moment we will expand and at the moment dry will wrinkled and massive, nature this can influence land to become plastic and has a shrinkage limit is at a threshold limit [11]

Limit test results soil plastic and liquid limit of soil boundaries (Table 3). From the value the can be explained that the connection between grain size soil and its soil mineral composition, affect which significant value, if details the more fine-grain clay and constituent minerals soil consists of clay minerals that have sufficient water big absorption will cause the soil will expansion and water store mainly montmorillonite mineral has a 2:1 crystal system, although that was detected on XRD analysis with percentage a small 1.3%, however still give influence at a moderate expansion potential value 30.2%-34.75%.

Table 3: Atterberg Value test results

No Sample	Sample Code	Atterberg Limits Test				Classification Soil Test (USCS)
		Liquid Limits %	Plastic Limits %	Plasticity Index (IP) -	Shrinkage Limits %	
1	Tengah Kanan (TK 3B	44.86	25.63	19.24	34.75	CL
2	Kanan Bawah (KB 1A	46.74	21.67	25.07	30.2	CL

Soil test sample KB 1A (Fig. 5), shows Atterberg's value is on value plastic limit and liquid limit values indicate is in the medium range (moderate), can cause because the percentage of clay minerals montmorillonite contained in the soil-clay grain sized in small amounts, so water absorption from the mineral montmorillonite in the soil it will too small, therefore will influence value liquid limit and plastic limit [19]. Shrinkage limit value between 30.2 % – 34.75% is at the limit safe [11].

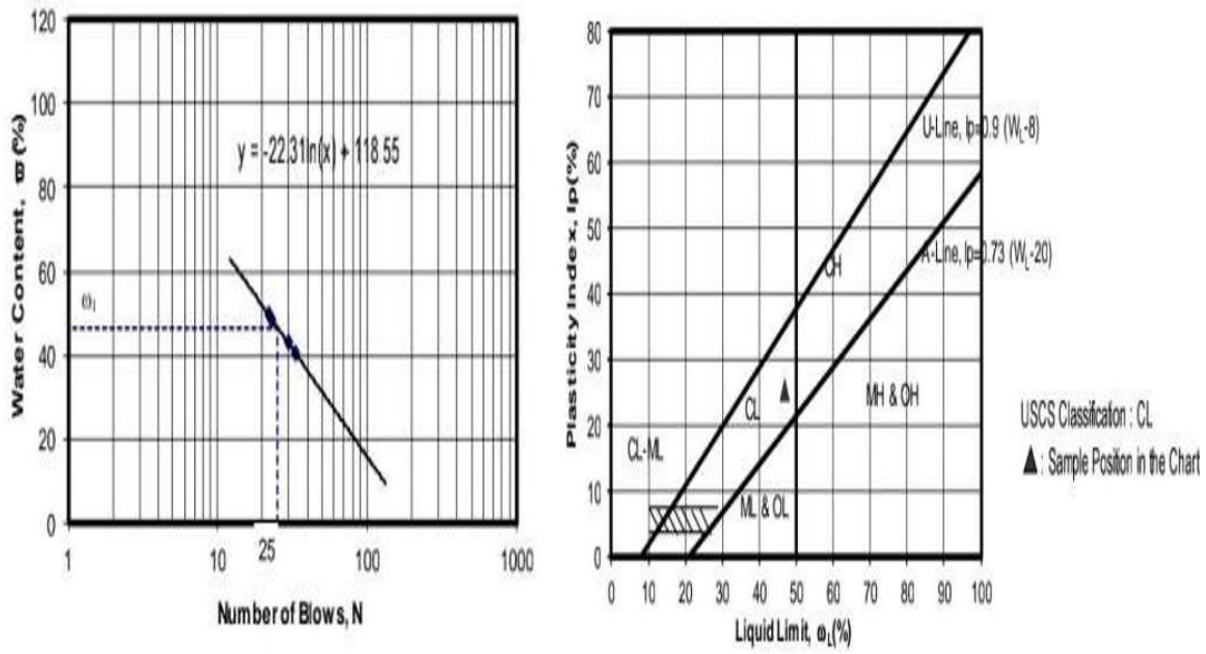


Figure 5: Graph K B 1 A; Charts for Liquid Limits and Determination Charts for the Unified Soil Classification System

Similarly, in the sample soil test TK 3B (Fig. 6), which shows Atterberg's value is on value plastic limit and liquid limit values indicate is in the moderate range (moderate), and the index plasticity 19.24% is in the moderate range.

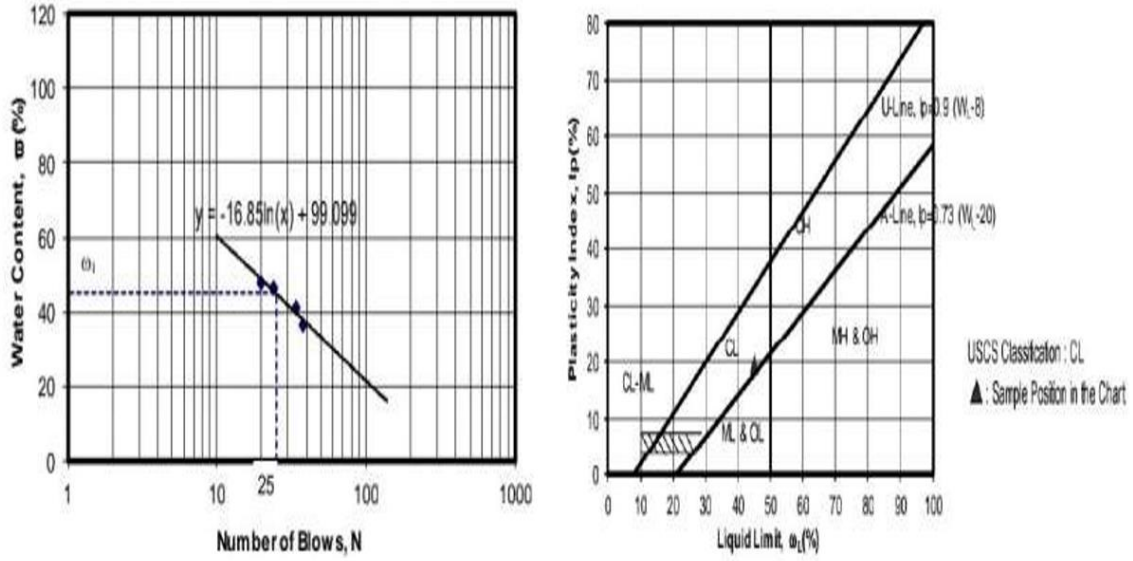


Figure 6: Graph of TK 3B; Charts for Liquid Limits and Determination Charts for the Unified Soil Classification System

6. CONCLUSION

Based on results XRD testing contains Montmorillonite minerals although the existence of a percentage small in the soil will influence the Index of moderate plasticity and cohesiveness. The moderate Atterberg values and the safe shrinkage limit show the influence biggest event the landslide in the Enrekang area, It can Take place due to high rainfall due to frequent flooding and the characteristics of the position of rock layers that are almost perpendicular and in the direction of the slope, So that the boundary layer field is easily weathered which can eventually become a sliding field and is influenced by steep topographic factors. Dip of rock layers can be interpreted as the activity of strong geological process, It can also be seen in the rock outcrops that local faults have occurred and shifted in the rock layers composed by mostly fine-medium clastic sedimentary rocks.

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