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Mineral Physics Analysis of Alluvial Rocks as a Source of Shallow Hydrocarbon Seepage in Belis Village, Waru Basin, Eastern Seram Island, Maluku Province

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Abstract

Belis Village is located in the Waru basin adjacent to the Bula basin on the eastern part of Seram Island and has potential shallow hydrocarbon manifestations. This research aims to determine the mineralogical characteristics of the rocks that make up shallow hydrocarbon manifestations at the research location. The research method used is physical analysis of minerals including petrographic analysis and XRD methods. The analysis results of the XRD method show an abundance of quartz minerals at 58%, followed by clay minerals at 35%, opaque minerals at 25%, and the rest in the form of cavities while feldspar minerals are secondary minerals. The results of the XRD analysis show that the more dominant mineral is protoenstatite ($MgSio_3$) with an average abundance of 70.33% as a carrier of shallow hydrocarbon seeps, Quartz (SiO_2) with an average abundance of 18.46%, and Clinoestatite with an average abundance of 11.21% as a mineral associated with shallow hydrocarbon seeps.

Introduction

Petroleum production in the Bula basins has begun to decline in recent years [1]. One important effort to increase efficiency and oil production is to conduct oil biomarker studies from several production wells to help solve continuity problems in a reservoir [2]. The search for hydrocarbon reserves in the Bula and Waru basins has become increasingly difficult in recent years, so a hydrocarbon exploration strategy with a high success rate is needed [3]. The petroleum system on Seram Island is composed of shale from the Kanikeh Formation and shale from the Saman-saman Members of the Manusela Formation as source rocks. The reservoir rock consists of the limestone of the Manusela Formation and the Kanikeh Formation sandstone [4,5,6]. The age of the Kanikeh Formation is Triassic to Jurassic [4,7,8]. The seal rock consists of the clay of the Wahai Formation and Fufa Formation. Traps that greatly affect the petroleum system in the Seram Island basins are factoring faults and folding patterns for Mesozoic plays [9,10].

To be able to determine the existence of shallow petroleum manifestations and the position of petroleum reservoirs in the Waru basin, [11] used the application of the resistivity geophysical method to identify shallow hydrocarbon manifestations in the Bula basin of Eastern Seram Island, precisely in the Belis village, Waru Basin, Eastern Seram Island. Based on the results of his research, shallow hydrocarbon manifestations were found in the form of petroleum seepage. Based on this information, research was carried out on shallow sand layer material (seal) that has undergone alteration from surface alluvial rocks in the village of Belis Cekungan Waru, Eastern Seram Island, which can be used as a material sample to enable it as a manifestation of shallow hydrocarbons. The concentration distribution of alteration material elements was analyzed using the application of Mineral Physics to rock materials [12]. Physical analysis of minerals consists of mineral analysis of sandy clay samples using the X-ray Diffraction (XRD) method which is used to determine the elemental composition of a material in the form of mineral content and percentage as a check on the minerals of the sample, so that it can be used to determine the accumulation of diffraction patterns used to determine the composition. particles in a solid pattern [12,13]. Meanwhile, petrographic analysis is used to determine the texture and mineralogy of surface rock samples from sandy clay rocks. So mineral physics analysis is used to determine the mineralogical characteristics of the materials that make up the manifestation of shallow hydrocarbon seep cells in the research area using mineral physics analysis.

Methodology

Research area

The research location is located at UTM (Universal Transverse Mercator) coordinates, namely 684026 meters east – 9625270 meters north and 684222 meters east – 9625117 meters north, and is at an altitude of (2.0 – 4.0) meters above sea level (Figure 1). The slope of the research area is around 1.5° – 3.5°, so it is categorized as plain.

To understand the initial picture of the geological conditions, the location of outcrop observations, and to find out the problems in this formation, namely the interpretation of the depositional environment. Samples were selected in good outcrop areas around the river.

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Physical analysis of minerals

In this research, field observation methods of prospect areas and laboratory analysis were carried out using physical mineral analysis methods. During field observations accompanied by rock sampling which will be used as material for laboratory analysis. In field observation activities, rock types, alteration, and mineralization are observed at shallow hydrocarbon manifestation locations by exploring each outcrop, a location that has previously been drilled so that the research location is not new. The rock sampling point is at a depth of 0.5 m next to a former drilled well (a legacy from the Netherlands) and another in the direction of the river. Sampling does not involve drilling but uses a crowbar to excavate rock samples. The samples are taken to the laboratory for megascopic testing, then sample preparation is carried out. The sample preparation results were analyzed using two methods, namely Petrographic analysis and XRD (X-ray diffraction) analysis, which produced mineral composition data [17].

Rock sample testing uses petrographic analysis and XRD methods to obtain the characteristics and mineral composition of rocks [14]. Petrographic analysis is to determine the texture and mineralogy of surface rock samples from sandy clay rocks by applying concepts of optical physics. The XRD method is used to detect and analyze the crystal structure of a material (rock). XRD is also used to determine types of minerals that are difficult to identify with a microscope, especially sandy clay rocks [15,16]. The measured parameters are the diffraction angle (2θ), half maximum peak width (*l*) and intensity (*I*).

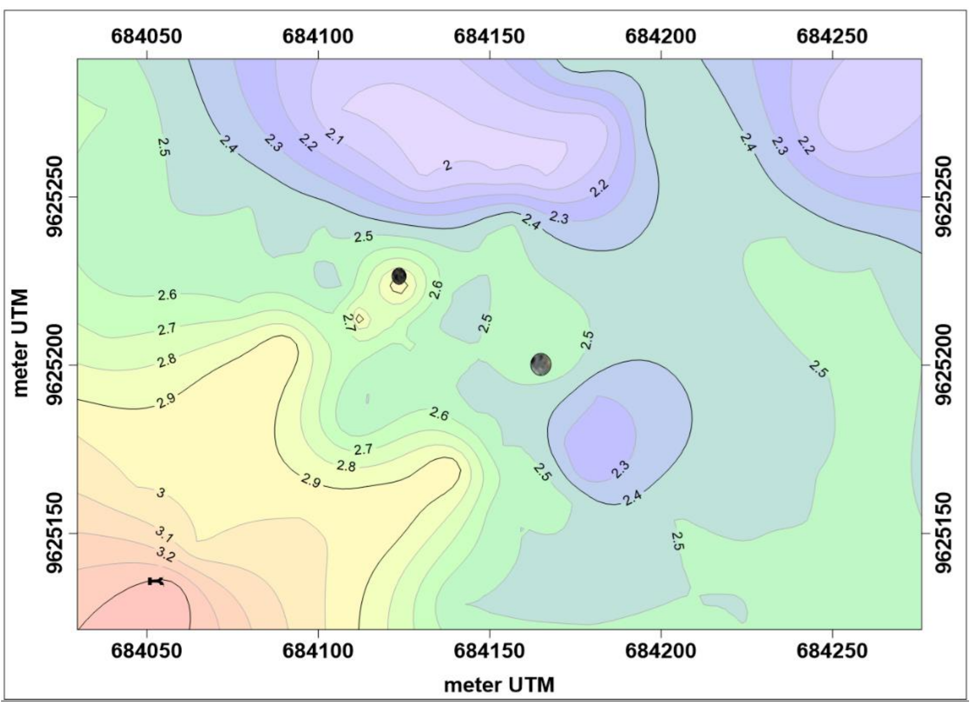

Figure 1. Map of research area

Result and Discussion

Surface rock samples

The field data collection survey was carried out in the form of observational data by taking rock samples at two observation points. Sampling does not involve drilling but using a crowbar to excavate rock samples. The sample is weathered brown alluvial rock (Figure 2). These two samples are located at an altitude of 2.5 m above sea level. The two samples were taken at research locations 20 meters apart.

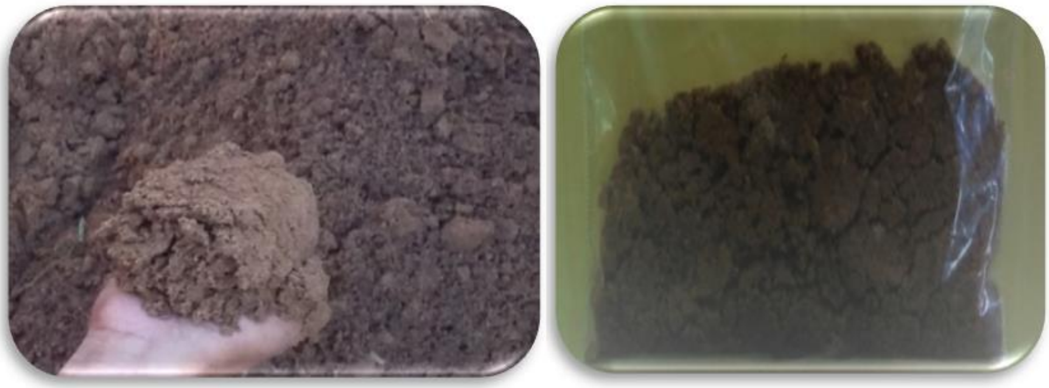

Figure 2. L1.P3 rock samples in the study area

Results of mineral physics analysis

Petrographic analysis results

Petrographic analysis is to determine the texture and mineralogy of surface rock samples from sandy clay rocks. One of the important factors in petrographic analysis is the color of each mineral, because each mineral has a special color. Rock samples were analyzed using half a handheld measure and three tablespoons. Measurements on samples L1.P3 and L2.P22 were carried out using microscopic observations.

1. *Rock sample L1.P3*

a. *Half a handheld rock sample*

The measurement results (Figure 3) show that the mineral composition has an abundance of quartz (A3) of 58%, using white PPL, and using XPL white-grey-black with low relief without cleavage or low pleochroism, has an anhedral crystal shape and is present spreads within the incision. The presence of oxide clay minerals (D7) with an abundance of 20% and in the PPL state is brown, in XPL the color is grey-blackish-brownish, with pleochroism relief, while the crystal shape and cleavage are not visible, there is the presence of spots in the incision. The abundance of 2% opaque minerals (H3) in PPL and XPL observations looks dark, present scattered in the incision. Furthermore, there is an abundance of cavities (I2) of 20%. In observation, PPL is bright, and XPL looks dark, spots are present in the incision.

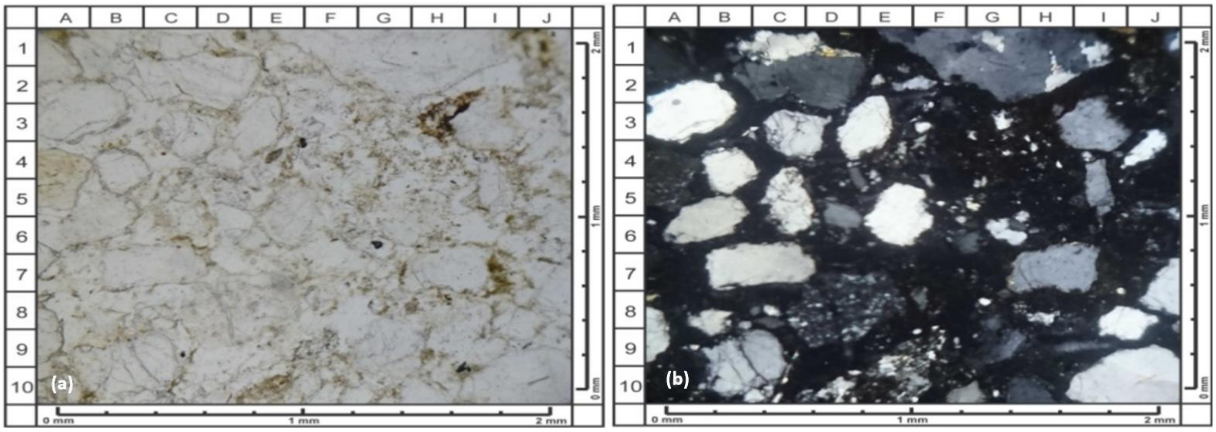

Figure 3. Sand sample L1.P3 (half handheld), (a) Appearance of sand sample L1.P3 (half handheld) PPL, and (b) microscope appearance of sand sample L1.P3 (half handheld) XPL

b. Three tablespoons of rock sample

The observation results showed that the mineral composition (Figure 4) was quartz (D3) with an abundance of 42%, white PPL was used, and white-gray-black XPL was used with low relief without cleavage or low pleochroism, had an anhedral crystal shape and was present spreads within the incision. There is also an oxide clay mineral (D7) with an abundance of 31%, and in the PPL state it is brown, in the XPL it is grey-blackish-brown in color, with pleochroism relief, while the crystal shape and cleavage are not visible, there is the presence of spots in the incision. The presence of the opaque mineral (H3) with an abundance of 2% means that in the PPL and XPL observations it looks dark, present spread out in the incision. Furthermore, there is an abundance of cavities (I2) of 25%. In observation, PPL is bright, and XPL looks dark, spots are present in the incision.

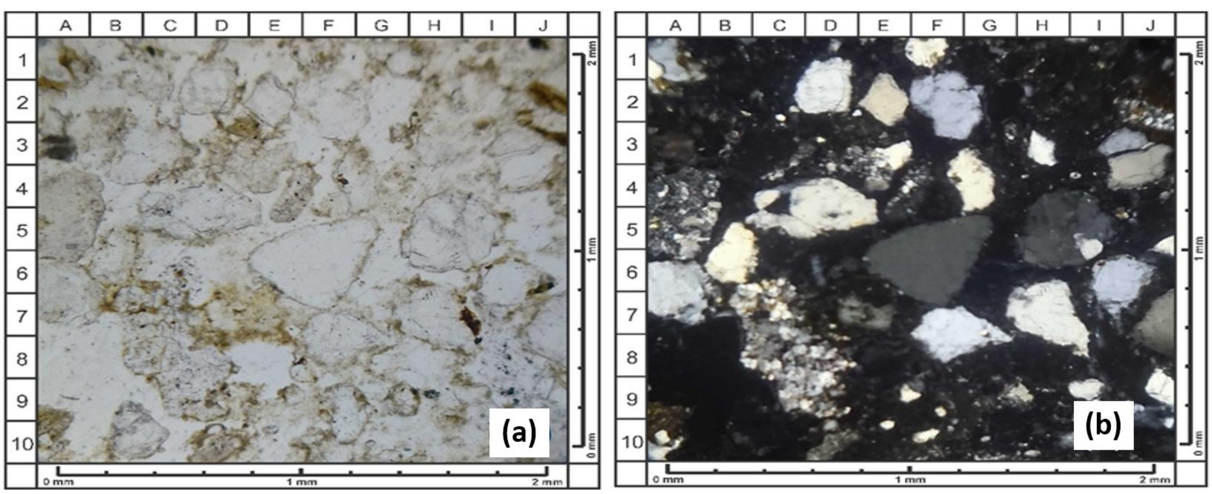

Figure 4. Sand sample L1.P3 (3 tablespoons), (a) Appearance of sand sample L1.P3 (3 tablespoons) PPL, and (b) microscope appearance of sand sample L1.P3 (3 tablespoons) XPL

2. Rock sample L2.P22

a. Half a handheld rock sample

Measurements on sample L2.P22 were observed using a polarizing microscope. The observation results showed that the mineral composition (Figure 5) was quartz (D3) with an abundance of 45%, using white PPL, white - gray - black XPL with low relief without cleavage and low pleochroism, anhedral crystal form, present scattered in the incision. Also found was an abundance of 2% feldspar (E6) in bright color PPL observations, pink-gray XPL, subhedral-euhedral, albite twinning, moderate pleochroism, 1-way cleavage, present scattered in the incision. There are also clay minerals - clay oxide (I1) with an abundance of 30%. The condition of PPL is brown, XPL condition is gray - blackish - brownish, relief - pleochroism - the shape of the crystals and cleavages are not visible, spots are present in the incision There is an abundance of Opaque Mineral (B1) of 3%, PPL and XPL observations appear dark, present scattered in the incision. In the sample there are 20% cavities (J5). Observations of bright PPL and dark XPL appear as spots appear in the incision.

b. Three tablespoons of rock sample

Measurements on sample L2.P22 (three tablespoons) using a polarize microscope. The observation results showed that the mineral composition (Figure 5) was quartz (D3) with an abundance of 48% and with white PPL and white-grey-black XPL with low relief without cleavage and low pleochroism. Anhedral crystal form, present scattered in the incision. Clay minerals - clay oxide (E2) were found with an abundance of 35%. The condition of PPL is brown, XPL is gray - blackish - brownish, relief - pleochroism - the crystal shape and cleavage are not visible, spots are present in the incision. The abundance of 2% opaque minerals (I3) in PPL and XPL observations looks dark, present scattered in the section. Abundance 15 % voids (B5). In observation, PPL is bright, and XPL looks dark, spots are present in the incision.

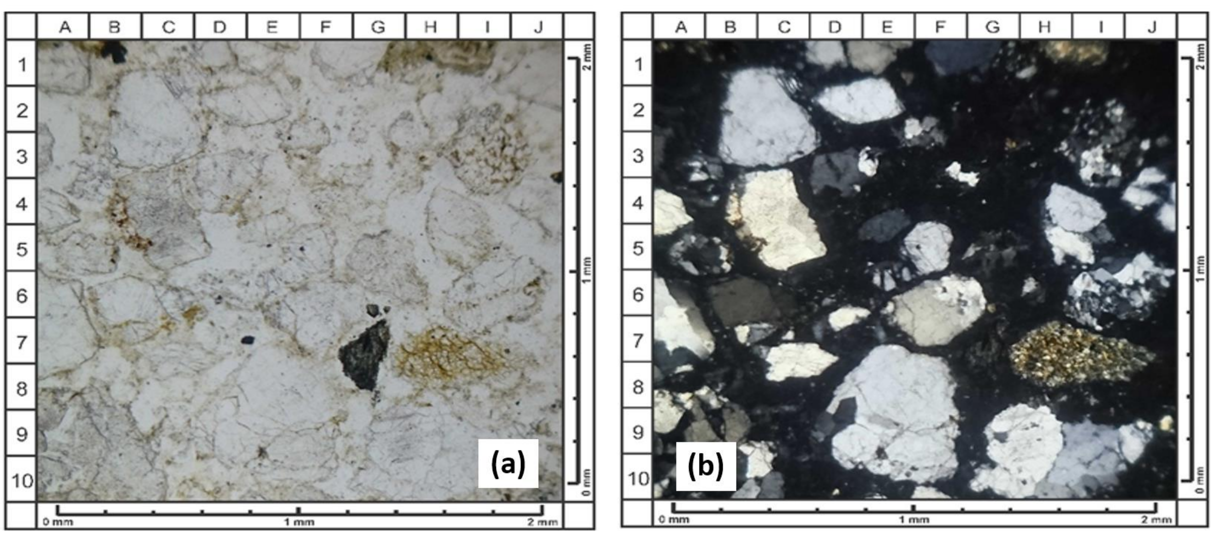

Figure 5. Sand sample L2.P22 (half handheld), (a) Appearance of sand sample L2.P22 (half handheld) PPL, and (b) microscope appearance of sand sample L2.P22 (half handheld) XPL

Petrographic analysis of the two rock samples with different sample names (Figure 6) shows almost the same mineralogical characteristics the difference is the percentage of these minerals.

The mineralogy percentage results determine the name of the mineral that makes up the rock. Based on the results of observations, various textures, shapes, colors, and abundances were found in rock samples in the research area. From the observations, the rock has characteristics of brown to dark, heavy and dense, and generally has a rough surface.

The surface of the research area has very dominant constituent minerals with an average abundance of quartz of 50.5%, followed by clay and opaque minerals. Meanwhile, the feldspar mineral is a secondary mineral that fills cracks. The results of petrographic analysis show that most of the rock samples have undergone alteration and sedimentation. Thin sections show the maximum interference color is brownish white, the constituent minerals begin to show a blackish-gray color change, and many fractures cut the minerals.

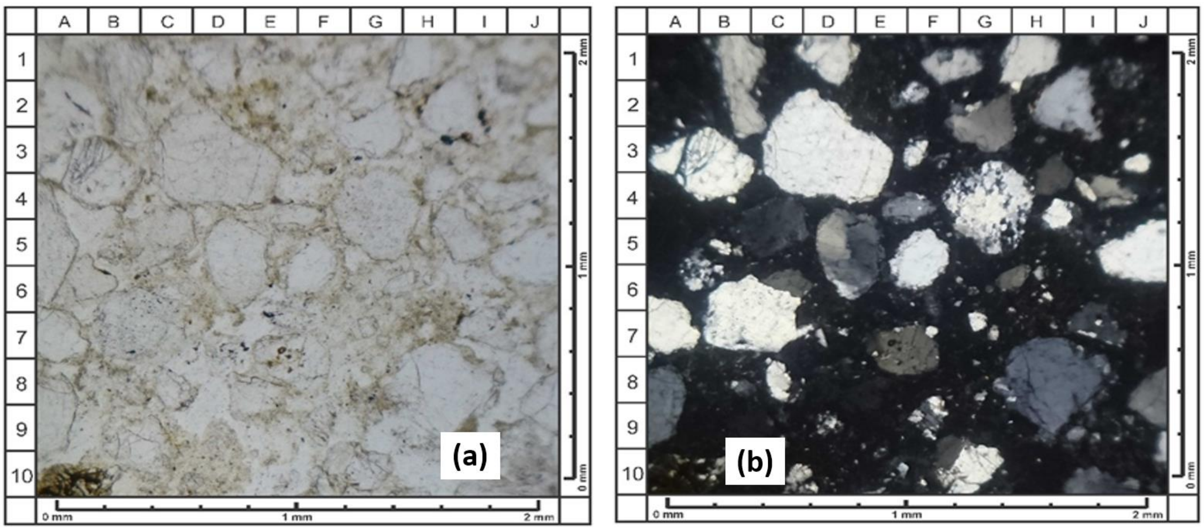

Figure 6. Sand sample L2.P22 (3 tablespoons), (a) Appearance of L2.P22 sand sample (3 tablespoons) PPL, and (b) microscope appearance of L2.P22 sand sample (3 tablespoons) XPL

Test results using the XRD method

Based on the results of the XRD analysis, rock minerals can be identified in each sample. The display of XRD test results on sandy clay rock samples in the research area is shown in Figure 7 and Figure 8, showing the presence of diffraction peaks [17,18]. Each spectrum (peak) that appears has a different intensity depending on the number of X-ray photons detected by the detector. Each spectrum that appears has a different intensity depending on the number of X-ray photons detected by the detector. This spectrum pattern arises as a result of X-ray diffraction from the plane of the rock sample being tested by XRD. The spectrum position determines the structure and crystal lattice parameters of the sample being tested [19]. The resulting diffractogram pattern shows that the minerals contained in the sample are still in the crystal phase.

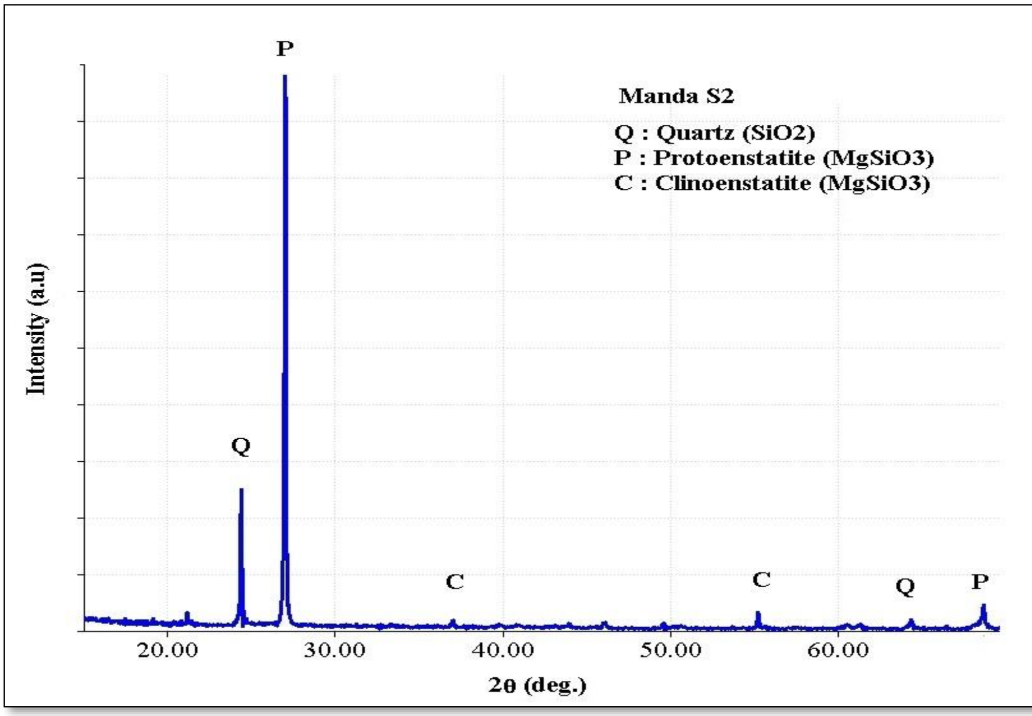

Figure 7. Results of analysis of rock sample L1.P3 using XRD

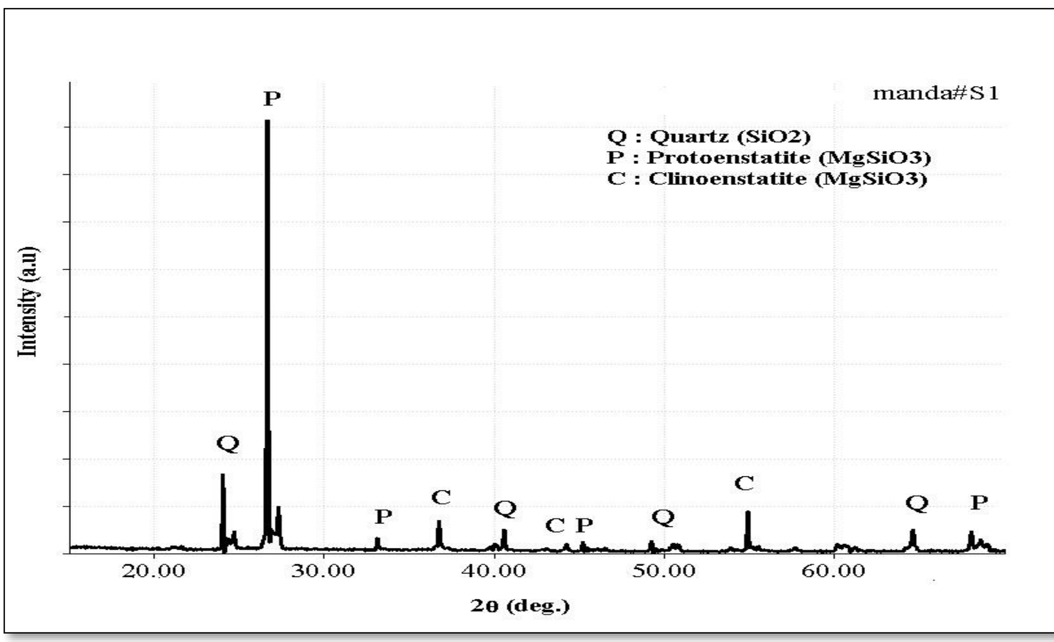

Figure 8. Results of analysis of rock sample L2.P22 using XRD

The results of qualitative analysis using XRD on both samples show that the diffraction pattern of each sample is dominated by the minerals Protoenstatite and Clinoentatite ($MgSiO_3$) and Quartz (SiO_2). The percentage of purity level is measured using intensity peaks and diffraction peaks [20]. This can be explained in Figure 9. The average percentage abundance of the main minerals that make up shallow hydrocarbon manifestation rocks in sample L1.P3 is Protoenstatite at 64.23%, Quartz at 22.63%, and Clinoentatite at 13.14%. Sample L1.P3 has the highest spectrum shown at a diffraction angle of 2θ = 26,450 with an intensity of 10,008 a.u. Furthermore, sample L2.P22 is Protoenstatite at 76.53%, Quartz at 14.29% and Clinoentatite at 9.29%. L2.P22 has the highest diffraction peak at an angle of 2θ = 27,130 with an intensity of 5,339 a.u. Thus, the average percentage abundance of Protoenstatite is 70.33%, Quartz is 18.46% and Clinoentatite is 11.21%.

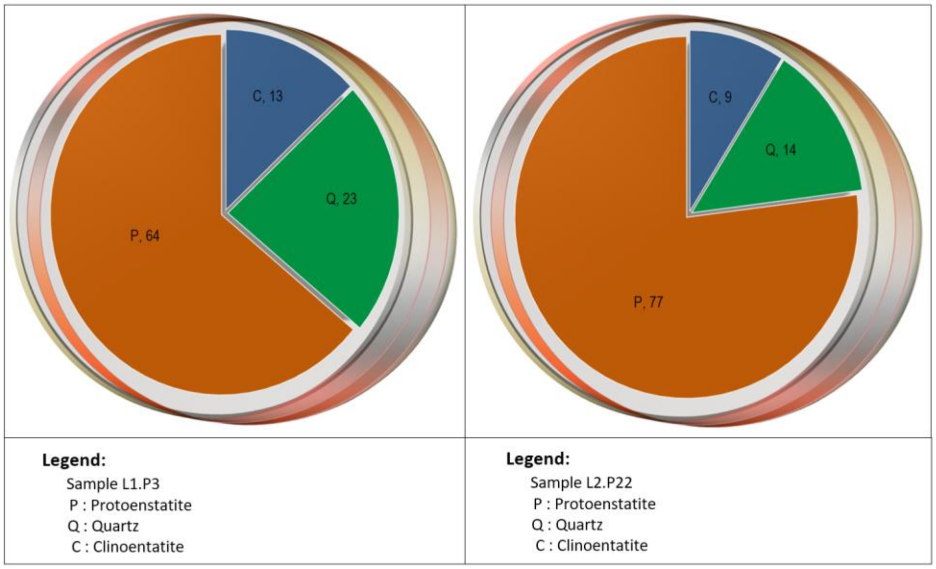

Figure 9. Minerals that make up rocks with shallow hydrocarbon manifestations

The rock abundance includes sandy soil used as a ceramic material consisting of Protoenstatile, Quartz, and Clinoestatile minerals [21, 22]. Protoenstatile mineral is a new mineral found in watermelon-colored Oregon sunstones. Protoenstatile is magnesium that occurs at very high temperatures. Protoenstatile occurs as a sediment layer associated with copper nanocrystals in gem quality labradorite phenocrysts (Oregon sunstones). Quartz mineral is a chemical compound consisting of one part silicon and two parts oxygen or commonly called silicon dioxide (SiO_2). Quartz is the most abundant mineral found on the earth's surface, and its unique properties can make it one of the most useful minerals [10]. Clinoenstatile mineral is a mineral produced from Protoenstatite in basalt rocks which are rich in magnesium.

The results of mineral physics analysis using petrography and XRD tests show that there are several different mineral elements in the rock. The differences in measurement results for these minerals are due to different measurement principles in petrography and XRD. Based on the results of the analysis of rock samples, quartz, and magnesium oxide minerals are present, so it can be said that the rocks at the research location are capping rocks. The cap rock with the mineral composition is SiO_2-$MgSiO_3$. The hydrocarbon source rocks in this area are estimated to come from the sedimentary rocks of the Fufa Formation [23,24]. Clastic sedimentary rocks of the Kanikeh Formation are also considered as source rocks for hydrocarbon manifestations at the research location. Based on the results of research conducted by [25], it shows that the hydrocarbon formations found in the Bula and Belis areas are sandstone which is suspected as a reservoir, clays which is suspected as caprock, traps in this petroleum system including structural traps. The Belis area, which is part of Waru Bay Sub-district, has the potential for a promising petroleum system in the future, because it is a former Dutch drilling site which is located right in the homes of local residents.

Conclusion

The results of the physical mineral analysis show indications of shallow hydrocarbon seepage due to the presence of the mineral Protoenstatite ($MgSiO_3$) with an average abundance of 70.33%, and the mineral Clinoestatite ($MgSiO_3$) with an average abundance of 11.21%. Samples at this location need to be identified in detail by carrying out Liquid Chromatography analysis. It is necessary to carry out an inversion analysis to get maximum results and first test the physical parameters of the rock in the laboratory. The hydrocarbon source rocks in this area are estimated to come from the sedimentary rocks of the Fufa Formation. They are considered source rocks for hydrocarbon manifestations at the research location.

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