MAPPING APATITE-ILMENITE RARE EARTH ELEMENT MINERALIZED ZONE USING FUZZY LOGIC METHOD IN SIJUK DISTRICT, BELITUNG

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Abstract. District of Sijuk located in Belitung Island is rich with non-lead mineral content. As the part of Southeast Asia's Lead Belt, the presence of Apatite-Ilmenite Rare Earth Element formed by the region's geological condition is very likely. However, there has not been any activity to map and identify the apatite-ilmenite distribution in this region. Therefore, the objective of this study was to map the mineralized apatite-ilmenite in Sijuk District. Using remote sensing technology, Landsat 8 OLI were utilized to map the distribution of mineralized apatite-ilmenite rare earth element. Alteration mineral carrier, geological structure, and lithology data were all used as variables. Landsat-8 was pre-processed using band ratio and Directed Principal Component Analysis (DPCA) method for gaining alteration variable. The fuzzy logic method was then deployed for integrating all data. The result of this research showed the potential distribution of mineralized apatite-ilmenite with a total area of 1,617 ha. The most prioritized areas for apatite-ilmenite mineral exploitation are located in Air Seruk Village's IUP (Izin Usaha Pertambangan/Mining Business License), Sijuk Village's IUP, and Batu Itam Village's IUP. This study also illustrates the orientation of the metal utilization of apatite-ilmenite in district Sijuk.

Keywords: *Apatite-ilmenite, fuzzy logic, Landsat 8, Rare earth elements*

1 INTRODUCTION

Rare earth element is not suitable as the name which consists of elements/metals are widely found quite a lot in nature. But the abundance of this mineral is not easy to find in large quantities because this mineral type is a mineral accessory or a disciple of other types of minerals. The use of rare earth element is very broad and closely related to high technology industrial products that make it as an economically valuable mineral (Suprapto 2009).

In Indonesia, the potential of rare earth element is present as a mineral accessory in alluvial gold and lead commodities. Suprapto (2012) mentions geologically, rare earth element can be found along with the formation of lead sediment. The Southeast Asia Lead line itself contains most of the world's lead resources through Indonesian territory ranging from Karimun Islands, Singkep to Bangka Belitung Islands. Lead mineralization in Southeast Asia is found in the granite belt that extends southward from China to Myanmar, Thailand, Peninsular Malaysia and to the Indonesian Lead Line, which extends from Riau Archipelago to Bangka Belitung

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(Sabtanto in Inatadaon 2015). Therefore, surely, these areas are also containing the potential for rare earth element sediment because they are associated with the formation of lead and gold minerals.

The Provincial Investment and Service Agency (*Badan Penanaman Modal dan Pelayanan Terpadu*/BPMPT) of Bangka Belitung Islands (Handayani 2016) said that in Bangka Belitung Islands itself, rare earth elements are a by-product of lead mining. The estimated potential of the hypothetical rare earth element in the Bangka Belitung Islands Province is 7,000,000 tons (Handayani 2016). The minerals that have economic value, that is ilmenite (32.43%), zircon (16.65%), cassiterite (12.59) and monastic (11.76%). Meanwhile, Suprapto (2009) mentions rare earth element can also be found in secondary minerals bastnaesite, monastic, xenotime, zircon, and apatite. These statistics certainly show the vast potential of rare earth metals in the Pacific Islands.

Sijuk district is geologically dominated by granite lithology in Trtg formation (Tanjungpandan). These granites were formed in Triassic to Limestone age, approximately 200 million to 65 million years ago (Geological Map of Belitung Sheet, Baharuddin, and Sidarto 1995). This rock is the result of the freezing of acid magma is with a high silica content of more than 65% and classified type of granite type "S" which contains a lot of basic minerals cassiterite as lead lines and rare earth elements.

Based on the explanation, Sijuk District, Belitung Regency is classified as a potential area for the distribution of rare earth element minerals with economic value. This is supported by statistical data from Provincial Investment and Service Agency (Handayani 2016) of Bangka Belitung Islands Province and the result of empirical method analysis of Belitung lithology relation with the potential of rare earth element formation. However, no specific mapping activities that have mapped the potential of rare earth element in Sijuk District. Therefore, it is necessary to mapping rare earth element as an effort to inventory the potential of natural resources in District Sijuk. Similar studies have previously been conducted by Berhe Abera (2005) in Western Ethiopia that detected the spread of the apatite mineralized zone using Landsat TM imagery. The method used by Berhe to detect the apatite mineralized zone is the band ratio by utilizing the Landsat TM 7/2, 5/1, and 3/1 bands. But, the variables used by Berhe in detecting apatite mineralization zone was just from alteration data of indicating minerals.

Yuniarsyah *et al.* (2013) used Crosta Technique to identify the alteration zone of gold mineralization by using Landsat 8 OLI. Moreover, Yuniar *et al.* (2013) only used the alteration zone as the variable to determine the mineralized zone of gold. Along with that, Han *et al.* (2015) use alteration zone and topography condition to describe and determine the mineralized zone pattern of gold in British Columbia. Both of the aforementioned studies didn't use the specific method for integrating all variables. Meanwhile, this study used other variables to get information about the apatite-ilmenite mineralized zone, namely lithology and geological structure which were integrated by the fuzzy logic method. It was all then deployed on Landsat 8 OLI, the latest generation of Landsat imagery.

Related to the exposure, the research "Mapping of Mineral Zone of Rare Earth Element Apatite-Ilmenite with Landsat 8 OLI" was conducted in Sijuk District, Belitung Regency. The objective of this research was to map the distribution of apatite-ilmenite mineralized zone in Sijuk District. Therefore, it is hoped that through this study, the distribution of apatite-ilmenite mineralized zone in the Sijuk District can be identified. The rare earth apatite-ilmenite ground mapping in Sijuk District was carried out by utilizing the Landsat 8 OLI (Operational Land Imager) image which has the ability to detect rare earth element minerals by recording spectral data of rare earth element minerals using band ratio method for gaining alteration variable. Meanwhile, the integration of all variables, namely alteration, lithology, and geological structure was done by the fuzzy logic method. The type of rare earth element that became the focus of this research is apatite-ilmenite which according to BPMPT Province of Bangka Belitung Islands (Handayani 2016) has economic value with the largest abundance (32,43%). Furthermore, the results of this mapping will be validated by the orientation of mining activities based on the priority scale of minerals mined in mining areas in Sijuk District. This paper was a development of an earlier paper that was published on Proceeding of "Seminar Nasional Penginderaan Jauh 2017".

2 MATERIALS AND METHODOLOGY

2.1 Location and Time of Research

The research area was conducted in Sijuk District, Belitung Regency. The analytical unit used was based on administrative boundaries based on the empirical approach that Sijuk District dominated by "S" granite lithology is a potential area of rare apatite-ilmenite earth element formation. This research was conducted for 3 months (February - April 2017).

2.2 Fuzzy Logic Method

The fuzzy logic concept is the development of Boolean / Classical logic, where Boolean logic states that everything is expressed in binary terms (such as 0 or 1, black or white, yes or no) (Faeyumi 2012). Fuzzy logic states everything expressed in terms of degrees of membership (such as between 0 and 1, "gray," "black" and "white", "a little", "middling" and "very") levels.

Moreover, fuzzy logic is including several memberships and operators. The memberships of fuzzy include are:

1. Fuzzy Small

   Fuzzy small is one of the functions in fuzzy logic, this function has the concept that to map something. If something gets closer or closer to the object in question it will produce a higher fuzzy value.

2. Fuzzy Large

   Fuzzy large is a reverse function of small fuzzy. In this function has the concept to map data sequentially. The greater the value of the data then the fuzzy value will be close to 1. Conversely the smaller the value of data, it will produce a smaller fuzzy value.

Based on classical theory, the member of an object in a collection of objects can only be expressed as a value of zero and one. While on the theory of fuzzy collection it is stated that a collection of fuzzy is described as a subset of objects where members in a collection of objects is a value of zero and one range (Faeyumi 2012).

Faeyumi (2012) explains that in GIS, the fuzzy values described as exploratory criteria can be combined or integrated using fuzzy logic operators including:

1. Fuzzy AND operator

   This AND fuzzy operator is the operator that generates the smallest fuzzy member value (minimum) of some input data.

The first operator is the AND fuzzy operator to merge the alteration data (alteration zone).

2. Fuzzy OR operator

This fuzzy operator generates the maximum fuzzy member value of some input data to generate a specific location.

This operator is effective in generating a potential map of an object (mineral) when the indication of mineralization is very rare and a positive indicator of one factor is sufficient to represent its prospectivity.

3. Fuzzy Gamma Operator

Fuzzy gamma operator is a combination of fuzzy algebraic product operators and fuzzy algebraic sum. The usefulness of fuzzy gamma applies when one or more data sets show the greatest possibility and the other shows the smallest. The combination of the two will produce the possibility of somewhere between the two possibilities, which is controlled by the magnitude of the gamma parameters used.

2.3 Research Framework

The selection of research areas was conducted with an empirical approach in which the presence of a mineral is associated with lithological conditions. In this case, the election of the Sijuk sub-district was done on an empirical approach that the conditions of granite lithology of type "S" in this region have the potential to have a rare earth element content of apatite-ilmenite.

This study uses three variables, namely mineral alteration data, lithology, and geological structure (lineation). Mineral alteration data were obtained from Landsat 8 OLI image processing, meanwhile lithology and geological structure data obtained from digitized Geological Map of Belitung Sheet Scale 1: 250,000. Research framework can be seen in Figure 2-1.

2.4 Data Acquisition

The research design for mapping the apatite-ilmenite rare earth element with the fuzzy logic method in Sijuk District, Belitung Regency starts with data collection and can be seen in Table 2-1.

Table 2-1: Matrix Data Collection

Data Types	Source of Data	Method	Output
1. Mineral Alteration 2. Lithology and Geological Structure 3. Map of Mining Business License Scale 1: 250,000	1. Processing Landsat 8 OLI (USGS) 2. Geological Map of Belitung Sheet (Baharuddin and Sidarto, 1995) 3. Ministry of ESDM 4. Field survey	1. Band ratio method of 7/3, 6/3, 4/2 2. Digitization from the map 3. Spatial interpretation 4. Digitization from map	The distribution of rare earth metal mineralized zone of apatite-ilmenite and the direction of its utilization in Sijuk District, Belitung Regency

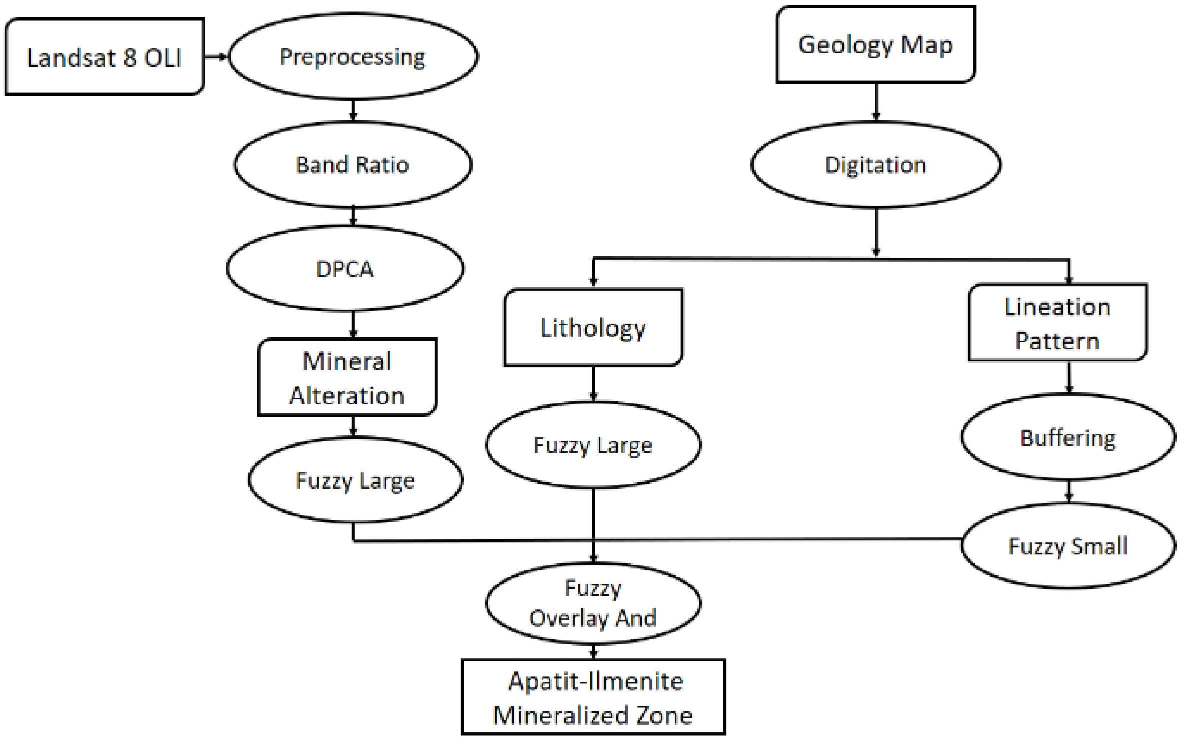

Figure 2-1: Workflow Chart

2.5 Data Processing

The initial data processing was done on Landsat 8 OLI satellite image. The pre-processing applied by doing a correction on the image to improve the visual quality using Envi software. Landsat 8 image was corrected for any radiometric error, i.e. errors in the form of shifting values or the gray level of image elements (pixels) in the image, in order to get closer to the supposed value. This correction was done by performing radiometric calibration to change the pixel values from DN (digital number) to top of atmospheric (ToA), followed by atmospheric correction using DOS method (dark object subtraction).

After the image was corrected, the distribution of mineralized zone of apatite-ilmenite metal was performed using ENVI and ArcGIS software. Using several band ratios of Landsat 8 OLI, different visual effects were obtained than corresponding to the certain object, one of which was the mineralized zones of the apatite-ilmenite rare earth element. The list of band ratios used in this study can be seen in Table 2-2.

The results from band ratio were then acted as the input for Directed Principal Component Analysis (DPCA). DPCA is a transformation that can minimize the vegetation effect on the earth surface (Pour *et al.* 2013). This step was also aimed to maximize the spectral response of each mineral. The determination of each band that will be chosen for mineral extraction depends on the eigenvector of each band. The band which has eigenvector more positive or more negative from the eigenvector of vegetation band will be selected as band extraction. Meanwhile, NDVI transformation was used as vegetation band that will be processed in the DPCA transformation.

After the processing of DPCA method, the mineralization process was performed on each mineral before it was extracted and further analyzed in ArcGIS Environment.

Table 2-2: Band mineral ratios Rare earth element apatite-ilmenite

No	Mineral/Bearer Stones	Band Ratio
1	Granite Mafic	7/3
2	Apatite-Ilmenite Hydroxide	6/3
3	Iron Oxide	4/2

(Berhe, 2005)

The classification was done by using the density slice method at the threshold value of each mineral. Formula 2-1 is used for find out the anomaly of mineral alteration by identifying the threshold value of each mineral.

$$Ai = \bar{X} + \sigma \qquad (2\text{-}1)$$

Where Ai is the mineral alteration, $\bar{X}$ is the mean of the threshold value, and σ is the standard deviation of the threshold. The determination of threshold value quantification of each mineral was done by calculating the mean value and standard deviation of digital number for each mineral detected. Furthermore, each of these alteration data will be processed further into fuzzy data with the fuzzy large operation.

Meanwhile, for the vector data, which includes lithology and the geological structure was obtained from manually digitized Geological Map of Belitung (Scale 1: 250,000). Based on the research of Geological Resource Center (2009) in analyzing the rare earth elements potential in Belitung Island, the mineralized zone of rare earth elements occurs in "S" granite type frozen rocks rich in rare earth element minerals. Based on that, lithology formation in Sijuk subdistrict will be classified based on its ability or not to produce rare earth element mineralization. The fuzzification process of this data was done by the fuzzy large operation (Faeyumi 2012).

The geological structure data was processed using buffer analysis on the geological structure (fault and folds). The buffer analysis was carried out at a distance of 250 meters to 2000 meters from the fault structure. The fuzzification process was performed with the fuzzy small operation (Faeyumi 2012).

After the initial data processing described above were all done, fuzzy overlay analysis was then deployed using gamma fuzzy operation. This method was done by integrating the processing result of the three variables with overlay concept. The results then consist of fuzzy potential zonation data of rare apatite-ilmenite metal earth element.

The information of the apatite-ilmenite potential mineralized zones will then be used in determining and creating work maps for data validation. Sample points were then determined as the reference used for data validation. The data validation was performed by matching the interpretation results of remote sensing images with conditions in the field. The work map in this study can be seen in Figure 2-2.

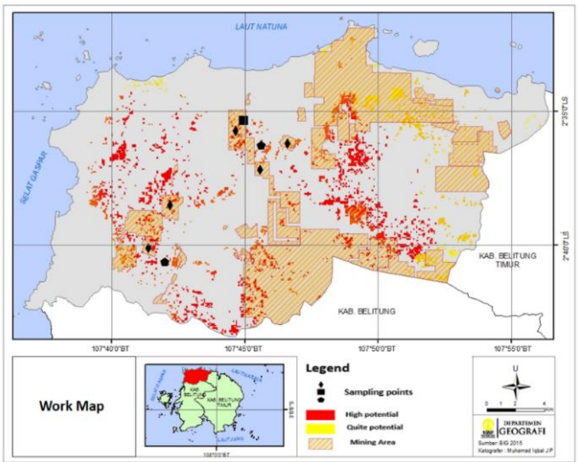

Figure 2-2: Map of research work

The final step in this research was to update the potential map of the mineral zones of the apatite-ilmenite rare earth element. This process was done by doing a field survey. Direct observation on the local geological conditions and mineralogical contents were done related to the apatite-ilmenite potential map obtained earlier. The correct number of reference and processed results were then calculated for the accuracy.

2.6 Data Analysis

This analysis was performed by identifying the distribution of physical variables that have a role in the process of mineralization of rare apatite-ilmenite earth element such as the existence of geological structures (faults and folds) in relation to alteration of rare earth element carrying minerals that fill the fractures. In addition, lithology is associated with the lithology of rare earth element minerals apatite-ilmenite. All of the above analysis was done using descriptive analysis.

Moreover, the analysis was also conducted to determine the orientation of rare earth metal utilization. The analysis of this variable was done by interviewing informants who perform mining activities at the mine points scattered in the area of Mining Business License (IUP) as well as informants of local government officials. The data obtained then processed to determine the scale of the minerals mined priority based on the mineralized zone map of rare apatite-ilmenite earth metals.

3 RESULTS AND DISCUSSION

3.1 Characteristics and Distribution of Mineral Zone of Rare Earth Element Apatite-Ilmenite in Sijuk District

The DPCA transformation produced several bands with different eigenvectors and can be seen in Table 3-1. From Table 3-1, the 4/2 ratio (Iron Oxide) will be selected from DPCA4 because the more negative value of eigenvector than NDVI that resulted in this transformation. Then, band ratio 6/3 (Apatite-Ilmenite Hydroxyl) will be selected from DPCA3 because the eigenvector is more positive from NDVI. Meanwhile, the band ratio 7/3 (Granite Mafic) will be extracted from DPCA1 because the eigenvector on this band is more negative than other bands.

Table 3-1: Eigenvector of DPCA

Eigenvector	NDVI	4/2	6/3	7/3
DPCA1	0	0	0	-1
DPCA2	1	0	0	0
DPCA3	-0.22	0	0.9	0
DPCA4	0	-1	0	0

(Source: data processing, 2016)

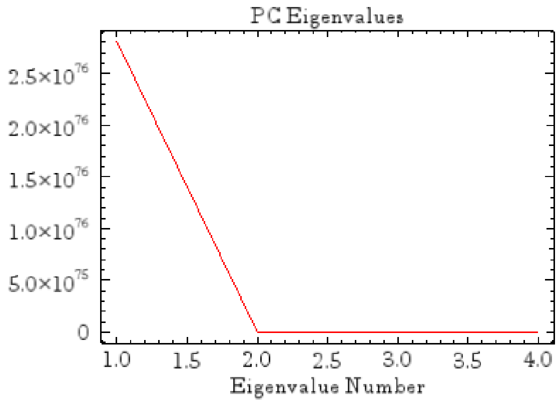

Figure 3-1: Eigenvalue of DPCA

Table 3-2: Alteration threshold

Alteration	Min	SD	Max	Alteration Threshold
Granite Mafic	164,7	67,0	255	231,8
Apatite-Ilmenite Hydroxyl	111,3	45,8	255	157,2
Iron Oxide	137,7	47,7	255	185,5

Source: data processing, 2016

Table 3-2 shows the list of a threshold value for each mineral that carried out by Formula 2-1. Granite mafic has alteration threshold of 231.8, apatite-ilmenite hydroxide has alteration threshold of 157.2, and iron oxide has alteration threshold of 185.5.

Moreover, mineralized zone distribution characteristics of the apatite-ilmenite rare earth are essentially the result of the integration of all variables treated with fuzzy logic function and one fuzzy operator, fuzzy gamma. The results of the potential visibility of the metal mineralization can be seen from the fuzzy values that range from 0 to 1. The fuzzy value close to 1 indicates that the area has potential to contain mineral mineralization of apatite-ilmenite. It indicates that between the potential of rare earth element content and physical variables are all located not far from the geological structure line, located in the "S" granite lithology, and is rich alteration zone of mineralization of rare earth element carriers.

The result of the potential integration of the rare earth element mineralized zone apatite-ilmenite was classified from potentially very high with a fuzzy value of 1 to highly unlikely potential with a fuzzy value of 0. Meanwhile, the others value in-between indicated a potential tendency. However, the potential area of rare earth element mineralization was also associated with the existing conditions in the field, and in this case was the existence of the mine area and the area of Mining Business License (IUP/*Izin Usaha Pertambangan*). This was done to facilitate the observation based on the data of excavation and geological condition on the excavation point. The results of the survey showed the alleged stratigraphy of apatite-ilmenite minerals at the area of active mining activities in Air Seruk Village and Air Selumar Village. In the field observation, a black stratigraphy appears indicating the physical appearance of the apatite-ilmenite mineral.

Areas that have the moderate potential of rare apatite-ilmenite earth element mineralization are distributed around the areas that have a high potential of apatite-ilmenite minerals. The further of the high potential areas, the diminished fuzzy value (0) indicates reduced potential level. However, low potential distribution or no potential does not mean that the area does not contain the apatite-ilmenite mineral potential, but whether or not the potential remains.

Based on the map, it can be seen as a reasonably large area that has the potential to have apatite-ilmenite rare earth element. Area categories can potentially be divided into two types, ie areas with potential rare earth element content to be assessed from the existing condition of the area. Figure 3-2 shows a map of the potential mineralized area of rare apatite-ilmenite earth element in Sijuk District.

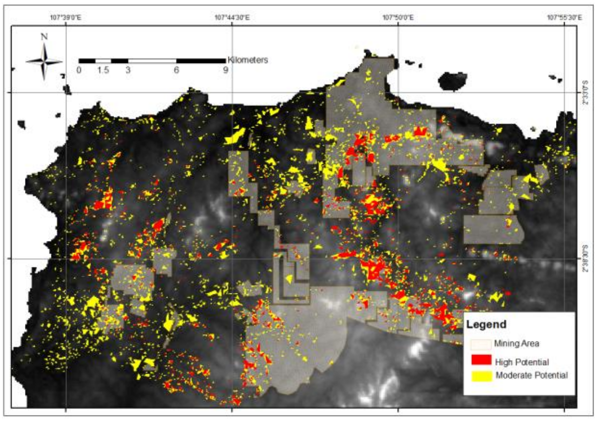

Figure 3-2: Map of potential distribution of mineralization

Potential area information in IUP areas is important information for the exploitation phase because these areas already have the license for exploitation. Meanwhile, potential areas of rare earth element content in non-IUP areas cannot be exploited. Complete information on the potential area can be seen in Table 3-3.

Table 3-3: The extent of potential rare earth element apatite-ilmenite

Types of Region	Area (Ha)
IUP Region	696
Non-IUP Region	921

Source: Data Processing

Meanwhile, from Figure 3-3, information on the potential mineral mining area of apatite-ilmenite can be determined based on the characteristics of its location distribution and the type of area. Areas with very high potential to be mined may be based on the potential distribution characteristics of potential areas that are classified and located within IUP locations. This is because if mining is worked in these areas, then the mining activities are in accordance with the regulation of the spatial region (licensed area) and the amount of excavated material that can be obtained will be more and can cost efficiency of mining.

Based on this, it can be determined by three main regions of excavation, namely the western region, the northeast, and the middle. The three regions visually in Figure 3-2 appear to meet two conditions, namely the potential and centered potential distribution of the area and are located within the IUP area.

Thus, it is suitable for mineral mining area of rare earth element apatite-ilmenite. The location was also proven to contain an indication of apatite-ilmenite mineral content based on field survey activities in Air Seruk Village. In Figure 3-3, these areas are shown in green circles.

Spatial analysis was conducted to determine which areas have a high potential for exploration using potential assessment method. This method compiles the parameter of mineralized area, the percentage of the mineralized area to the IUP region, and the distribution characteristic pattern. The scoring was done on IUP region per village administration area in order to know the area with the highest potential value for the exploited apatite-ilmenite mineral. These characteristics can be seen in detail in Table 3-4.

The percentage of the area of mineralization and spreading pattern contains scores with values of 1, 2, and 3. The greater the percentage of the area of mineralization, the resulting score will be even greater. Meanwhile, according to the scattering pattern, the scatter pattern has a score of 1, elongated has a score of 2, and the pattern of grouped mineralization has a value of 3. The scores of each parameter are then summed resulting in a final score that will determine the potential classification of each IUP area by village area. Total score 0-3 classified Low Potential, score value 3,1-6 classified Medium Potential, and score value 6,1-9 classified High Potency. The full results of the potential scoring method can be seen in Table 3-5.

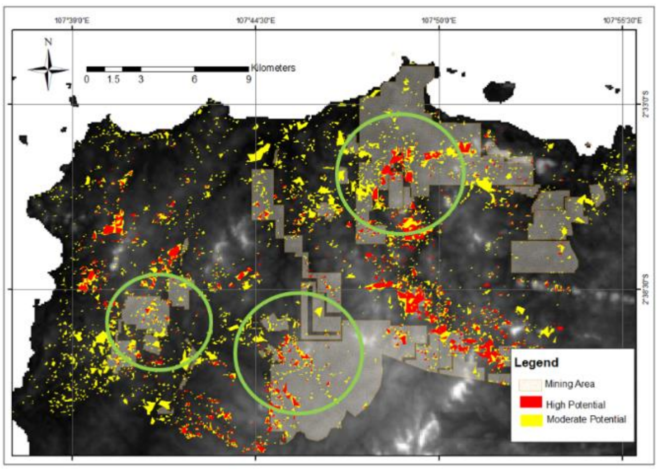

Figure 3-3: Map of exploitation priority

Table 3-4: Characteristics of the mineralized area of rare apatite-ilmenite earth element

IUP Village Area	Area of Mineralization (ha)			Pattern of Distribution
	High Potential	Mid Potential	Total	
Air Selumar	69	156	225	Spreading
Air Seruk	82	184	266	Grouping
Sijuk	57	212	269	Grouping
Sungai Padang	83	242	325	Lengthwise
Batu itam	9	42	51	Grouping
Palepakpute	214	273	487	Spreading

Source: data processing, 2016

Table 3-5: Classification of potential areas based on potential scoring results

IUP Village	Scorring Pattern Distribution (%)		Scorring Pattern Distribution	Total Scoring	Classification
	High potential	Mid Potential			
Air Selumar	1	3	1	5	Average
Air Seruk	1	3	3	7	High
Sijuk	1	3	3	7	High
Sungai Padang	1	3	2	6	Average
Batu Itam	1	3	3	7	High
Palepakpute	2	2	1	5	Average

Based on the results of the scoring calculation, it is found that IUP area of Air Seruk Village, Sijuk Village, and Batu Itam Village have high potential and very good for exploitation of containing apatite-ilmenite metal. Meanwhile, the IUP area in Air Selumar Village, Sungaipadang Village, and Palepakpute Village have a moderate potential.

3.2 The Result of Field Survey

The orientation of rare apatite-ilmenite earth element utilization in Sijuk District, Belitung Regency can be seen from how information and knowledge of society and government officials about the type of mineral itself. In addition, the miners' knowledge of this type of minerals was able to illustrate how the orientation of mineral utilization in this period.

Based on field survey activity by interview method, it was found that the orientation of mineral utilization of apatite-ilmenite in Sijuk District still not very good. The society and government has not much knowledge about the

potential existence of apatite-ilmenite minerals that exist in their region.

However, in the area of Air Seruk Village, there is an indication of the presence of mineral apatite-ilmenite. This is based on mineral stratigraphic findings that resemble apatite-ilmenite formation. These findings certainly need to be supported by laboratory tests to ensure the accuracy of apatite-ilmenite minerals based on laboratory testing. The result of validation can be seen in Table 3-6.

Utilization of apatite-ilmenite metal in the context of self-exploitation can be done by referring to mining priority areas which can be seen in Figure 3-3. In the figure, the priority area of apatite-ilmenite mining is prepared on the basis of the territory belonging to the IUP (Mining Permits) potentially clumping potential areas. It means, the area visually from the map is an area that will be greatly benefited to be mined from an economic point of view. Administratively, the area is one of them located in Air Seruk Village. Thus, referring to this information, the Air Seruk Village can exploit the potential of rare earth element apatite-ilmenite wisely as an economically valuable resource.

However, research to identify apatite-ilmenite mineralization distribution with fuzzy logic method integration has not yet resulted in accurate research results. This is evidenced by the discovery of only two positive results from eight samples (25%) of suitability between models with real conditions in the field (Table 3-6). The low level of model accuracy can be caused by two reasons, namely because the algorithm method fuzzy logic does have a poor accuracy or due to low spectral capabilities of Landsat 8 OLI caused by the magnitude of spatial resolution of 30 x 30 meters. This deficiency indicates the imperfect fuzzy logic algorithm or Landsat 8 OLI used in identifying the phenomenon of apatite-ilmenite mineralization.

Table 3-6: Sampling Location

Coordinate		**Data Target**	**Method**	**Result**
Latitude	**Longitude**			
2.676 S	107.699 E	Apatite-Ilmenite Mineralized	Observation and Interview	Positive
2.585 S	107.801 E	Apatite-Ilmenite Mineralized	Observation and Interview	Negative
2.605 S	107.76 E	Apatite-Ilmenite Mineralized	Observation and Interview	positive
2.652 S	107.831 E	Apatite-Ilmenite Mineralized	Observation and Interview	Negative
2.62 S	107.76 E	Apatite-Ilmenite Mineralized	Observation and Interview	Negative
2.674 S	107.752 E	Apatite-Ilmenite Mineralized	Observation and Interview	Negative
2.668 S	107.689 E	Apatite-Ilmenite Mineralized	Observation and Interview	Negative
2.462 S	107.704 E	Apatite-Ilmenite Mineralized	Observation and Interview	Negative

4 CONCLUSIONS

4.1 Conclusions

Potential distribution of rare apatite-ilmenite element mineralization in Sijuk District, Belitung Regency is formed following the direction of geological structure distribution, lithology, and alteration data of carrier minerals with characteristics close to the fault structure, located in "S" granite lithology, and alteration of minerals, which is indicated by the fuzzy value approaching the value 1. The farther from the center of the high potential area, the fuzzy value closer to the value 0 indicating the area has no apatite-ilmenite mineralization potential.

The priority areas of mineral exploitation of apatite-ilmenite in Sijuk sub-district are IUP areas in Air Seruk Village, Sijuk Village, and Batu Itam Village. These areas have a high potential level for apatite-ilmenite mineral exploitation.

Meanwhile, the orientation of this mineral utilization in Kecamatan Sijuk is still not very good even though the statistical data shows the amount of mineral apatite-ilmenite potential abundance in Sijuk District. This is because people's dependence on tin mining is still bigger than apatite-ilmenite minerals.

4.2 Suggestions

The results show that satellite images, Landsat 8 OLI satellite can be utilized in the mapping of mineral resources in a region. However, the utilization of this type of satellite imagery in mineral resource mapping is constrained by the low level of information detail given the spatial resolution in the range of 30 x 30 meters. Therefore, mapping of mineral resources such as rare earth element should be possible using satellite imagery that is doing better by spatial resolution such as Sentinel 2 (10x10 meter) satellite images, ASTER (15 meters), or GeoEye-1 (0.5 meters).

In addition, the mapping results are still basic information and early stage in mining exploration activities. Therefore, to ensure more accurate results, it is necessary to conduct a laboratory test that measures precisely the chemical content so as to determine the exact distribution of apatite-ilmenite minerals in Sijuk District as a geological resource for the area.

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