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INTEGRATION OF LANDSAT AND SRTM DATA FOR PRELIMINARY EXPLORATION OF BAUXITE DEPOSITS, CASE STUDY: SOUTH EASTERN BINTAN ISLAND, RIAU ISLANDS PROVINCE

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Abstract: Bintan and surrounding islands are well known for the vast reserves of bauxite deposits in Indonesia. In Indonesia, Bauxite is generally formed through a laterization process of rocks such as granite, granodiorite, diorite, gabbro, and andesite which are rich in aluminosilicate minerals containing aluminum oxide (Al2O3). At this time with very high exploration costs, a minimal cost exploration support method is needed to find new potential reserves. Thus, remote sensing techniques can be effectively used as tools to identify the potential areas that contain bauxite deposits. This study presents the use of Landsat 7 and 8 imagery data from years 2000 and 2020, integrated with SRTM to analyze the spatial distribution of bauxite deposits around the Southern Bintan Islands. These data were processed and analyzed by the response of soil reflectance which may be similar to the mining/ex-bauxite mining area. The interpretation keys such as color, morphology, texture, and geological knowledge are used as a guidance of visual interpretation. The results of this study show that the region with bauxite potential has a slightly dark red color characteristic and a small partition of dark white in band 457 (Landsat 7) and 567 (Landsat 8). In addition, the morphology shows a gentle slope with a smooth to slightly rough texture. One of the small islands located in the southeast of Bintan Island, namely Poto Island, has these characteristics. Thus, it can be concluded temporarily that Poto Island has bauxite potential until the detailed mapping is carried out in further research.

Keywords: Bauxite, remote sensing, Southeastern Bintan Island, Poto Island

Introduction

Bintan and the surrounding islands is one of the islands which is rich in bauxite content. However, there are also other mining commodities such as sand, andesite, granite and tailings from bauxite processing (Rohmana, 2007). This is due to the fact that Bintan and its surroundings are traversed by the granitoid path of Southeast Asia that spread from Burma to Bangka Belitung (Cobbing, 1992). There are various types of granite through which the granitoid belt passes.

Bintan and its surrounding islands are composed of I-type granite (Crow, 2005). This I-type granite is a batholith pluton that acts as a source rock of bauxite in the Bintan area and its surroundings (Hutabarat,

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2016), which is also found on Selayar Island to the north of Singkep Island (Irzon, 2018). The formation of bauxite is the result of chemical weathering of the source rock which is rich in alumino silicate (Ahmadnejad *et al*., 2017; Alex and Kumar, 2017; Argyraki *et al*., 2017; Buccione *et al*., 2016).

Exploration of new bauxite reserves is quite expensive task. Therefore, application of remote sensing data (Landsat data and SRTM) and processing the color patterns produced on the former bauxite mine. It is very useful in a preliminary study to determine the potential resources of bauxite minerals in the Southeastern Bintan and its surroundings areas. The study area is administratively included in two sub-districts, namely East Bintan District and Mantang District. These two sub-districts are part of the Bintan Regency (Figure 1).

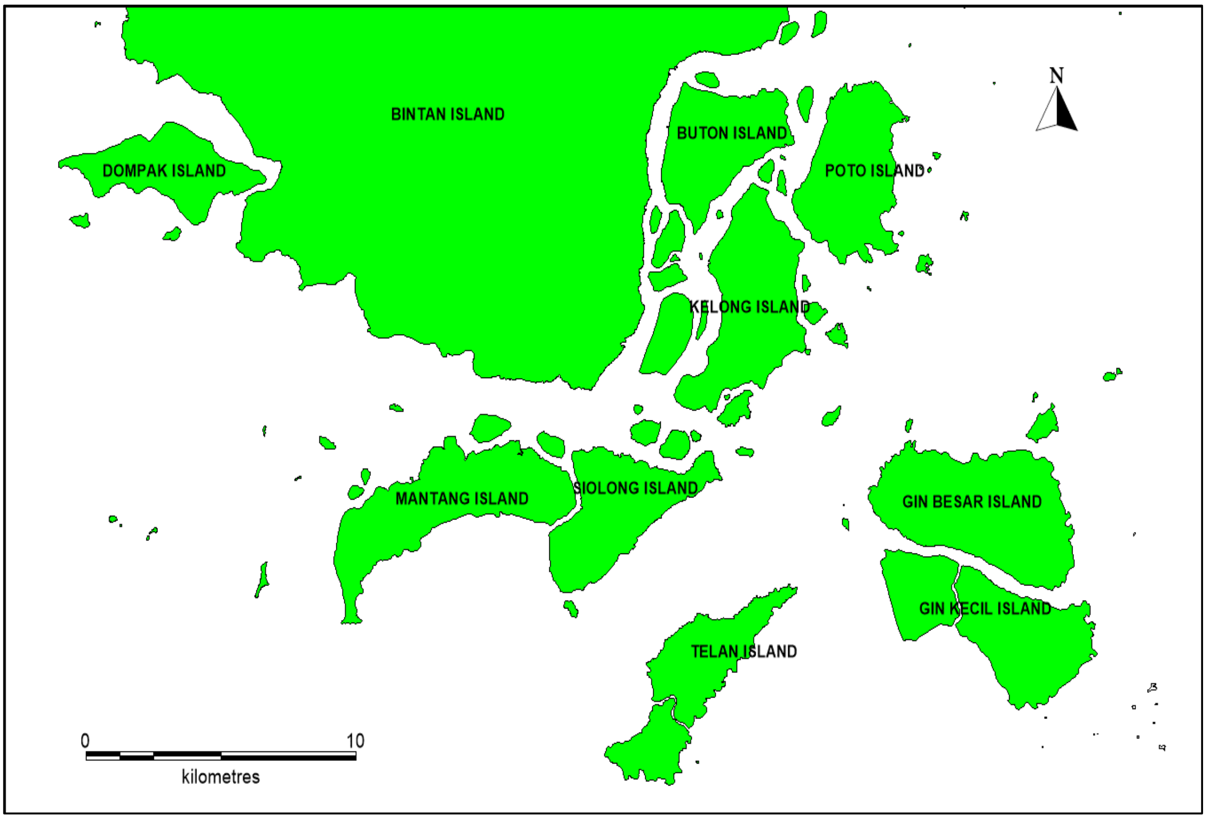

Figure 1. Map of Study Area

Regional Geology

Regionally, geological formation of Bintan Island and its surroundings to Kundur Island belongs to the Triassic - Cretaceous era are part of the East Malaya Block (Figure 2), which consists of sedimentary rocks derived from continental crust (Crow and Barber, 2005). Metcalfe (2013a, 2013b) also agrees that these islands are still part of the East Malaya Block because there is also an I-type granite intrusion which describes the continuity of the Sukathai Arc (Figure 2).

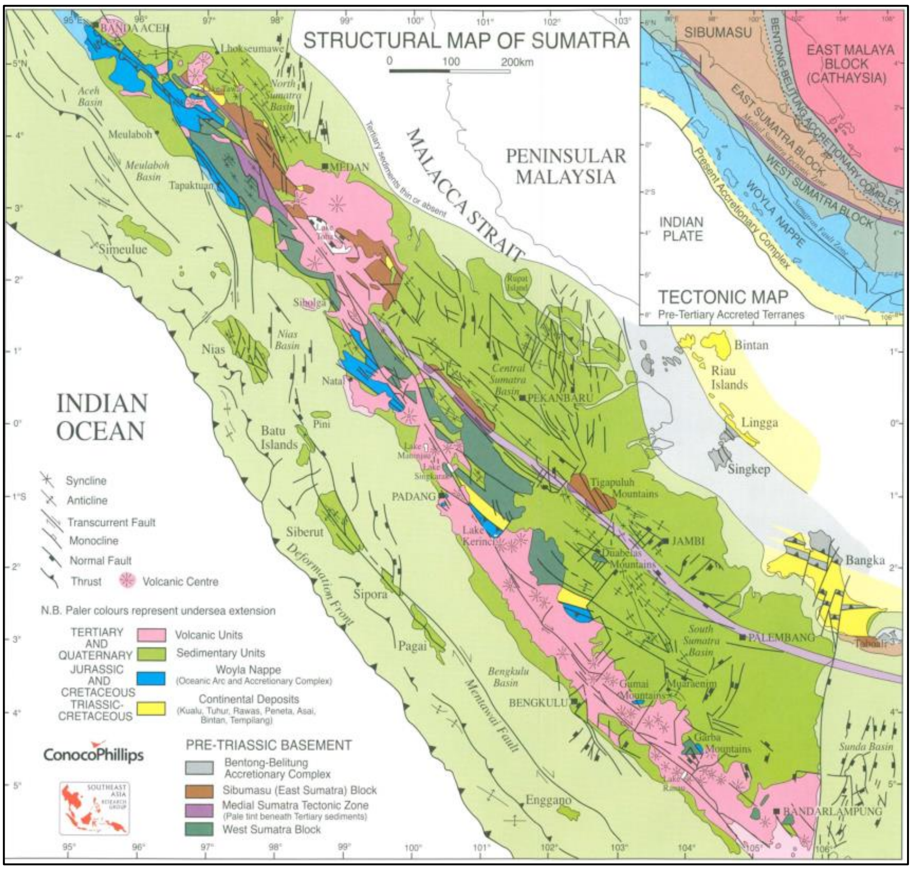

Figure 2. Regional Structure Map of Sumatera (Crow and Barber,2005)

Regional stratigraphy of Bintan Island and its surroundings is composed of several rock formations (Kusnama, 1994), namely:

Late Triassic Granite (Trg), reddish gray color, coarse grained. The mineral composition consists of quartz, hornblende, and biotite. Mineral assemblages displays primarily texture represent a plutonic batholith which is widely exposed on Batam and Bintan Islands. The results of weathering processes produced economic minerals such as bauxite. Based on the location and mineral composition, this granite rock is divided into several plutons such as the Kawal Granite Pluton in Bintan and the Nongsa Granite Pluton in Batam.

Middle Miocene - Late Miocene (Tma) Andesite rocks, gray in color with mineral composition is consisting of plagioclase, hornblende, and biotite. Porphyritic texture with a micro-crystalline base mass of feldspar crystals, this rock is partially expanded and is generally found in the form of fresh rock.

The Tanjungkerotang Formation is Middle Miocene - Early Pliocene (Tmpt): This formation is conglomerate type and comprises of various materials with components such as granite, quartz sandstone, feldspar and metamorphic embedded in a well consolidated coarse sandstone matrix. There is a layer structure with cross-shaped. It is suggested that this formation was deposited in the terrestrial and coastal environment. The thickness of this formation is estimated around 600 meters.

The Goungon Formation is Pliocene - Plistocene (QTg) age: This formation is composed of tuffaceous sandstones which have a white colour, fine - medium grained, parallel lamination structure. In addition, there are also siltstone, dacitic tuffs and white feldspatic lithic tuffs, fine grains, locally interspersed with tuffaceous sandstones, showing the presence of parallel and cross-sectional laminated sedimentary structures. There are also reddish white tuffs and slightly carbonated gray siltstone containing plant remains. This formation is limited by unconformities with the Tanjungkerotang Formation. The thickness of this formation is estimated to be up to 200 meters.

Holocene aluvium (Qa), this alluvium consists of sand, with a yellowish red color with the main mineral composition in the form of quartz, feldspar, hornblende and biotite which are also thought to be weathered products of granite. In addition there are conglomerates with gravel, granite and sandstone components, poorly sorted and not well consolidated. These rocks cover by unconformities with the older rocks. These stratigraphic sequences are summarized in a stratigraphic column (Figure 3).

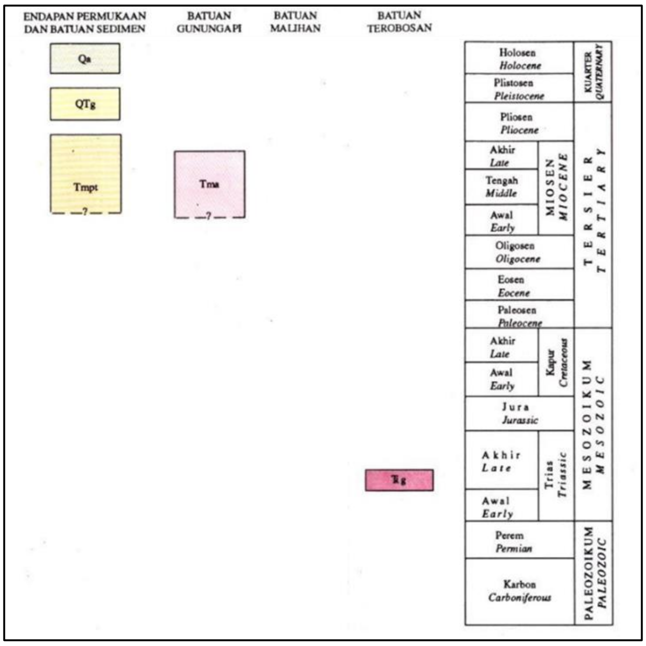

Figure 3. Stratigraphy Column of Bintan Island and Surrounding (Kusnama, 1994)

Bauxite in Bintan Island

The bauxite mine on Bintan Island has existed since 1935 with a total production of 10,000 m^3 / ton and has accelerated production to 200,000 m^3 / ton in 1938 (van Bemmelen, 1941). The exploitation of bauxite in Bintan Island is the largest in the Asian region, and is one of the most important bauxite suppliers in the world, most of the bauxite in Bintan Island is the result of lateritization.

Bauxite laterite is a concretion layer which is rich in aluminum and iron, reddish-brown in color due to presence of iron oxides, and is present in subtropical - tropical regions (Toreno, 2012). Toreno (2012) also states that bauxite is included in the aluminum hydroxide group such as gibbsite (Al $(OH)_3$), boehmite (y-AlO (OH)) and diaspor (α-AlO (OH)).

It is derived from weathering process which causes the dissolution of Na, K, Mg and Ca elements to become residual alumina hydroxide (Al $(OH)_2$). This residue became hardens to form bauxite after experiencing a dehydration process. Laterite according to Eggleton (2001) is the upper part of the land horizon which is rich in iron oxide and poor in silica as a result of the intensive weathering of regolith.

Bauxite concretion in Bintan Island occurs at the top of weathered granite rock and on the weathered clay shale (van Bemmelen, 1941). For further bauxite exploration, it needs to be directed to areas that have similar conditions to the existing bauxite mine.

Methods

This study uses Landsat 7, Landsat 8 and SRTM imagery data to be interpreted visually in order to map the distribution of landforms associated with surface geological conditions. Changes in land use were obtained from multitemporal image analysis of Landsat 7 in year 2000 and Landsat 8 in year 2020. The two Landsat image datasets were made of a composite band RGB 321 (natural color) and 457 on Landsat 7, as well as RGB 432 (natural color) and 567 on Landsat 8. The selection of the composite band is based on wavelength to be able to display images of the real appearance of the earth (natural color) and images to facilitate interpretation and identification of surface geological conditions.

Two images are then overlaid with SRTM data that has been shaded relief in order to obtain the morphological appearance so as to sharpen the geological analysis of the surface area.

Result

The result of combining SRTM imagery with Landsat RGB using data from years 2000 and 2020 shows hues and textures that describe the condition of the rock on the surface. The results of this data processing can be used to identify the initial stages of rock formation on the surface, such as research conducted by Firdaus (2018), Puspitasari (2016), Ismawati (2014), and Reditya (2010). Previous research has shown rock formations that represents more detailed and diverse features than regional geology at a scale of 1:100,000 (Firdaus, 2018). However, when this method is used in the southern area of Bintan Island and its surroundings it shows that there are 3 groups with 2 rock formations as a constituent.

Image Interpretation Result

Based on the results of the interpretation, there are 3 groups, namely: granite and lateritization, sandstones and mining / ex-mining areas.

Granite and lateritization

The results of SRTM and Landsat image processing with the 457 band composite show a slightly dark red color which is partly mixed with a slightly dark white color. The composite band 321 shows a medium green color which is partially mixed with brown, bright red and dark green. The red color is slightly darker in the 457 band composite or the bright green color in the 321 band composite, due to the growing vegetation that is not too dense because the surrounding land has a porosity that is not too good to absorb water. The morphology of the area shows relatively gentle slope, except for the southern part of Siolong Island which shows a steep slope.

The texture looks from a smooth to slightly rough. With these characteristics, this area is interpreted as an area dominated by granite and weathered rocks (Figure 4). When compared with regional geology, areas that have these characteristics are included in the late Triassic Granite (Kusnama, 1994).

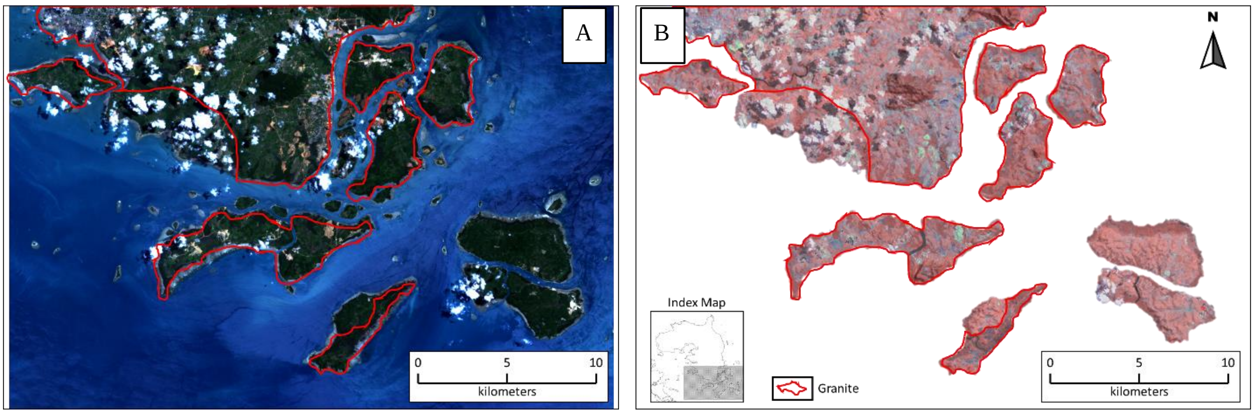

Figure 4. Interpretation of Granite used Landsat 7 + SRTM: A) Band 321; B) Band 457

Sandstone

The results of SRTM and Landsat 7 image processing with the 457 band composite show a bright red color which is partly mixed with a slightly dark red color. The composite band 321 shows a dark green color which is partially mixed with medium green. The bright red color in the 457 band composite or the dark green color on the 321 band composite is due to the growing vegetation that is quite dense because the surrounding land has good porosity to absorb water. The morphology of this area shows relatively sloping relief with visible dendritic flow patterns, and the texture looks a bit rough. With these characteristics, this area is interpreted as an area dominated by sandstone lithology (Figure 5). When compared with regional geology, areas that have these characteristics are included in the Pliocene - Pleistocene Goungon Formation (Kusnama, 1994).

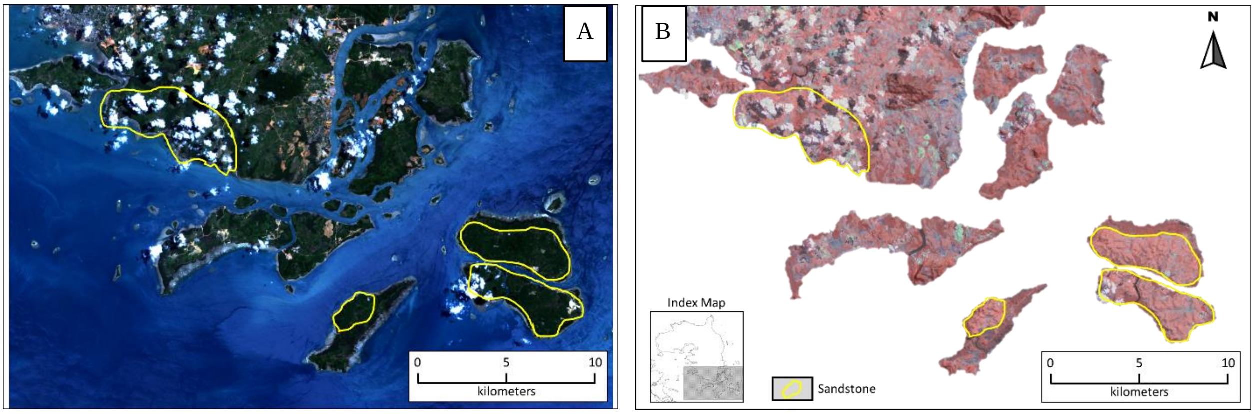

Figure 5. Interpretation of sandstone used Landsat 7 + SRTM: A) Band 321; B) Band 457

Mine / ex-mining area

The results of SRTM and Landsat 7 image processing with the 457 band composite show a dark white color. The composite band 321 shows a medium brown / light brown color. This color indicates open field where there is no vegetation. The morphology of this area shows a sloping relief with a smooth texture. These characteristics are interpreted as either active or ex-mining areas (Figure 6). Figures 6A and 6B are image data from year 2000. In (year) 2000, it was seen that mining activities were still not very intensive, so that the vegetation was still quite good and dominated 80 - 90% of the islands. The next 20 years or 2020, shows a very significant change. Where the mining/ex mining areas in Figures 6C and 6D are dominated around 30-90% and getting wider.

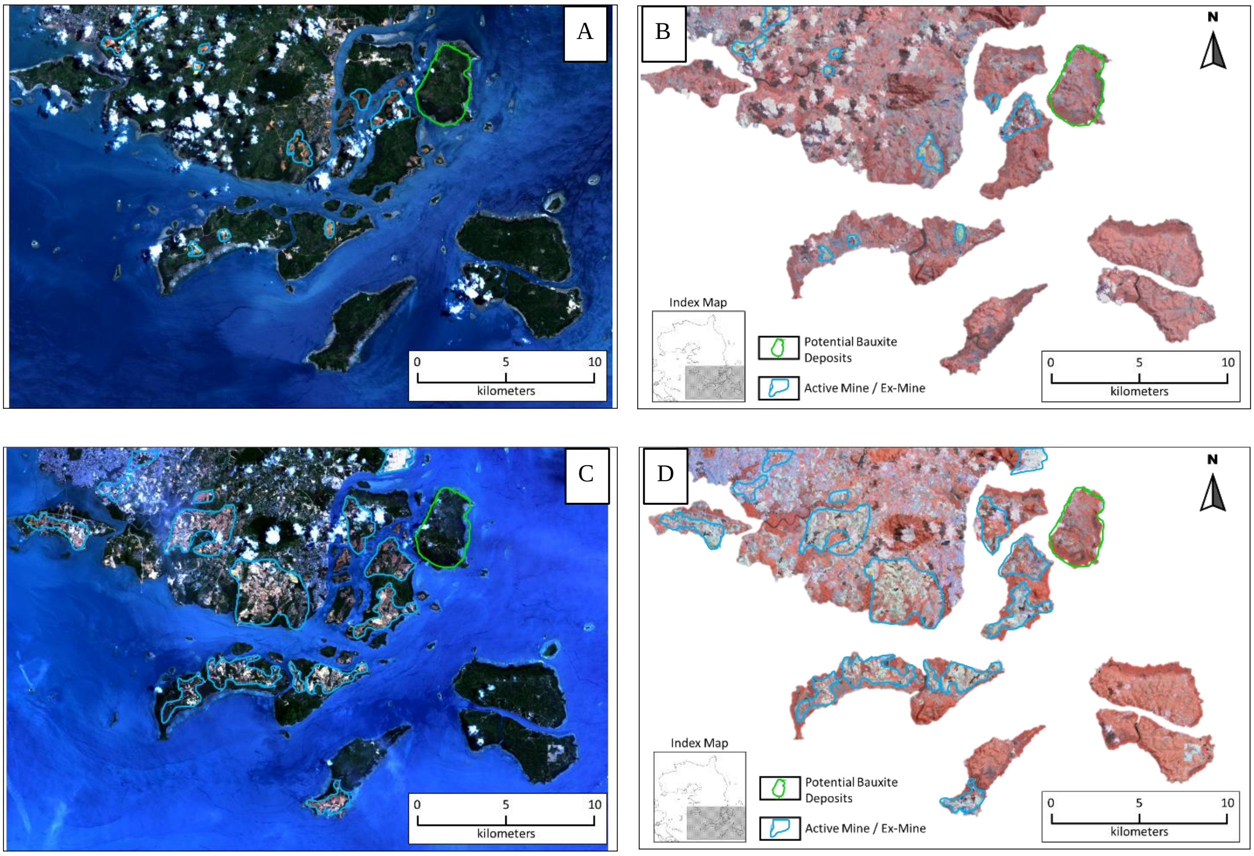

Figure 6. Interpretation of Bauxite Mining used Landsat + SRTM: A) Band 321 in 2000; B) Band 457 in 2000; C) Band 432 in 2020; D) Band 567 in 2020

Discussion

Based on the interpretation of Landsat+SRTM imagery in 2000 and 2020, most of the islands around Southeastern Bintan Island show a lot of development in the bauxite mining/ex mining area which can be seen from changes in texture, morphology, and color characteristics. Almost all islands are interpreted as granite clusters or lateritization zones from 2000 and 2020 have extensive mining/ex-mining areas. This proves that the weathered granite area has the potential for bauxite deposits. The weathering of this granite are also seen in North Bintan and East Bintan with the appearance of "corestone" (Hutabarat, 2016).

There is no exception for small islands around Southeastern Bintan Island where mining/ex mining activities are visible, but this is not seen in Gin Besar Island, Gin Kecil Island, and Poto Island. Gin Besar and Gin Kecil Island when we viewed in terms of texture, morphology, and color characteristics, these islands have similar lithology with sandstone. So, this area has limited potential resources for bauxite deposits. In spite of that, Poto Island has different characteristics from Gin Besar and Gin Kecil Islands. This island shows the same lithology, texture, morphology, and color characteristics as other islands that have mining/ex-bauxite mining areas. Thus, Poto Island is estimated to have the same potential for bauxite deposits as those islands. However, for further research, detailed mapping and ground check of the outcrop data obtained in the field are required.

Conclusion

Most of the southern part of Bintan Island and the small islands around it have a lot of bauxite deposits. However, based on observations of Landsat + SRTM imagery, the region that have a large bauxite potential (mining/ex-bauxite mining area) have a slightly dark red color characteristic with a small part of dark white in band 457 (for Landsat 7) and 567 (for Landsat 8). In addition, the morphology shows a gentle slope with a smooth to slightly rough texture. Poto Island also has these characteristics, so it can be concluded that Poto Island has the same bauxite potential as other islands.

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