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Interpretation of Groundwater Potential Zones Based on Lineament Pattern Data Analysis in Ambon Island, Moluccas Province, Indonesia

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Abstract

The application of remote sensing technology may cover many fields of studies, especially in structure geology, mineral exploration, even groundwater exploration. Where the remote sensing is a useful for lineaments and structure features extractions. Lineaments are linear features which provide information about the underlying geological structure. Lineament is one of the most important features showing subsurface elements or structural weakness such as faults and is usually extracted by visual analysis of enhanced image data. Their analysis are widely considered in the location or siting of suitable groundwater exploration sites since the water will tend to flow along the fracture zones. A different expert may extract different segments through a visual approach. The purpose of this study was to interpret Groundwater Potential Zones Based on Lineament Pattern Data Analysis in Ambon Island, Moluccas Province, Indonesia. There are two general methods of extracting lineaments from satellite imagery; the first involves manual digitizing of visually identified lineaments after image processing and the second is automated lineament extraction where the satellite image is subjected to automated processing by specifying different parameters such as curve length, linking distance, kernel size. Landsat 8 satellite data were used and band-7 was found as the most suitable band in automatic delineation (Ibrahim, 2012). The edge sharpened image was then used as an input for the Lineament Extraction tool, LINE, which applied edge detection, thresholding and curve extraction. From data analysis The main trends observed in the lineament map could be recognized in these diagrams, showing strongly major trend in N-S, and the subdominant directions were in NW-SE. Area with high density of lineament located at the NE Ambon Island and SW Ambon Island.

Keywords: Groundwater, Lineament, Landsat 8

INTRODUCTION

Studies of linear geologic features (lineaments) of both local and regional significance have been progressing rapidly [1][2]. Lineaments have long attracted the interest of field geologists with remote sensing satellite imagery that the character and extent of these features have been realized, and lineament analysis of remotely sensed data, either by visual or automatic interpretation, is a valuable source of information for studying the structural setting. A lineament is any extensive linear surface on a planet, as a fault line or fracture line. The term "lineament" is one of the most commonly used terms in geology. [3] first used the term lineament to define a "significant line of landscape within basement rocks. [10] described the term lineament as a mappable simple or composite linear feature of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differ from the pattern of adjacent features and presumeeably reflects some sub-surface phenomenon. The purpose of this study was to interpret Groundwater Potential Zones Based on Lineament Pattern Data Analysis in Ambon Island, Moluccas Province, Indonesia.

Lineaments are linear features evident at land surface that are an expression of the underlying geological structure [5]. It is a mappable linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship which may be caused by an existing fault or other line weakness [5]. The surface features making up a lineament may be geomorphological, i.e. caused by relief or tonal, i.e. caused by contrast differences [4]. Analyses of lineaments in an area are a widely used method for ground water exploration since water naturally tends to be found near fracture zones.

The detection of lineament can be done using satellite imagery. The are a number of technique including; applying sobel and gradient. There are two general methods of extracting lineaments from satellite imagery; the first involves manual digitizing of visually identified lineaments after image processing and the second is automated lineament extraction where the satellite image is subjected to automated processing by specifying different parameters such as curve length, linking distance, kernel size [5]. The most popular automated processing tool used over the past few years has been LINE from PCI Geomatica [4].

Landsat 8 satellite data were used and band-7 was found as the

most suitable band in automatic delineation [5]. The edge sharpened image was then used as an input for the Lineament Extraction tool, LINE, which applied edge detection, thresholding and curve extraction. They further noted that the algorithm of the automated lineament extraction method does not work successfully in the identification of all the lineaments present in the area; it thus requires some mathematical enhancements and also needs to be applied with different satellite images, different resolutions, and different geological environments. They did conclude however, that it is still a useful technique though expert knowledge is always required to evaluate the extracted lineaments.

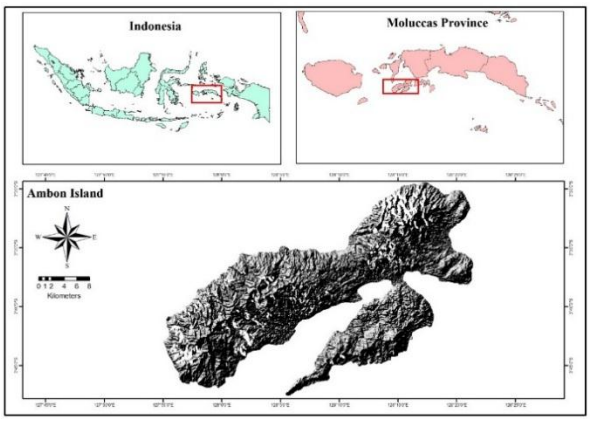

Figure 1: Location map of the study area.

GENERAL

The study area lies at Ambon Island is part of the Maluku Islands of Indonesia (Figure 1). The island has an area of 775 km^2 (299 sq mi) and is mountainous and fertile. Ambon Island consists of two territories. The main city and seaport is Ambon (with a 2009 population of 284,809), which is also the capital of Maluku province and Maluku Tengah (with a 2009 population of 370,931).

Ambon Island lies off the southwest coast of the much larger Seram island. It is on the north side of the Banda Sea, part of a chain of volcanic islands that encircle the sea. It is 51 kilometres (32 miles) long and is of very irregular shape, being almost divided in two. The southeastern and smaller portion, a peninsula (called Leitimor) is united to the northern (Hitoe) by a narrow neck of land. Ambon city is on the northwest of Leitimor, facing Hitoe, and has a safe harbor on Amboina Bay.

The highest mountains, Wawani at 1,100 metres (3,600 feet) and Salahutu at 1,225 metres (4,019 feet. They are volcanoes, and the mountains of the neighboring Lease Islands are extinct volcanoes. Granite and serpentine rocks predominate, but the shores of Amboina Bay are of chalk and contain stalactite caves.

Wild areas of Ambon Island are covered by tropical rainforest, part of the Seram rain forests ecoregion, together with neighboring Seram. Seram, Ambon, and most of Maluku are part of Wallacea, the group of Indonesian islands that are separated by deep water from both the Asian and Australian continents and have never been linked to the continents by land.

GEOLOGY SETTING

Ambon Island is located at the margin of three large lithospheric plates, the Australian, Southeast Asian, and Southwest Pacific, and its geology records their complex interaction. Ambon, and the nearby islands of Ceram and Baru, represent slivers of continental crust that were faulted off of New Guinea. Paleomagnetic data indicate these slivers have moved westward and northward during, and perhaps preceding, Miocene time [8].

Although the island has a complex history, the stratigraphy of Ambon is relatively simple. The oldest exposed rocks are part of Kanikeh Formation of Triassic to Jurassic age. Lithologically this formation consist of interbedded sandstone, shale, siltstone, with intercalations of conglomerate and limestone. The detrital sediments include arkose and graywacke.

The next youngest rocks are ultrabasic rocks of Jurassic and Cretaceous age. Lithologically this unit contains harzburgite, dunite, serpentinite, and gabbro. The relation of the ultrabasics to the Kanikeh Formation is not clearly indicated on Ambon, but on Seram show it to be structural contact, with the ultrabasics thrust over the Kanikeh Formation. [8] suggest that the ultramafics represent oceanic crust formed in a passive margin about 14.5 Ma ago. They believe the oceanic crust was obducted onto Ambon, Baru and Seram Islands before 4.4 Ma ago, at which time the Ambon volcanic rocks were erupted.

The Ambon volcanic rocks are composed of andesite, dacite, breccia, and tuff. K/Ar geochronology of the Ambon volcanic rocks has yielded dates of 3.4 to 4.4 Ma (Abbott and Chamalaun, 1981). The volcanic rocks are intruded by the Ambon Granite which consists of biotite granite and biotite cordierite granite. While the Ambon volcanic rocks are widely distributed across the island, the Ambon Ganite only crops out in the western half of the northern peninsula. The outcrops of Ambon granite occur within an area about 20 kms long and 10 kms wide, and have a crude radial pattern, reflecting the distribution of the stream drainages.

the Ambon volcanic rocks and intrusive rocks were formed as the result of thrusting of continental slivers beneath the Banda ridges. Alternatively, Linthout and Helmers (1994) suggest that the volcanic rocks and intrusive rocks are the result of mixing magma derived from partial melting of pelitic rocks due to obduction of the oceanic crust, with basaltic/andesitic magmas emplaced along transform faults. They believe the transform faults had left lateral movement and were the mechanism for moving Ambon, Baru and Seram Islands north and westward in a counter-clockwise rotation. The pattern of the fault shown on the geologic map of Ambon is consistent with left lateral movement.

Quarternary coral limestone crops out at many places on the island. The occurence of Quarternary limestones at elevations up to 500 meters above sea level attest to the rapidity of recent uplift on Ambon Island. The youngest unit on the island is Quarternary alluvium which on Ambon is principally beach material. See figure 2 for the information of regional geology of Ambon Island.

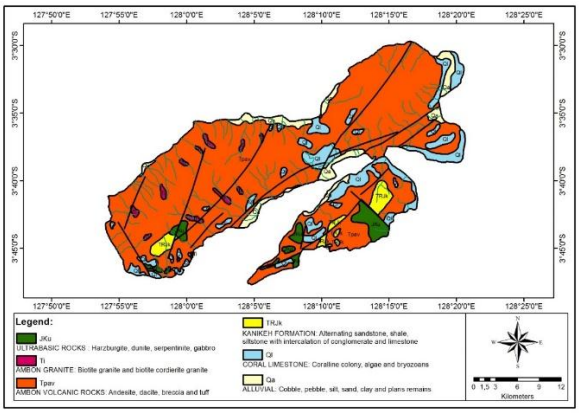

Figure 2: Geological map of the study area.

MATERIALS AND METHOD

There are several techniques that were developed for determine the linear features and geomorphologic characteristics of the terrain. According to this paper the automatic lineament delineation was based on decision of the most appropriate band for edge enhancement, followed by edge sharpening enhancement technique which gives the best result of lineaments that are not delineated by human eyes, and apply LINE module of PCI Geomatica V9.1 for recognized lineaments. Landsat 8 OLI satellite data were used and the first step was to select the band that should be used for lineament extraction [12][9]. Visual inspection of the individual bands was carried out, based on the ability to identify features, and band 5 (1.55 - 1.75 μm) (SWIR) was selected and it was stretched linearly to output range 0 to 255. The second step was to select the filter type. For this purpose, different types of filters are tested. Edge sharpening filter was the best which convolved over band 5. Edge sharpening enhancements make the shapes and details for analyses [11]. Edge sharpening was applied using PCI Geomatic software package. And finally the final image of the study area was used for automatic lineament extraction. According to [1] the lineament extraction algorithm of PCI Geomatica software consists of edge detection, thresholding and curve extraction steps. These steps were carried out under the default parameters of the software as follows:

RADI = Radius of filter in pixels; GTHR = Threshold for edge gradient; LTHR = Threshold for curve length; FTHR = Threshold for line fitting error; ATHR = Threshold for angular difference, and DTHR= Threshold for linking distance (PCI Geomatica, 2001).

According to the six parameter above. Several lineament maps were generated using different threshold values. The most suitable threshold values were selected (below) considering these lineaments as fault lines. General properties of faults were taken into consideration such as the length, curvature, segmentation, separation and so on in order to determine the threshold values.

Landsat 8 Operational Land Imager (OLI) images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9. The resolution for Band 8 (panchromatic) is 15 meters (USGS, March 3rd 2014). The automatic extraction involved using the LINE tool from Geomatica 2014. The tool extracts linear features from an image and records the polylines in a vector layer. The module was designed to extract lineaments from radar images; however, it can also be used on optical images to extract curve-linear features. The input in this case was optical; the mosaicked Landsat 8 Band 7 scenes [2].

RESULTS AND DISCUSSION

The orientations of lineaments and faults lines were created by using rose diagrams (Figure 4). The main trends observed in the lineament map could be recognized in these diagrams, showing strongly major trend in N-S, and the subdominant directions were in NW-SE. Area with high density of lineament located at the NE Ambon Island and SW Ambon Island. The lineaments extracted using this methodology can be used to compute the lineament density of the region; which is a known indicator of groundwater sites. The fewer line density in the south west of Ambon Island indicate low groundwater potential in the area.

Lineaments can be defined as mappable, simple or composite linear features of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the patterns of adjacent features and presumably reflects a subsurface phenomenon.

Often, these represent faults, fractures, sharp anticline fold axes, geological rock formation contacts or vertical beds such as flat irons or hogbacks. Generally, lineaments are underlain by zones of localized weathering and increased permeability

and porosity.

Lineaments give a clue to movement and storage of groundwater and therefore are important guides for groundwater exploration. Recently, many groundwater exploration projects made in many different countries have obtained higher success rates when sites for drilling were guided by lineament mapping.

In the research area, the lineaments have been identified with the aid of lineament filters and visual comments on the Landsat 8 band. The main trends observed in the lineament map could be recognized in these diagrams, showing strongly major trend in N-S, and the subdominant directions were in NW-SE. Area with high density of lineament located at the NE Ambon Island and SW Ambon Island.. Minimum lineament length is 1 m and the longest lineament observed was 1785 m. A lineament density map was prepared by IDW interpolation method used with one grid cell per square km (Fig. 3). Groundwater potential in the area increases with higher lineament density strongly major trend in N-S, and the subdominant directions were in NW-SE. Area with high density of lineament located at the NE Ambon Island and SW Ambon Island.. Minimum lineament length is 1 m and the longest lineament observed was 1785 m. A lineament density map was prepared by IDW interpolation method used with one grid cell per square km (Fig. 3).

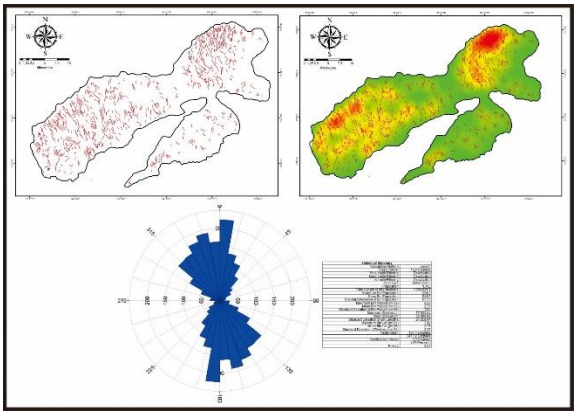

Figure 3: Lineament density map of the study area.

CONCLUSION

The directional analysis of the automatically extracted lineament maps have been done and the major trends of lineaments in the study area are N-S (Figure 4-6). . It very useful for ground water exploration as it was known that lineaments could be useful as secondary porosity that increase recharging wells. Zone where potential for groundwater exploration located at NE-SW in ambon island.

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