Geological structure mapping for gold exploration targets using PALSAR remote sensing data in the Central Gold Belt, Peninsular Malaysia

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Abstract

The Phased Array type L-band Synthetic Aperture Radar (PALSAR) data significantly improved the quality and availability of satellite remote sensing data for geological structure mapping and gold prospecting in tropical environments. PALSAR is an active microwave sensor for all-weather conditions observation. The Central Gold Belt (CGB) of peninsular Malaysia with widespread small-scale gold mining areas and tropical climate has been investigated to explore new potential areas. Gold mineralization in this belt is structurally controlled and hosted in sedimentary rocks. Adaptive Local Sigma and Directional filters were applied to the Level 4.1 PALSAR data for tracing structural elements associated with gold mineralization. Structural features along the Bentong-Raub suture zone have been traced as highly potential areas for prospecting gold mineralization. Four sets of lineaments trending N-S, NE-SW, NNW-SSE and ESE-WNW associated with fault-related rocks have been identified. Results of this study demonstrate the applicability of PALSAR remote sensing data to assist more feasible gold exploration plans in the Central Gold Belt (CGB) and reduction of exploration costs for epithermal or polymetallic vein-type mineralization in tropical environments.

Key words: PALSAR; Gold exploration; Central Gold Belt; Peninsular Malaysia.

1. Introduction

Peninsular Malaysia has been a significant producer of gold and tin, and more recently, petroleum and natural gas from offshore Cenozoic basins that have contributed significantly to Malaysia's economic development (Ariffin, 2012). Peninsular Malaysia comprises of three main geological domains that strike parallel to the peninsula. It is characterised by three north-south belts (Fig. 1), the Western Tin Belt, Central Gold Belt, and Eastern Tin Belt that recognized based on distinct differences in stratigraphy, structure, magmatism, geophysical signatures and geological evolution. The Central Belt of peninsular Malaysia is well-known as the Gold Belt (Yeap, 1993). It is a 20km wide and approximately 500km length with major North-South trend of gold mining districts. Many gold mines and prospects in peninsular Malaysia are located in the Central Gold Belt (CGB) (Fig. 1). Gold mineralization in this belt is structurally controlled and erratic laterally and vertically (Arffin and Hewson, 2007, Arffin, 2012). The ore mineral assemblages include gold, pyrite, arseopyrite, chalcopyrite, pyrrhotite, sphalerite, galena, geochronite (Makoundi, 2012). Major gold mineralization is observed along the steeply dipping faults and hosted in sedimentary rocks such as sandstone, carbonaceous shale, tuffaceous siltstone, tuffaceous conglomerate (Arffin and Hewson, 2007; Makoundi, 2012).

The CGB is a highly potential region for prospecting gold exploration targets along the major lineament structures (Bentong-Raub suture zone) using remote sensing technology. To date, this gold belt has not received any scientific study using recent generation of fine satellite remote sensing imagery. The identification of geological structures and lineament analysis using remote sensing imagery are always considered complimentary for any precious metals exploration program in arid and semi-arid regions (Pour and Hashim, 2011, 2012 a,b, 2013). However, in tropical environments, the application of remote sensing data for geological srtucture mapping has been much more limited (Hashim et al., 2013), because of the persistent cloud coverage, limited bedrock exposures, and vegetation. Preliminary studies by Pour et al. (2013, 2014 a,b,c) in the Bau gold mining district, Sarawak, East Malaysia, on the island of Borneo demonstrated the applicability of satellite remote sensing imagery for mineral exploration in tropical climate. This observation would roughly suggest more investigation related to the application of remote sensing data for locating potential gold exploration targets in the Central Gold Belt (CGB) of peninsular Malaysia.

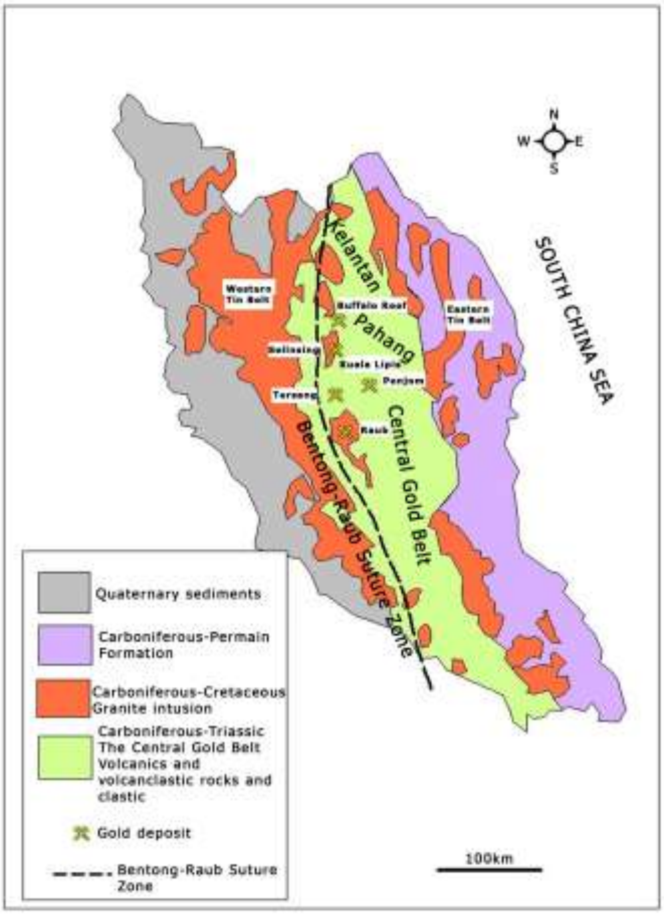

Figure 1: The Central Gold Belt (CGB) of the peninsular Malaysia and the locations of gold occurrences. Modified from Makoundi, (2012).

2. Materials

2.1 PALSAR data

Phased Array type L-band Synthetic Aperture Radar (PALSAR), put onboard the Advanced Land Observing Satellite (ALOS), and was launched on January 24, 2006 by an H-IIA rocket from Tanegashima Space Center. PALSAR is an active microwave sensor for all-weather conditions observation and operable both daytime and nighttime (ERSDAC, 2006). It was developed by Japanese Ministry of Economy, Trade and Industry (METI) as a joint effort with Japan Aerospace Exploration Agency (JAXA). PALSAR not only enables the earth observation regardless of weather conditions, day or night, but also provides many sophisticated observation function. PALSAR sensor is a L-band synthetic aperture radar, with multi mode observation function (Fine mode, Direct downlink, ScanSar mode, and Polarimetric mode) of multi polarization configuration (HH, HV, VH, and VV), variable off-nadir angle (9.9 to 50.8 degrees), and switching spatial resolution (10 m, 30 m, 100 m for Fine, Polarimetric, and ScanSar modes, respectively) and swath width observation (30 km, 70 km, and 250-350 km for Polarimetric, Fine and ScanSar modes, respectively) (ERSDAC, 2006).

3. Methods

To facilitate tracing the structural patterns and investigate the relationship between structural setting and gold mineralization in the Central Gold Belt (CGB) of peninsular Malaysia, Level 4.1 PALSAR data required to be filtered for speckle reduction. Radar images are inherently corrupted by speckle. The presence of speckle in an image reduces the detectability of ground targets, obscures the spatial patterns of surface features, and decreases the accuracy of automated image classification. Therefore, it is necessary to treat the speckle by filtering the data before it can be used in various applications. A speckle suppression filter is expected to filter the homogeneous areas with reasonable speckle reduction capability, retain edges, preserve features (linear features and point features), and have reasonable theoretical assumptions. Adaptive filters remove radar speckle from images without seriously affecting the spatial characteristics of the data (Sheng and Xia, 1996).

The adaptive Local Sigma filter was selected for this study and applied to the Level 4.1 PALSAR image to accomplish speckle reduction and preserving both edges and features. The Local Sigma filter uses the local standard deviation computed for the filter box to determine valid pixels within the filter window. It replaces the pixel being filtered with the mean calculated using only the valid pixels within the filter box (Eliason and McEwen, 1990). Local Sigma filter can be used to preserve fine detail (even in low contrast areas) and to reduce speckle significantly (Research Systems, Inc., 2008).

For more detailed lineament extraction and edge enhancement, spatial domain filtering technique (Convolution filters) was applied to Local Sigma resultant image. Convolution filters produce output images in which the brightness value at a given pixel is a function of some weighted average of the brightness of the surrounding pixels (Haralick et al., 1987). Convolution of a user-selected kernel (convolution mask) with the image array returns a new, spatially filtered image. User can select the kernel size and values, producing different types of filters. The size of the neighborhood kernel is usually 3*3, 5*5, 7*7, or 9*9. Standard convolution filters include: High Pass, Low Pass, Laplacian, Directional, Gaussian, Median, Sobel, Roberts (Haralick et al., 1987; Research Systems, Inc., 2008). In this study, Directional filters were applied to the resultant images for edge enhancement and detailed identification of linear features.

4. Results and discussion

Figure 2 was generated from PALSAR polarimetry observation data. The adaptive Local Sigma filter was applied for speckle suppression, and then a single Red-Green-Blue (RGB) color combination was used to provide better visual interpretation. Horizontally transmitted and Horizontally received (HH) polarization image was assigned to red, Horizontally transmitted and Vertically received (HV) polarization image was assigned to green, and Vertically transmitted and Vertically received (VV) polarization image was assigned to blue. R, G, and B were specified for each polarization image of HH, HV and VV respectively, and they were superimposed to form a synthetic color image. Full-polarimetry mode data make it possible to obtain more data with different polarization on the RGB color-composite overlay. It creates false colors that are reflective of perceived surface roughness of the imaged surface which is governed by geological structures and lithology.

Two dominant directions can easily be identified, namely, N-S and NW-SW sets of lineaments from the image in Figure 2. However, if observed carefully it is also seen that there are some lineaments that are striking approximately around the E-W direction. N-S striking is composed of continuous lineament in the central to eastern part of the images, which corresponds to the boundary of the Bentong-Raub Suture zone. Collision zone and compressional structures appear clearly. Generally, most of the lineaments are clustered in western part of the images. These lines have general direction of NNW. N-S trending structures of Bentong-Raub Suture zone are apparent in the Figure 2.

A PALSAR scene covers most of the gold mining districts in the state of Pahang (Kuala Lipis) was selected for detail analysis of known gold occurrences in this study. It covers the eastern part of the Bentong-Raub Suture Zone and the central part of the Central Gold Belt (CGB). Panjom, Raub, Selinsing, Buffalo reef, Rubber hill, Tersang, Kechau-Tiu mines are located in this PALSAR scene. Figure 3 shows the RGB results for N-S, NE-SW, and NW-SE filtering directions applied to dual polarization of HH and HV, respectively.

Lineaments and form-lines are detected, including the long lineaments and short lineaments that form linked systems of long lineaments (Fig.3). The western and northern parts of the images exhibit longer and more lineaments than eastern part. Two major trends NS and NE are detected generally in the western part of the images. However, the central and eastern parts of the images are dominated by lineaments, which are elongated mainly to the NE and few to the NW (Fig. 3). Lineaments mapped in northern and central part of the images express several fold systems as curvilinear structures. Lineaments associated with stream (central north part) are interpreted to be fracture or fault controlled.

NS and NE-SW trending lineament systems are clearly extensive in the region. Most of longer lineaments are concentrated in the NS direction. NS-trending, normal-slip faults parallel to the Bentong-Raub Suture Zone trend are defined by an obvious, west facing fault escarpment. This NS trend is similar to the orientation of the Bentong-Raub Suture Zone (Fig. 3). Some NW trending lineaments are associated with normal faults. It is a less important direction, which can be seen in vein branches. A particular attention is carried in the NW-SE and NE-SW strike slip faults which can be often conjugated. Indeed, in this region they are respectively sinistral and dextral showing a maximal directed constraint N-S. Most of the known gold deposits are located along of splay faults in the CGB, which are confined within brittle-ductile share or brecciated zones (Yeap, 1993; Ariffin and Hewson, 2007).

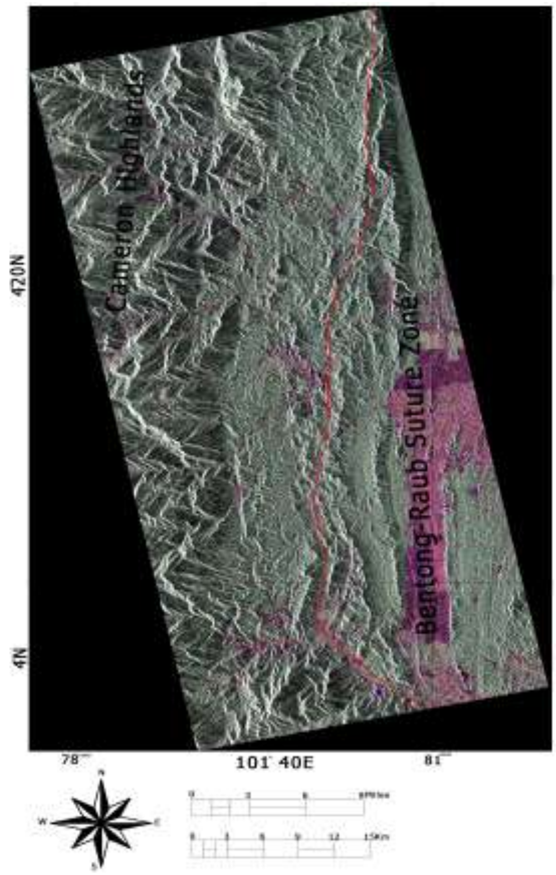

Figure 2: RGB color combination of PALSAR polarimetric HH, HV and VV images southeastern part of Bentong-Raub Suture zone.

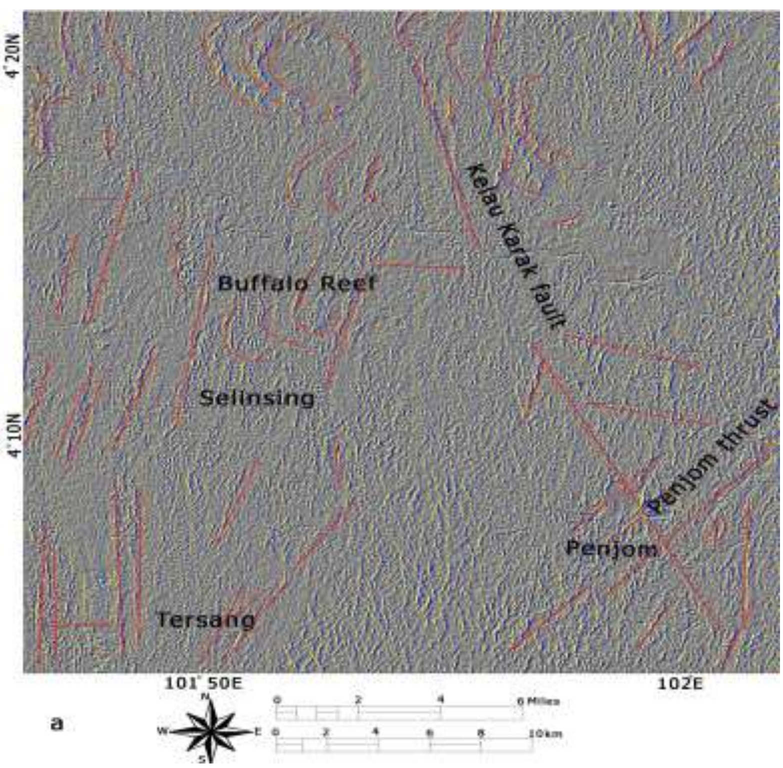

Figure 3: RGB color combination of N-S, NE-SW, and NW-SE directional filters.

5. Conclusions

Results of this study provide an exploration approach for discovering new potentially areas of gold mineralization along Bentong-Raub Suture Zone, central Malaysia and tropical environments using PALSAR remote sensing data. Structural investigation has shown sets of N-S, NE-SW, NNW-SSE and ESE-WNW oriented mineralized veins associated with fault-related rocks and hydrothermal alteration zones. These main trends were intercepted by many shear or lateral fault zones. Exploration plan should also give more attention to narrow down target zones of alteration types and shear zones that show the presence of mylonite, cataclasite and felsic intrusive. Much attention should be paid in areas where sericitic alteration is ubiquitous. The results of this investigation should assist more feasible mineral exploration plans in the Central Gold Belt (CGB) and its surroundings. The study presented here encourages further applications of PALSAR remote sensing data for mapping regional structures in tropical environments, which can be helpful in understanding structural controls on vein-type mineralization.

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