# Sediment-hosted/orogenic gold mineral systems exploration using PALSAR remote sensing data in Peninsular Malaysia

Amin Beiranvand Pour[1], Mazlan Hashim

Geoscience and Digital Earth Centre (Geo-DEC), Universiti Teknologi Malaysia

Abstract. The Bentong-Raub Suture Zone (BRSZ) is genetically related to the sediment-hosted/orogenic gold deposits associated with the major lineaments and form-lines in the Central Gold Belt of Peninsular Malaysia. In this investigation, the Phased Array type L-band Synthetic Aperture Radar (PALSAR) satellite remote sensing data were used to analyse major geological structures in Peninsular Malaysia and provide detailed characterization of lineaments and form-lines in the BRSZ, as well as its implications for sediment-hosted/orogenic gold exploration in tropical environments. The pervasive array of N-S faults in the study area and surrounding terrain is mainly linked to the N-S trending of the BRSZ Suture Zone. N-S striking lineaments are often cut by younger NE-SW and NW-SE-trending lineaments. Three generations of folding event have been discerned from remote sensing structural analysis. Gold mineralized trends lineaments are associated with the intersection of N-S, NE-SW, NNW-SSE and ESE-WNW faults and curvilinear features in shearing and alteration zones. Compressional tectonics structures such as NW-SE trending thrust, ENE-WSW oriented faults in mylonite and phyllite, recumbent folds and asymmetric anticlines in argillite are high potential zones for gold prospecting.

## 1. Introduction

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. It was developed by Japanese Ministry of Economy, Trade and Industry (METI) as a joint effort with Japan Aerospace Exploration Agency (JAXA). PALSAR is an active microwave sensor for all-weather conditions observation and operable both daytime and nighttime [1]. It has 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), 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) [1]. PALSAR data can be used in

[1] Corresponding Author. Tel: +607 -5530666; Fax: +607- 5531174; Email address: beiranvand.amin80@gmail.com; a.beiranvand@utm.my; mazlanhashim@utm.my.

specific fields, include (i) land area basin mapping (geological structural analysis of target areas); (ii) coastal area basin mapping; (iii) monitoring of environments and natural disasters; and (iv) research and development for the processing and application of multi polarimetric SAR data (geological structural analysis on the first stage of resource exploration).

Many gold mines and prospects in the Peninsular Malaysia are located in the Central Gold Belt (CGB). Gold mineralization in this belt is structurally controlled. The CGB is a highly potential region for prospecting gold exploration targets along the major lineament structures using remote sensing technology. To date, this gold belt has not investigated using recent generation of very high resolution satellite remote sensing imagery [2, 3]. This research presents a remote sensing approach for geological structure mapping in tropical environments. The objectives of this study is to map structural elements associated with sediment-hosted/orogenic gold deposits in the Central Gold Belt of the Peninsular Malaysia using the Phased Array type L-band Synthetic Aperture Radar (PALSAR) satellite remote sensing data at both regional and local scales.

## 2. Materials and methods

In this investigation, two fine Mode dual polarization Level 4.1 PALSAR scenes were obtained from the Earth and Remote Sensing Data Analysis Center (ERSDAC) Japan (http://gds.palsar.ersdac.jspacesystems.or.jp/e/) for the Central Gold Belt (CGB) of the Peninsular Malaysia. PALSAR fine observation scene covering many of the gold mining districts in Kuala Lipis region in the state of Pahang was selected for detailed analysis of structural features associated with known gold deposits. It covers the eastern part of the Bentong-Raub Suture Zone and the central part of the CGB. Panjom (101° 58′ 58″ E, 4° 08′ 27″ N), Buffalo reef (101° 47′ 11″ E, 4° 15′ 59″ N), Selinsing (101° 47′ 38″ E, 4° 14′ 57″ N), Rubber hill (101° 47′ 55″ E, 4° 14′ 38″ N), Kechau-Tui (101° 58′ 49″ E, 4° 16′ 27″ N) and Tersang (101° 51′ 96″ E, 4° 04′ 81″ N) mines are located in this PALSAR scene. Figure 1 shows the district-scale geological map of the selected study area.

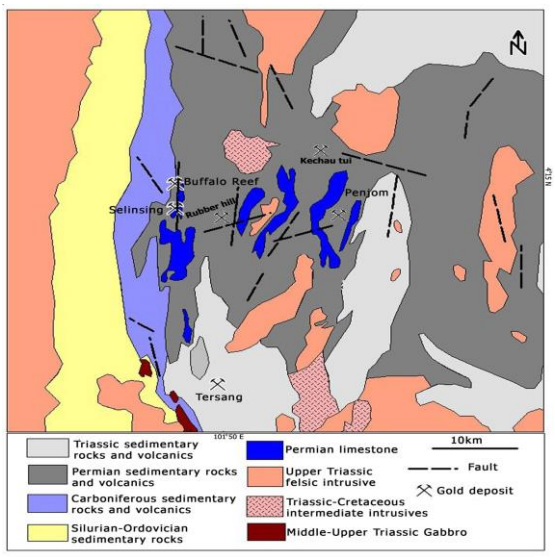


Figure 1. District-scale geological map of the gold deposits, Kuala Lipis, Pahang, Central Malaysia [2].

To facilitate tracing the structural patterns and investigate the relationship between structural setting and gold mineralization in the Central Gold Belt (CGB) of the Peninsular Malaysia, Level 4.1 PALSAR data required to be filtered for speckle reduction. Adaptive filters remove radar speckle from images without seriously affecting the spatial characteristics of the data [4]. Therefore, adaptive filtering was applied to the Level 4.1 PALSAR data. The data were processed using the ENVI (Environment for Visualizing Images) version 4.8 software package.

Directional filters were used to enhance specific linear trends in the Local Sigma resultant images. Four principal Directional filters: N-S, E-W, NE-SW, and NW-SE with a 7*7 kernel size were applied (Table 2). Filters were chosen to highlight the main lineament directions in the Central Gold Belt (CGB) of the Peninsular Malaysia. Directional filter angles were adjusted as N-S: 0°, E-W: 90°, NE-SW: 45°, and NW-SE: 135°. North (up) is zero degrees and the other angles are measured in the counterclockwise direction. 7*7 kernel matrix was selected to enhance semi-smooth and smooth/rough features. Image Add Back value was entered 40%. The Image Add Back value is the percentage of the original image that is included in the final output image. This part of the original image preserves the spatial context and is typically done to sharpen an image.

## 3. Results and discussion

Directional filtering was implemented to the PALSAR data for tracing structural elements in the selected spatial scene covering the Panjom, Buffalo reef, Selinsing, Rubber hill, Kechau-Tui and Tersang goldfields. Figure 2 shows the RGB results for N-S, NE-SW, and NW-SE (R: 0°, G: 45°, B: 135°) filtering directions applied to HV image. The above mentioned Directional filters have been selected for RGB color combination because NE-striking thrust, NS-striking normal faults and NW-striking strike-slip faults are the most important structural elements for gold targets exploration in the CGB [5]. Lineaments and form-lines are detected (Figure 2), including the long lineaments and short lineaments that form linked systems of long lineaments. 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 (Figure 2). Lineaments mapped in northern and central part of the images express several fold systems as curvilinear structures. Lineaments associated with stream are interpreted to be fracture or fault controlled on the central north part. 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 (Figure 2). Penjom gold deposit is located along of the significant splay faults. The Kelau-Karak fault (normal) is one of the major faults running across the Penjom goldfield that control major plutonic emplacements. Localized distribution is caused by faulting and folding, and the Penjom thrust has an NE-SW strike and southerly dip within the deposit. Major gold mineralization took place within the footwall of this thrust. The Kelau-Karak fault and Penjom thrust are detected in the south-eastern part of the image (Figure 2). A regional view of the open-pit quarry of Penjom is shown in Figure 3. The Penjom thrust is the dominant feature controlling the distribution of ore at Penjom and strikes NE (35°) and dips to the southwest (30°-40°).

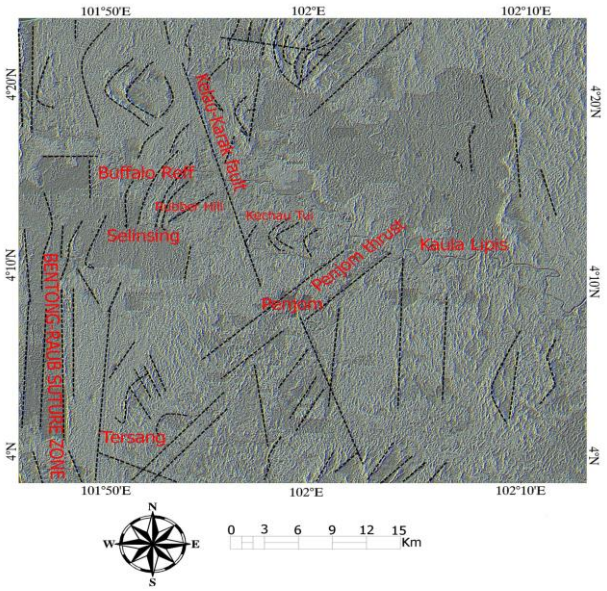


Figure 2. RGB image of N-S (0°), NE-SW (45°), and NW-SE (135°) directional filters covering gold mining districts in Kuala Lipis region, Pahang.


Figure 3. A regional view of the open-pit quarry of Penjom ore deposit.

Figure 3 shows selected spatial subset scene covering northern parts of the Bentong-Raub Suture Zone and CGB in the Kelantan state. RGB color combination was assigned for N-S (R: 0°), NE-SW (G: 45°), and NW-SE (B: 135°) directional filters. The HV polarization PALSAR image was selected to perform directional filtering. The N-S orientation of the Bentong-Raub Suture Zone as a regional strike is detected in the western part of the image (Figure 3). The structural lines with NE-SW and NW-SE directions are in accordance with the tectonic framework of the study area. Major N-S and NE-SW orientations and strike-slip faults with sharp boundaries are revealed in Figure 3. Several small faults and fractures with NE-SW direction are clearly visible in the south and central part of the image. However, few small faults with N-S and NW-SE directions are observable in the north and eastern part of the image. Curvilinear features and some curving faults with NE-SW and NW-SE trends are apparent in the image especially in the central part (Figure 3). These lineament and curvilinear structures have great potential for hosting many quartz-gold lodes. Many of major gold deposits have been found along N-S Bentong-Raub Suture Zone trend in the CGB. In primary stages of exploration plans for identifying potential areas in the north of the CGB a particular attention would be to N-S structural elements at a regional scale.


Figure 4. RGB image of N-S (0˚), NE-SW (45˚), and NW-SE (135˚) directional filters covering the northern part of the CGB, Kelantan state.

## 4. Conclusions

Results of this investigation provide an exploration approach using PALSAR data to map structural elements associated with gold mineralization along the Bentong-Raub Suture Zone in the Central Gold Belt (CGB) of the Peninsular Malaysia. Structural investigation has shown sets of N-S, NE-SW, NNW-SSE and ESE-WNW mineralized trends associated with fault-related rocks and hydrothermally 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. The results of this investigation should assist more feasible mineral exploration plans in the CGB of the Peninsular Malaysia. The study presented here encourages further applications of PALSAR satellite remote sensing data for mapping regional and district structural elements associated with epithermal and polymetallic vein-type mineralization in tropical environments.

**Acknowledgements**

This study was conducted as a part of Fundamental Research Grant scheme (FRGS) (Vote no: R.J130000.7809.4F455), Ministry of Higher Education (MOHE) Malaysia. We are thankful to the Universiti Teknologi Malaysia for providing the facilities for this investigation.

## References

[1] Igarashi T 2001. ALOS Mission requirement and sensor specifications. Advances in Space Research 28(1), 127-131.

[2] Pour AB, Hashim M, 2015. Structural mapping using PALSAR data in the Central Gold Belt Peninsular Malaysia, Ore Geology Reviews 64, 13-22.

[3] Pour AB, Hashim M, 2015. Integrating PALSAR and ASTER data for mineral deposits exploration in tropical environments: a case study from Central Belt, Peninsular Malaysia. International Journal of Image and Data Fusion 6(2), 170-188.

[4] Pour BA, Hashim M, Marghany M, 2014. Exploration of gold mineralization in a tropical region using Earth Observing-1 (EO1) and JERS-1 SAR data: a case study from Bau gold field, Sarawak, Malaysia. Arabian Journal of Geosciences 7(6), 2393-2406.

[5] Pour BA, Hashim M, 2014. Structural geology mapping using PALSAR data in the Bau gold mining district, Sarawak, Malaysia. Advances in Space Research, 54(4), 644-654.