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# MULTI-POLARIZATION FOR ANALYSIS OF GEOLOGICAL STRUCTURES AS FORMATION OF HYDROCARBON TRAPS CONTROLLER IN EAST JAVA BASIN

## MULTI-POLARISASI UNTUK ANALISIS STRUKTUR GEOLOGI PENGONTROL PERKEMBANGAN PERANGKAP HIDROKARBON DI CEKUNGAN JAWA TIMUR

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***ABSTRAK***

*Penurunan cadangan minyak dan peningkatan kebutuhan energi minyak dan gas bumi mendorong untuk dilakukan pencarian cadangan baru. Pola struktur geologi yang digunakan untuk mengetahui pola persebaran dan perkembangan perangkap hidrokarbon di Cekungan Jawa Timur merupakan salah satu informasi penting yang dapat diekstrak melalui data penginderaan jauh sistem multi-polarisasi. Sistem multi-polarisasi penelitian ini penggabungan Citra Alos Palsar berpolarisasi HH dan HV, dan Citra Sentinel berpolarisasi VV dan VH. Pengolahan kedua data citra melalui kalibrasi, multilook,speckle filtering, koreksi geometrik dan mosaik. Citra terfilter dilakukan komposit dan penajaman. Teknik filtering yang digunakan filter Lee kernel 5x5 dilanjutkan filter median kernel 5x5. Hasil interpretasi citra sistem multi-polarisasi dapat mengidentifikasikan struktur perlipatan, struktur sesar naik, struktur sesar normal/turun, struktur sesar mendatar/geser, perlapisan batuan, dan closure structure. Pada daerah penelitian perkembang struktur berlangsung dua periode yaitu dengan tegasan utama arah U – S pada orde-1 dan tegasan utama arah BD – TL pada orde-2. Perangkap hidrokarbon dan target ekplorasi dapat dibedakan dalam tiga zona (Zona A, Zona B, dan Zona C). Closure di Zona A meliputi closure 3, 4, 5, 7, 8, 9, 10, 11, 22, 23, 24, 25, 26, 27, 28, 29, 30. Closure di Zona B meliputi closure 1, 2, 6, 12, 13, 14, 15, 16, 17, 31, 32. Closure di Zona C meliputi closure 18, 19, 20, 21.*

**Kata Kunci:** *multi-polarisasi, perangkap hidrokarbon, struktur geologi*

**ABSTRACT**

The decline in oil reserves and the increasing demand for oil and gas energy led to the search for new reserves. The geological structure pattern used to know the pattern of distribution and formation of hydrocarbons traps in the East Java Basin is one of the important information that can be extracted through remote sensing data of multi-polarization system. The multi-polarization system of this study merged the \ Alos Palsar imagery with HH and HV polarization, and Sentinel Image polarized VV and VH. Processing both image data through calibration, multilook, speckle filtering, geometric correction and mosaic. Filtered imagery is composite and sharpening. The filtering technique use Lee 5x5 kernel filter and then continue with 5x5 median filter. The results of multi-polarization system image interpretation can be identified by fold, thrust faults, normal faults, strike-slip faults, bedding, and closure structure. In the formation research area the structure lasted two periods, with the main emphasis N-S in the order of 1 and the main direction of the SW-NE direction in the order-2. The hydrocarbon traps and exploration targets can be distinguished in three zones (Zone A, Zone B, and Zone C). Closure in Zone A includes closures 3, 4, 5, 7, 8, 9, 10, 11, 22, 23, 24, 25, 26, 27, 28, 29, 30. Closure in Zone B includes closures 1, 2, 6, 12, 13, 14, 15, 16, 17, 31, 32. Closure on Zone C includes closure18, 19, 20, 21.

**Keywords:** multi-polarization, hydrocarbon traps, geology structure

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## I. INTRODUCTION

The decline in oil reserves and the increasing demand for oil and gas energy led to the search for new reserves. Napitupulu (2016) states that the increase in hydrocarbon reserves can be done by increasing exploration activities and reservoir engineering or EOR method. Increased exploration activities can be done by utilizing new technology in the old field, and / or in the utilization of old technology and new technology on mature or proven area. The development of such concepts includes remote sensing methods.

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through analysis of data obtained through a device not connected to the object, area, or phenomenon under examination (Lillesand et al. 2015). Remote sensing system is having two developed system consisting of passive system and active system. SAR radar images are one of the active remote sensing systems. The identification and interpretation of geological structures are based on the specific characteristics of multi-polarization SAR (Synthetic Aperture Radar) which can provide better view of surface the earth.

Radar stands for radio detection and ranging. The radar resolution is determined on the basis of its ability to distinguish between two objects separated by minimum distance (McCandless & Jackson 2004). SAR radar recording geometry moves forward in the flight direction with the nadir directly below the platform. The microwave light is transmitted at an angle to the right angle to the flight that shines on the swath (Natural Resources Canada 2016). Synthetic Aperture Radar (SAR) has the advantage of being blocked by cloud cover, data can be obtained during the day or night in any weather, and over a large area (ESA 2013).

The polarization system in the radar system as described by Sirgal and Giliespie, 1980 in Sutanto (1994) is a method of directing electric vectors on electromagnetic waves according to a flat plane. Natural Resource Canada (2015) explains that the two most common basic polarizations are horizontal or H linear polarization, and vertical linear polarization or V. Further Wolff (2007) explains that in linear polarization, the vertically and horizontally mounted receiver antenna is designed to receive waves are polarized vertically and horizontally.

A complex radar system, the antenna is designed to transmit and receive more waves than a polarization. Based on the delivery and reception system, the linear radar polarization system H and V can have four patterns namely (1) HH polarization, horizontal sending and horizontal receiving, (2) polarization VV, vertical sending and vertical receiving, (3) HV polarization, horizontal sending vertical receiving, and (4) VH polarization, vertical sending horizontal receiving (Natural Resources Canada 2015).

The use of imagery in the geological field, relatively only use single polarization radar image. In this study, the pattern of geological structures will be identified not only using single polarization images but will utilize multi-polarization images. The nature of the different recording directions is likely to provide a better level of detail information.

## II. METHODOLOGY

### A. Remote Sensing

The study is a part of the East Java Basin, geographically located at longitude 110 ° 42’40.53 ” E - 111 ° 54’37.34” E, latitude 6 ° 48’24.94 ” S - 7 ° 10’9.24” S, 49 M, WGS datum 84. The multi-polarization system in this study is the incorporation of Palsar Alos imagery that polarized HH and HV and Sentinel Images polarized VV and VH. Alos Palsar imagery used Alos Palsar imagery Level 1.1 or Single Look Complex / LSC Level, recording 27-08-2009 for Path / Frame: 4030/7050 & 4030/7040; recording 10-08-2009 for Path / Frame: 4029/7050 & 4029/7040; recording 08-09-2009 for Path / Frame: 4028/7050 & 4028/4040. Sentinel 1 A image used Sentinel 1A Image (Level 1.1) recording January 3, 2017 and recording December 29, 2016.

Veci (2016), explains that there are several steps taken to process the two images based on polarization to obtain the necessary information, ie (1) calibration, (2) multi-looking, (3) speckle filtering, and (4) geocoding and mosaic. Radiometric calibration improve radar image so that the pixel value actually represents the radar's backscatter reflection from the earth's surface. Multilook processing is used to produce a product with a nominal pixel size (Veci, 2016). Furthermore, Gagnon and Joan (1997) explain that speckle noise is a common phenomenon in all coherent imaging systems such as laser, acoustic and SAR images. The source of this noise is due to random interference between the coherent results returned from various scatterers present on the surface, on the scale of the wavelength of the radar (ie, resolution cells). Speckle noise is highly undesirable, so speckle filtering is an important pre-processing step. Hatwar and Kher (2015) further explained that the use of filters is good enough to improve the image, where the model can maintain the area in a structured manner. The mosaic process is performed to obtain the image in a unified region of research and the geometric correction is performed on the mosaic and consists of resampling into a uniform grid on the ellipsoid reference. Mosaic processing and geometric correction can be performed automatically in SNAP software v.5.1. Corrected geometric imagery is incorporated through layer stacking techniques, it is intended that the four polarizations can be composited and sharpened.

Sentinel 1A and Alos Palsar images that have been processed further are interpreted by the structure and closure. Interpretation of the geological structure in the image according to Richards, 2000, in Hung et al. (2005) states that the geological structure is a result of all phenomena tectonic processes that may be a fault, fracture, or folds. Furthermore, Soetoto (2015) describes the geological structure as: (a) folds, in the image recognizable by the banded tone, parallel or curved line pattern for the folds of anticline and syncline; (b) fracture, the image is interpreted as the basis of the apparent alignment of the tone or lineament of the valley, (c) fault, in which the image is interpreted according to the lineament pattern. The dimensions of the fault section are relatively longer than fracture, and (d) unconformity, horizontal layers of rock, disconformity and paraconformity in the image are difficult to recognize because the young rock layers cover the older rocks.

The closure interpretation is associated with a hydrocarbon trap system. A hydrocarbon trapping system that may be recognized by radar data is a structural trap. The closure interpretation is used to estimate the presence of a hydrocarbon trap. In closure interpretation, geological and stratigraphic maps are used as input data on rock formation information. The rock formation and stratigraphy as information on the existence of petroleum system elements related to the information of the sources rock, reservoir rock, and seal. Interpretation results are confirmed based on field check data and subsequent analysis of hydrocarbon prospects. In the hydrocarbon prospect analysis, is required supporting data information on the hydrocarbon play model is obtained from the previous research. The existence of hydrocarbon play is used as a reference in the determination of exploration targets.

**B. Regional Geology of East Java Basin**

The current Indonesian tectonic and physiography configurations are interpreted to have been formed since Late Neogen, as a result of interactions between three major plates, the Philippine Sea Plate moving north-northwest, the Indo-Australian plate moving north-northeast, and the relatively quiescent Eurasian plates or moving very slowly to the southeast (Minster & Jordan 1978 in Bachri 2014).

In the East Java Basin there are generally two major fault patterns influenced by two regional tectonic phases. The first tectonic phase occurs at the Paleogen, which is the extension phase. In this phase formed half-graben and normal fault associated with the extension with the orientation of northeast-southwest and west-east. The second phase of reactivation was during the Neogene inversion when all of the major Palaeogene faults experienced movement reversal, producing maximum uplift in the areas of preexisting Palaeogene depocentres. (Bransden 1992).

Stratigrafi of East Java Basin is composed by the oldest rocks which is the basement in the East Java Basin, they are metasedimen and igneous rock (granite). This basement is estimated aged Cretaceous-Jura/Pratersier. Overlies unconformable the Cretaceous basement rock are Tersier sedimentary which can be divided into two groups of sediments ie the Paleogen Sediment Group and the Neogen Sediment Group (Mudjiono and Pireno, 2002). The stratigraphic sequences of the East Java Basin as shown in Figure 1.

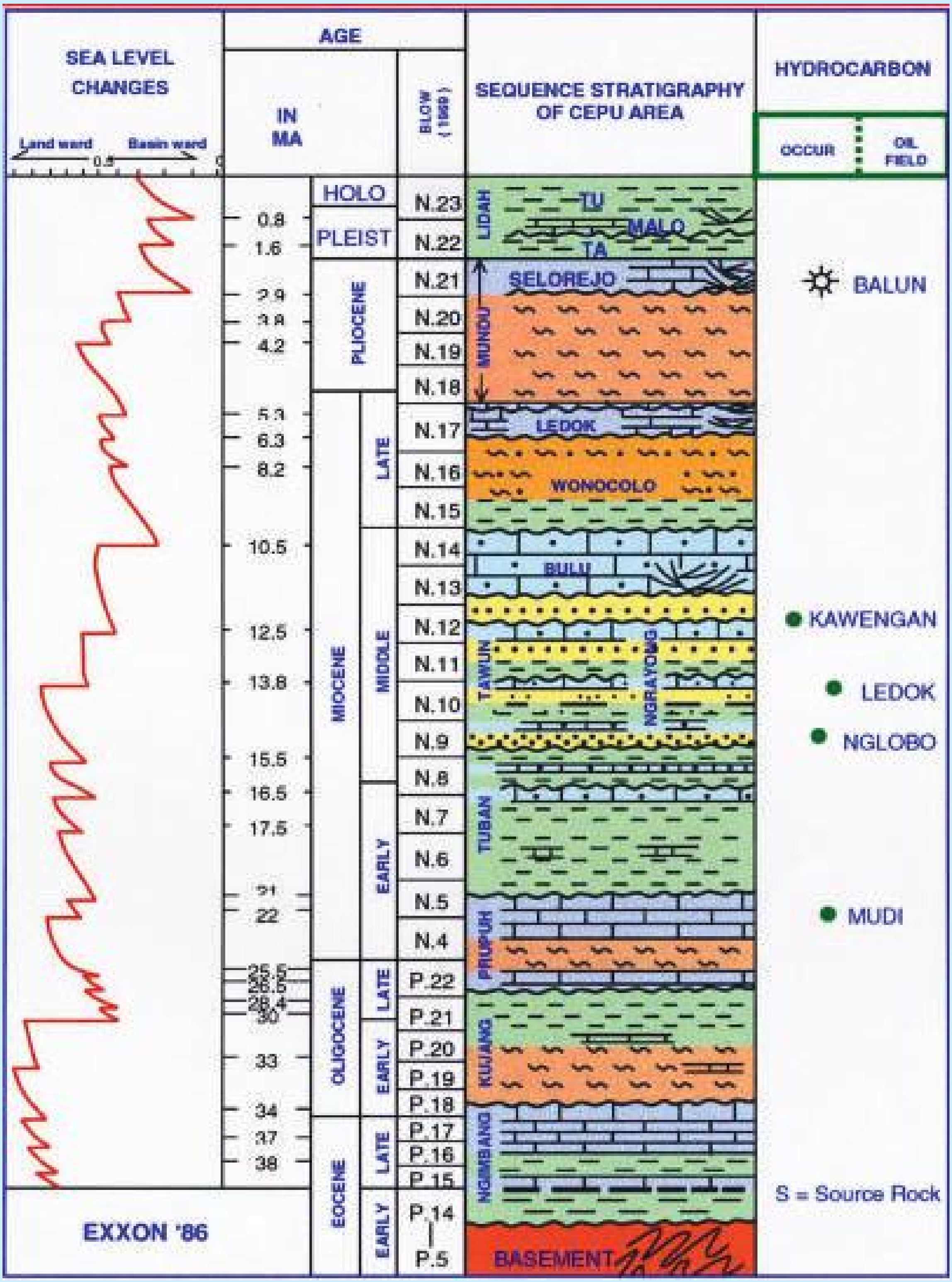



**Figure 1**
**Stratigraphyc Rembang Zone (Exxon, 1986 on IPA-Pusdiklat Migas Cepu, 2003).**

Petroleum System developed in the East Java Basin, with its sources rock is believed to be derived from black shale from the lower Ngimbang Formation, and the calcareous claystone of the lower Kujung Formation, besides that some of the shale that leds be the sources rock is the shale of the Lower Tuban Formation. According to Noble (1989), Ngimbang and Kujung Formations in Cepu and surrounding areas is a good formation as good sources rock. Reservoir target in this region consists of clastic and Carbonate Ngimbang Formations, Carbonate Kujung, Ngrayong Formations Sandstone, and Wonocolo Formations Sandstone (Hadipandoyo et al. (2006) & BPMigas-LAPI ITB (2008)).

Furthermore Hadipandoyo et al. (2006) explains, hydrocarbon migration in the form of vertical migration (through active fault system) and lateral migration is interpreted through dipping layer/up dip. The hydrocarbon traps that develop in this area is a structural trap in the form of anticline and fault blocks traps, in addition to some stratigraphic traps of carbonate reefs and pinch-outs of sandstone. While the seals that develops in this area comes from the shale of the Tuban Formation, the shale of the Kujung Formation, and the intraformational shale.

Hydrocarbon Play in the East Java Basin can be divided into 5 (five ) play (Hadipandoyo et al. (2006) dan BPMigas-LAPI ITB (2008)), ie: Middle Eocene Sandstone Play of Ngimbang Formation, Upper Eocene Limestone Play of Ngimbang Formation, Oligocene - Early Miocene Carbonate Reef Play, Middle Miocene Quartz Sandstone Play of Ngrayong Member, and Upper Miocene sandy Limestone Play of Wonocolo Formation.

## III. RESULT AND DISCUSSION

In this study to improve image quality in addition to calibration and multi-looking, the filtering process used is a combination of Lee filter and median filter with 5x5 kernel width. Combination of both filtering is always maintaining and assert edge boundary also reduce noise without making image to blur. In interpreting these geological structures, an understanding of the process of deformation of rocks is necessary. Deformation is the process of changing the body of the rock due to the forces acting on it.

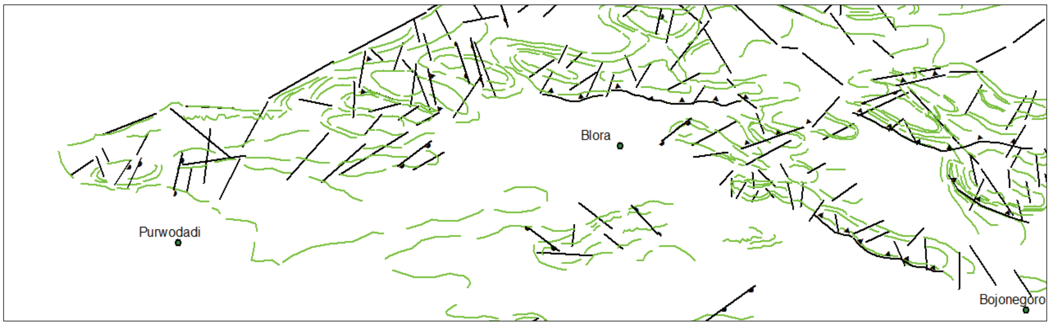
The fold structure occurs because of the compression force. In the identified research area of radar image that is in the form of anticlinal structure and synclinic structure. In the second image of the geological structure is recognized by the pattern of the arch, the existence of a system of rock layers, and a pair of dip direction, if each other away the dip direction then form anticlinal structure and form a syncinical structure when dips direction are nearing each other.

If the compression force continues, when it exceeds the rock elasticity threshold then the rock may be cracked and eventually fault. In the fault structure, as previously described, there are three main types of faults that develop on the surface of the earth, ie normal faults, thrust fault, and strike-slip fault. The closure may associate with a hydrocarbon trap system, because without closure, hydrocarbons will not accumulate. Hydrocarbons trap system may be recognized by radar data is a structural trap in this case a trap caused by folds of anticline or by a fault system. To obtain the closure of the structure, the result of the interpretation of the geological structure is overlaid with geological map. This overlay is intended to obtain rock information on each of the anticlines that have been identified. An anticline is interpreted as a closure when the constituent rock formation layer contains 5 (five) petroleum system elements.

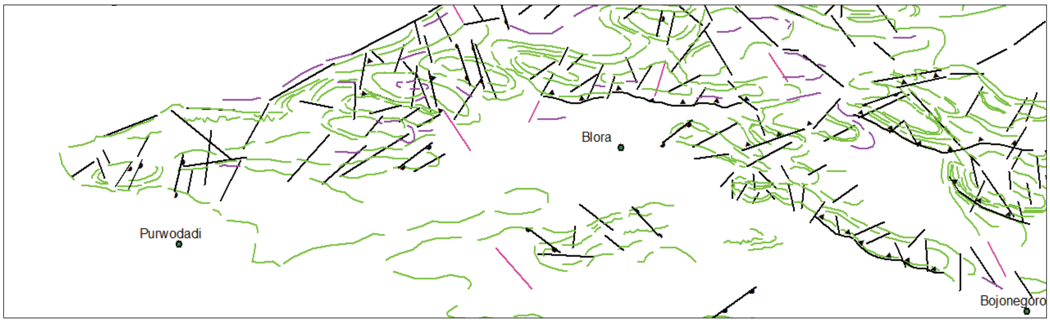
Interpretation of geological structures and closures is done by interactive visual interpretation, ie manual interpretation sequentially each polarization, where the interpretation starts from the image with the best possible appearance on an ongoing basis. In this study the interpretation begins HH - HV - VV polarization image and the last polarization V. In Figure 2 is shown interactive visual interpretation stage for structural and closure interpretation and Figure 3 shows the result of interpretation of geological structure and closure.

Based on Moody and Hill model, 1956 in LEMIGAS (2007) and the result of image interpretation, it can be concluded that there are 2 order of development of geological structure in research area. Which are shown by the two main direction, as follows;

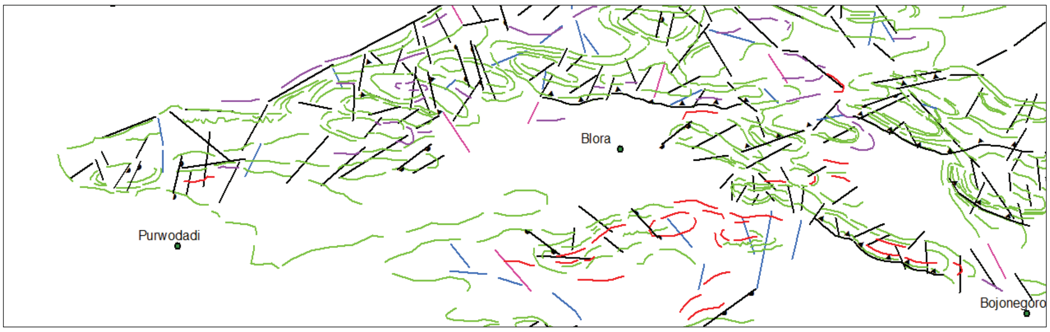
(i) The firts order with the direction N-S, or the direction of movement of the South China Sea Plate (Eurasia) from the North and the Indian Ocean Plate from the South. This is indicated by the presence of a thrust fault pattern with the W-E direction, the anticline and syncline structure patterns with W-E direction, the strike slip fault pattern with the NW-SE, SW-NE directions, and the normal fault structure pattern N-S;



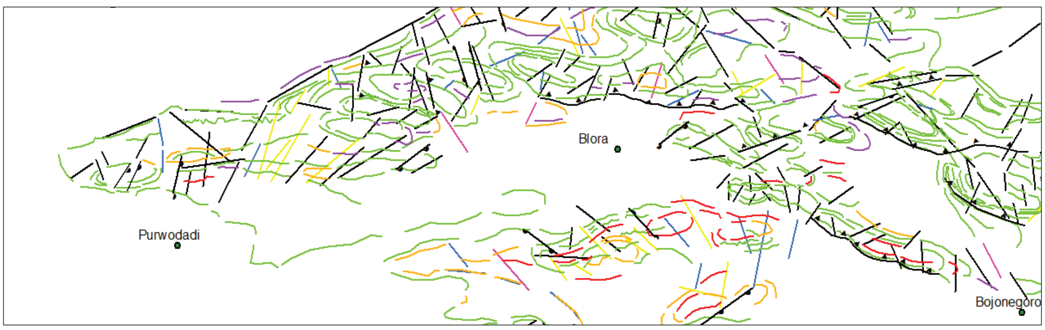

HH polarization interpretation




HH+HV polarization interpretation




HH+HV+VV polarization interpretation




HH+HV+VV+VH polarization interpretation

**Figure 2**
**Geological and closure structure interactively visual interpretation.**

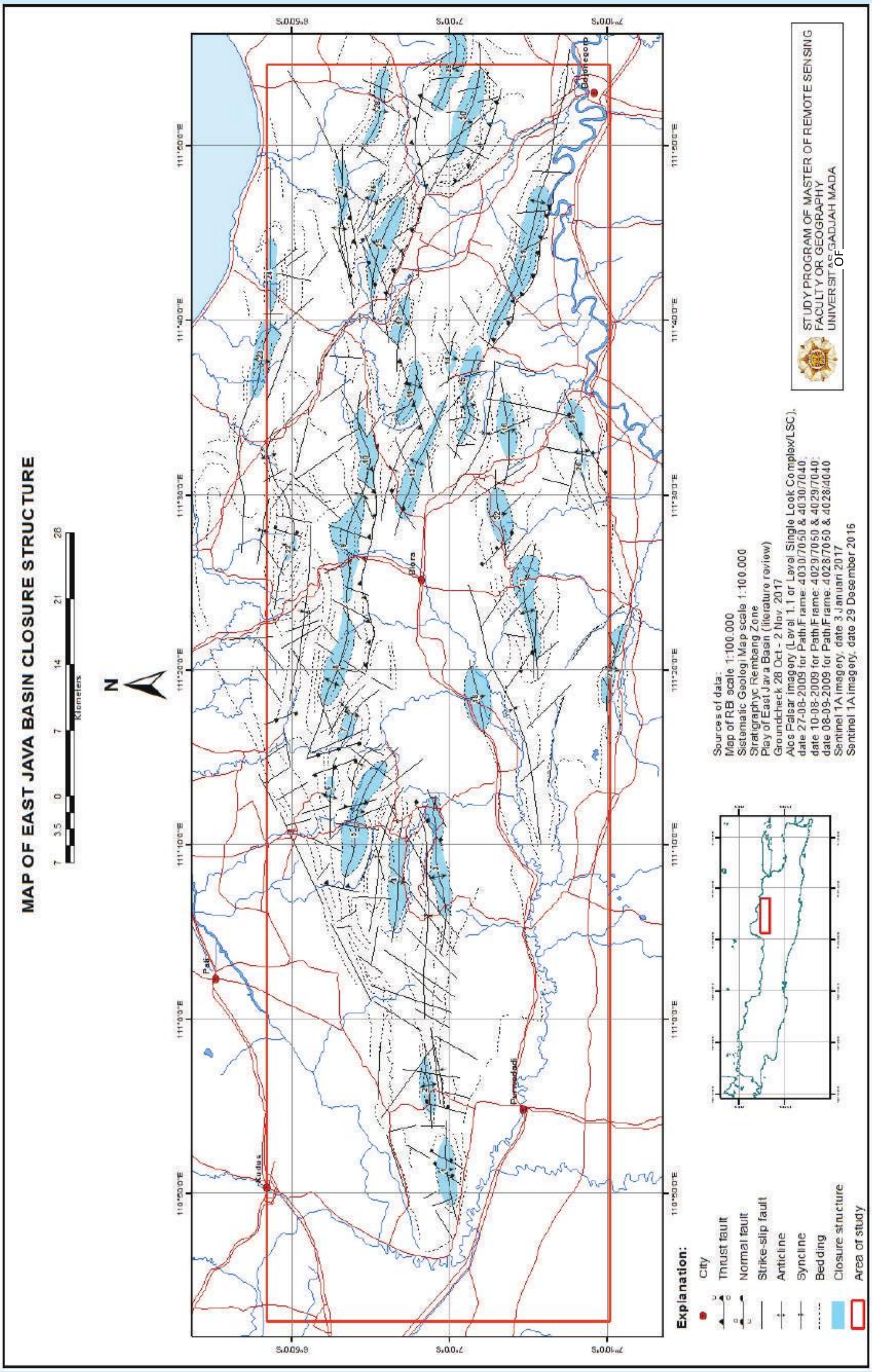



**Figure 3**
**Closure structure map in East Java Basin based on geological and closure interpretation.**

(ii) The 2nd order with SW-NE direction. This is indicated by the presence of a thrust fault pattern in the direction of NW-SE, anticline and syncline structure patterns with NW-SE direction, strike slip fault pattern with N-S, W-E direction and normal fault structure pattern SW-NE.

The hydrocarbon traps analysis needs to know the elements of the petroleum system and hydrocarbon play that develop in the study area. In this research to identify hydrocarbon trap system, by arranging matrix of result of closure interpretation which has identified its petroleum system element and hydrocarbon play from existing research. Based on existing research, hydrocarbon play in research area can be divided into 5 (five) play (Hadipandoyo et al. (2006) & BPMigas-LAPI ITB (2008)), they are:

a. The Middle Eocene Sandstone Play of the Ngimbang Formation.
b. The Upper Eocene Limestone Play of the Ngimbang Formation.
c. The Oligocene - Early Miocene Carbonate Reef Play.
d. The Middle Miocene Quartz Sandstones Play of the Ngrayong Member.
e. The Upper Miocene Sandy Limestone Play of the Wonocolo Formation.

The matrix of the closure and hydrocarbon play interpretation results as shown in Table 1 and Figure 4 shows the distribution map of the hydrocarbon trap in the research area.

Table 1 shows that all the identification closures in the study area, potentially on the The Middle Eocene Sandstone Play of the Ngimbang Formation, The Upper Eocene Limestone Play of the Ngimbang Formation, and The Oligocene - Early Miocene Carbonate Reef Play. The Middle Miocene Quartz Sandstones Play of the Ngrayong Member and The Upper Miocene Sandy Limestone Play of the Wonocolo Formation only develops on several closures, that is:

- The Middle Miocene Quartz Sandstones Play of the Ngrayong Member only develops on 1, 2, 6, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 31, 32.
- The Upper Miocene Sandy Limestone Play of the Wonocolo Formation only develops on some closures 18, 19, 20, 21.

From the result of hydrocarbon trap analysis and closure distribution in the research area, it can be seen that the research area can be divided into 3 (three) zones (Figure 5), ie (i) play zone A, (ii) play zone B, and (iii) play zone C.

The zoning of the three categories is limited by the growing play and the pattern of structures that are formed. The characteristics of each zone are as follows:

(i) play zone A is a zone with play that develop older than Middle Miocene such as the The Middle Eocene Sandstone Play of the Ngimbang Formation, The Upper Eocene Limestone Play of the Ngimbang Formation, and The Oligocene - Early Miocene Carbonate Reef Play. The Middle Miocene Quartz Sandstones Play of the Ngrayong Member and The Upper Miocene Sandy Limestone Play of the Wonocolo Formation is not developed, because in this zone the two play has been outcrop. The pattern of structures developed in this zone has a general W-E direction.

(ii) play zone B, that is apart from a play that develops in the old age play zone (zone A), this zone also develops The Middle Miocene Quartz Sandstones Play of the Ngrayong Member. The Upper Miocene Sandy Limestone Play of the Wonocolo Formation does not develop in this zone because it has been outcrop. In this zone the structural pattern that develops has NW-SE direction.

(iii) play zone C, the zone where the five plays in the research area are still well developed, it is because all are not yet outcrop on the surface. In this zone the structural pattern that develops has W-E direction.

Based on the above description, the exploration target can be determined based on the three zonations. In determining the exploration targets these three zones have little in common and differences. The exploration target equation of the three zones is on the deepest target or age target of the play, the three zones on The Oligocene - Early Miocene Carbonate Reef Play. The difference lies in the target of exploration play and the growing number of hydrocarbon plays that can be explored. The differences are:

- Zone A, the exploration play target of the Middle Eocene Sandstone Play of the Ngimbang Formation or The Upper Eocene Limestone Play of the Ngimbang Formation, and there are 3 (three) developing hydrocarbon play which can be explored. Closure in Zone A includes closures 3, 4, 5, 7, 8, 9, 10, 11, 22, 23, 24, 25, 26, 27, 28, 29, 30.

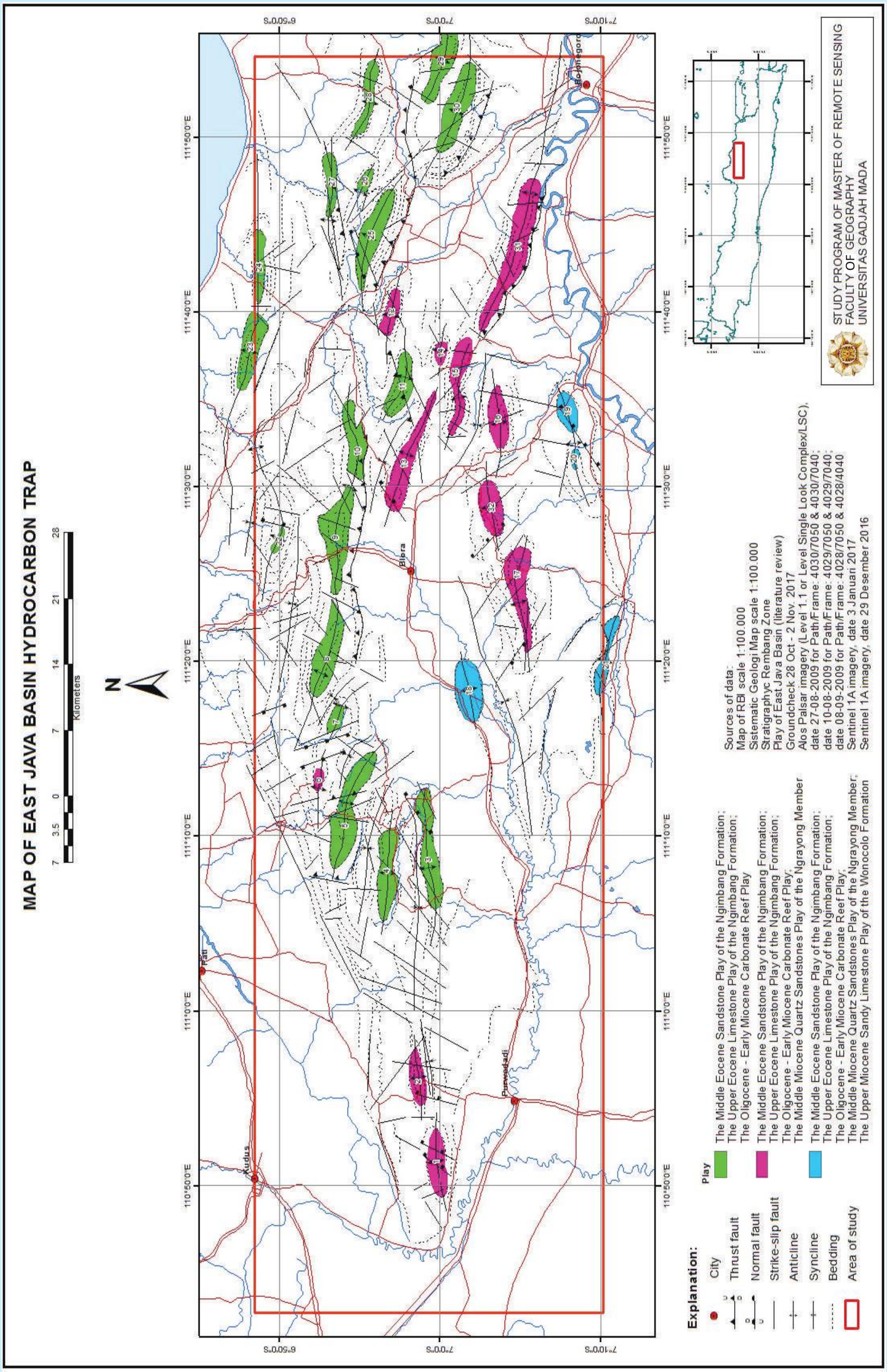



**Figure 4**
**Map of East Java Basin hydrocarbon trap.**

**Tabel 1**
**Matrix of closure and hydrocarbon play interpretation result.**

| Closure | *Hydrocarbon Play* in the East Java Basin | | | | |
|---|---|---|---|---|---|
| | The Middle Eocene Sandstone Play of the Ngimbang Formation | The Upper Eocene Limestone Play of the Ngimbang Formation | The Oligocene - Early Miocene Carbonate Reef Play | The Middle Miocene Quartz Sandstones Play of the Ngrayong Member | The Upper Miocene Sandy Limestone Play of the Wonocolo Formation |
| 1 | + | + | + | + | - |
| 2 | + | + | + | + | - |
| 3 | + | + | + | - | - |
| 4 | + | + | + | - | - |
| 5 | + | + | + | - | - |
| 6 | + | + | + | + | - |
| 7 | + | + | + | - | - |
| 8 | + | + | + | - | - |
| 9 | + | + | + | - | - |
| 10 | + | + | + | - | - |
| 11 | + | + | + | - | - |
| 12 | + | + | + | + | - |
| 13 | + | + | + | + | - |
| 14 | + | + | + | + | - |
| 15 | + | + | + | + | - |
| 16 | + | + | + | + | - |
| 17 | + | + | + | + | - |
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| 23 | + | + | + | - | - |
| 24 | + | + | + | - | - |
| 25 | + | + | + | - | - |
| 26 | + | + | + | - | - |
| 27 | + | + | + | - | - |
| 28 | + | + | + | - | - |
| 29 | + | + | + | - | - |
| 30 | + | + | + | - | - |
| 31 | + | + | + | + | - |
| 32 | + | + | + | + | - |

Information :

+ : prospects
- : no prospects

Source of play information from Hadipandoyo et al (2006) and BPMigas-LAPI ITB (2008), Geology Map of P3G KESDM, Interpretation of multi-polarized image geological structure.

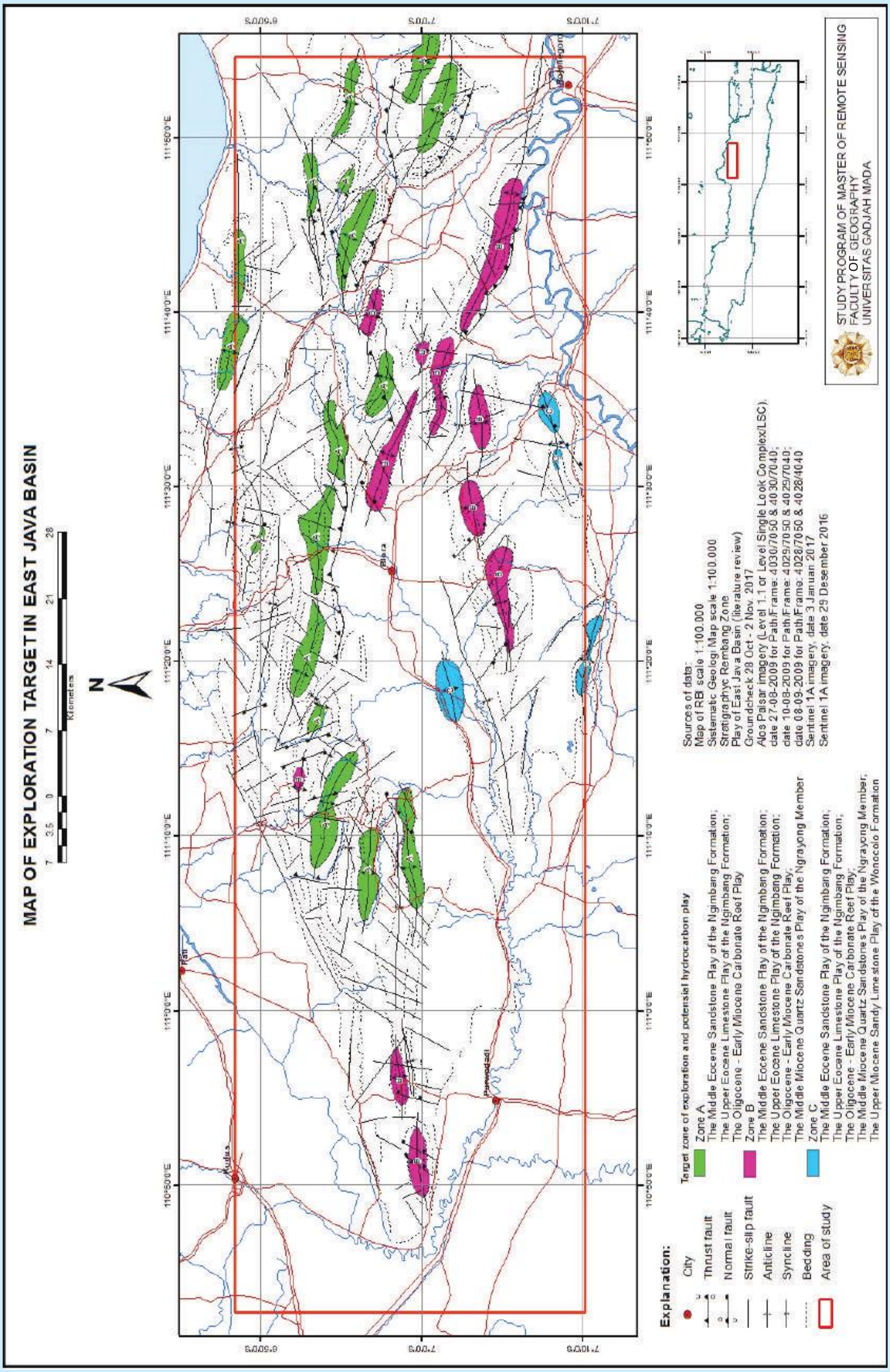


**Figure 5**
**Map of exploration target in East Java Basin.**

- Zone B, the exploration play target of the Middle Miocene Quartz Sandstones Play of the Ngrayong Member, and there are 4 (four) developed hydrocarbon play which can be explored. Closure in Zone B includes closures 1, 2, 6, 12, 13, 14, 15, 16, 17, 31, 32.
- Zone C, the exploration play target of the Upper Miocene Sandy Limestone Play of the Wonocolo Formation, and there are 5 (five) developed hydrocarbon plays that can be explored. Closure on Zone C includes closure18, 19, 20, 21.

## IV. CONCLUSIONS

The multi-polarization system generated from HVV / VH polarized Alos Palsar imagery and the VV / VH polarized Sentinel 1A 1 image is very good used for the analysis of the geological structure of the hydrocarbon trap controller. Geological structures such as rise normal faults structures, thrust fault structures, and strike-slip fault structures can be well identified. The information displayed by each polarization can be mutually supportive and complementary although not much a difference.

In the development research area the structure lasted two periods, with the main emphasis N-S in the order of 1 and the main direction of the SW-NE direction in the order-2. The hydrocarbon traps and exploration targets can be distinguished in three zones (Zone A, Zone B, and Zone C). Closure in Zone A includes closures 3, 4, 5, 7, 8, 9, 10, 11, 22, 23, 24, 25, 26, 27, 28, 29, 30. Closure in Zone B includes closures 1, 2, 6, 12, 13, 14, 15, 16, 17, 31, 32. Closure on Zone C includes closure18, 19, 20,

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## REFERENCES

**Bachri, S.** 2014. Pengaruh Tektonik Regional Terhadap Pola Struktur dan Tektonik Pulau Jawa. J.G.S.M. Vol.15, No. 4, hal. 215-221.

**BPMigas-LAPI ITB.** 2008. Cekungan Sedimen Tersier Indonesia 2008 : Buku 3. Jakarta : BPMigas (tidak dipublikasi).

**ESA.** 2013. Sentinel-1 User Handbook. Eropa : European Space Agency.

**Gagnon, L.,** and **Joan, A.** 1997. Speckle Filtering Of SAR Imagery – A Comparative Study Between Complex-Wavelet-Based and Standart Filter. Conference "Wavelet Applications in Signal and Image Processing V", San Diego, Vol. 3169.

**Hadipandoyo, S., Setyoko, J.H., Guntur, A., Riyanto, H., Sunarjanto, D., Suliantara, Suprijanto, Hadiwiryono, T., dan Sutikno.** 2006. Kuantifikasi Sumberdaya Hidrokarbon Volume I Kawasan Barat Indonesia. Jakarta: PPPTMGB Lemigas (tidak dipublikasi).

**Hung L.Q., Batelaan O.1,** and **De Smedt F.** 2005. Lineament extraction and analysis, comparison of Lansat ETM and ASTER imagery. Case study: Suoimuoi tropical karst catchment, Vietnam. Remote Sensing for Environmental Monitoring, GIS Applications, and Geology V, SPIE Vol. 5983, 59830T, hal. 1-12.

**Indonesian Petroleum Association 28th Annual Convention.** 2002. 2002. Exploration of the North Madura Platform, Offshore East Java, Indonesia. Mudjiono, R., and Pireno, G.E. IPA, hal. 707-726.

**Indonesian Petroleum Assosiation Eighteenth Annual Convention**. 1992. Structural And Stratigraphic Evolution Of The Java Sea, Indonesia. Bransden, P.J.E and Matthews, S.J. IPA, hal. 417-453.

**IPA-Pusdiklat Migas Cepu.** 2003. Geological Trip to Cepu Area for Non-geoscientist Personel. Pusdiklat Migas Cepu

**LEMIGAS.** 2007. Studi Evolusi Tektonik Dan Struktur Daerah Semenanjung Muria Dan Sekitarnya. PPPTMGB "Lemigas" Balitbang KESDM (tidak dipublikasi).

**Lillesand, T.M., Kiefer, R.W, Chipman, J.W.** 2015. Remote Sensing and Image Interpretation 7th Edition. USA: Wiley.

**McCandless, S.W.** and **Jackson, C.R.** 2004. Chapter 1. Principle Of Synthetic Aperture Radar, dalam Synthetic Aperture Radar Marine User's Manual. Washington, DC: US Department Of Commerce NOAA.

**Napitupulu, H.** 2016. Usaha Meningkatkan Cadangan Migas Nasional. http://eksplorasi.id/usaha-meningkatkan-cadangan-migas-nasional/. Dilihat pada tanggal 21 Januari 2017.

**Natsir, M.** 2014. Klasifikasi Palsar Multi-Polarisasi di Daerah Aceh. Seminar Nasional Penginderaan Jauh 2014.

**Natural Resouces Canada.** 2015. Tutorial: Fundamentals of Remote Sensing. http://www.nrcan.gc.ca/node/9309 (Diakses 21 Februari 2017).

**Natural Resouces Canada.** 2016. Tutorial: Fundamentals of Remote Sensing. http://www.nrcan.gc.ca/node/9309 (Diakses 21 Februari 2017).

**Noble, R.A.,** 1989. Geochemical Evaluation of Late Eocene Ngimbang Formation Source Rocks, Kangean Block, Indonesia. Arco, hal. 44. *Unpublished Report*.

**Radarsat.** 1996. RADARSAT GEOLOGY HANDBOOK. Canada: Canada Centre for Remote Sensing RADARSAT International.

**Soetoto.** 2015. Penginderaan Jauh Untuk Geologi. Penerbit : Ombak. Yogyakarta.

**Sutanto.** 1994. Penginderaan Jauh Jilid 2. Yogyakarta: Gadjah Mada University Press.

**Veci, L.** 2016. SENTINEL-1 Toolbox Polarimetric Tutorial. ESA.

**Wolff, C.** 2007. Polarization of electromagnetic waves. http://www.radartutorial.eu/06.antennas/Polarization.en.html (Diakses 23 Juni 2017).