LEAD IDENTIFICATION BASED ON SEISMIK 2D DATA, NORTH KABAENA SUB-BASIN, BONE BASIN, SOUTHERN SULAWESI

Fiqry Darwansyah [1*], Edy Sunardi[1], Nisa Nurul Ilmi[1], Agus Santa Ginting[1]

[1]*Faculty of Geological Engineering, Padjadjaran University*
*Correspondending author: *Fiqrydarwansyah@yahoo.com

ABSTRACT

The research was conduct in north Kabaena sub – basin in the middle of the Bone Bay and it is the result of tectonic development of Sulawesi since the early Miocene. Since early Miocene tectonic development creating spaces for the accommodation process of sedimentation in Bone Bay. The existence of a process of sedimentation in the Bone Bay allows the existence of oil and gas. As a contribution to the development of science and oil & gas industry in Indonesia, study of the north Kabaena sub – basin was conducted with seismic 2D and gravity anomalies. This study is aiming to find out potential area through the subsurface contour maps. This research start with the analysis of the fault on the 2D seismic interpretation and aided by gravity anomaly data, followed by horizon interpretation using tectonostratigraphy approach as a marker. Both interpretation is a material to make subsurface contour maps. Through this research, we identified 5 packs of rocks from old to young is unit X, unit A, unit B, and unit C&D, and we proposed a lead's which is at unit C with carbonate build up type.

Keywords: Bone Bay, North Kabaena Sub – basin, Lead’s

INTRODUCTION

The research area is a sub-basin located in southern Sulawesi precisely located in the Gulf of Bone which is between the southern arm and southeast arm of Sulawesi. The research area is one of the sub-basins identified by Camplin & Hall (2014), Bone Bay is divided into 4 sub-basins namely the Padamarang sub-basin to the north, the cub-Kabaena basin to the south, Liang-liang sub-basin to the east, and the Bone sub-basin to the west, and there is one trough, the Selayar trough on the southwest. The research area is the northern Kabaena sub-basin which has an area of 11,886.4375 km². The fact that production and consumption of oil and gas in the country (detik finance) are unbalanced, causing efforts to increase production so that a balance between production and consumption occurs through the use of sedimentary basins in Indonesia. These efforts can be realized through exploration, maintenance of wells, EOR, and further research on basins that have not been or have been explored. One of the efforts that can be done by the writer is to do research for the development of science and is expected to be able to contribute to the development of the oil and gas industry in Indonesia.

REGIONAL GEOLOGY

Sulawesi is an archipelago located in the central part of Indonesia with an area of 174,600 km². Sulawesi is the main point of the world's three major plates, namely the continental plate of India - Australia which is relatively moving to the north, the Eurasian continental plate which moves relatively south-southeast, and the Pacific and Philippine oceanic plates which are relatively westward (Armstrong, 2012). Sulawesi has a form resembling the letter K with four peninsulas that point east, northeast, southeast and south, the peninsula is bordered by the island of Borneo to the west, the Philippines to the north, the island of Flores to the south, Timor to the southeast, and Maluku to the east. Plate collisions that occur cause Sulawesi's very complex geological conditions, including the mixing of types of constituent rocks to structures that develop in Sulawesi. Sulawesi's tectonic development is inseparable from two events, namely rifting which occurred in the Makassar strait in Paleogene and compressional at the time of the Miocene

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which was affected by collisions of fragments of archipelago arcs in the east (Buton, Ironworker and Sula). Compression that occurs causes the formation of the folds of West Sulawesi (West Sulawesi Fold Belt) which developed in the early Pliocene. Compression does not only cause the formation of the folds of West Sulawesi (West Sulawesi Fold Belt) but is believed to affect tectonic events in all parts of Sulawesi (Calvert, 2003).

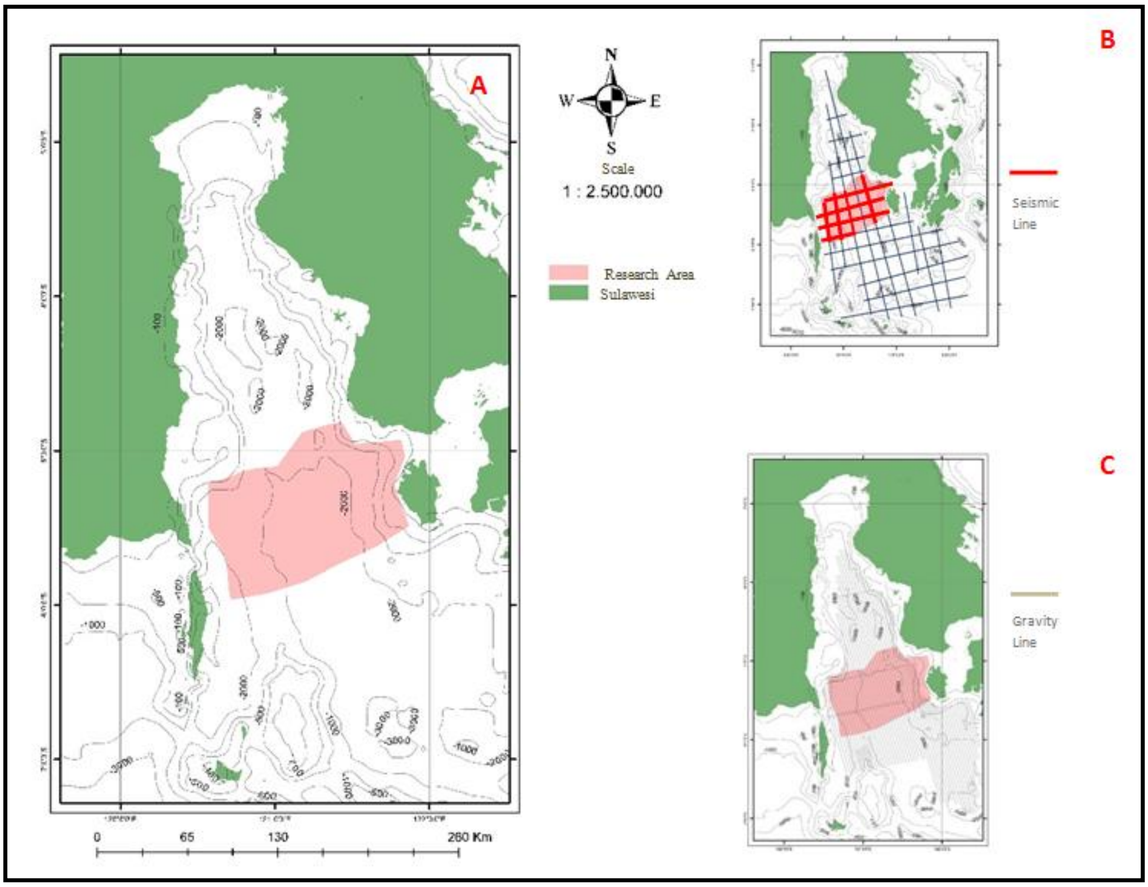

Figure 1. (A) Research area, (B) Seismic aquisition line of research area (C) Gravity aquisition line of research area

METHOD

This research was conducted using secondary data in the form of gravity anomalies and 2D seismic data. The study was conducted by analyzing variables such as geological structure, stratigraphy, and the potential of oil and gas identified through 2D gravity and seismic anomalies. Gravitational anomaly data is used to help analyze the geological structure of the northern Kabaena sub-basin in 2D seismic sections. Furthermore, rock package analysis was carried out based on the tectonostratigraphy approach of the northern Kabaen sub-basin. Finally, this research will produce potential areas of oil and gas availability in the northern Kabaena sub-basin.

RESULTS AND DISCUSSION

FAULT INTERPRETATION

GRAVITY ANOMALY

From the interpretation of free air anomaly maps and gravitational anomaly maps, the contrast limits of rocks found in Bone Bay have a dominant pattern northwest - southeast with an approximate orientation of ± N340° / ± N120°. The contrast that is identified is assumed to have a fault line in the direction of dip with a decrease in rock blocks that are indicated by differences in anomalous values (graviral anomalies and free air anomalies).

SEISMIC

Withdrawal of the main fault is aided by a straight line interpretation of the contrast value

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of the gravity anomaly and the free air anomaly contrast value limit. The main faults in the study area were 13 (2 main faults in the Selayar trough) with different dimensions of the cesarean section (vertically). The faults interpreted can be seen in the 2D window picture of Petrel 14 (Figure 4), when viewed from the picture, the faults interpreted have different lengths and the continuation of faults in the middle of the study area starting from the Padamarang sub-basin to the northern Kabaena sub-basin. The main fault interpreted has a main northwest-southeast pattern with an approximate orientation of ± N345° / ± N125°, the main faults formed have similar patterns and orientations to the regional structure according to Camplin-Hall (2013).

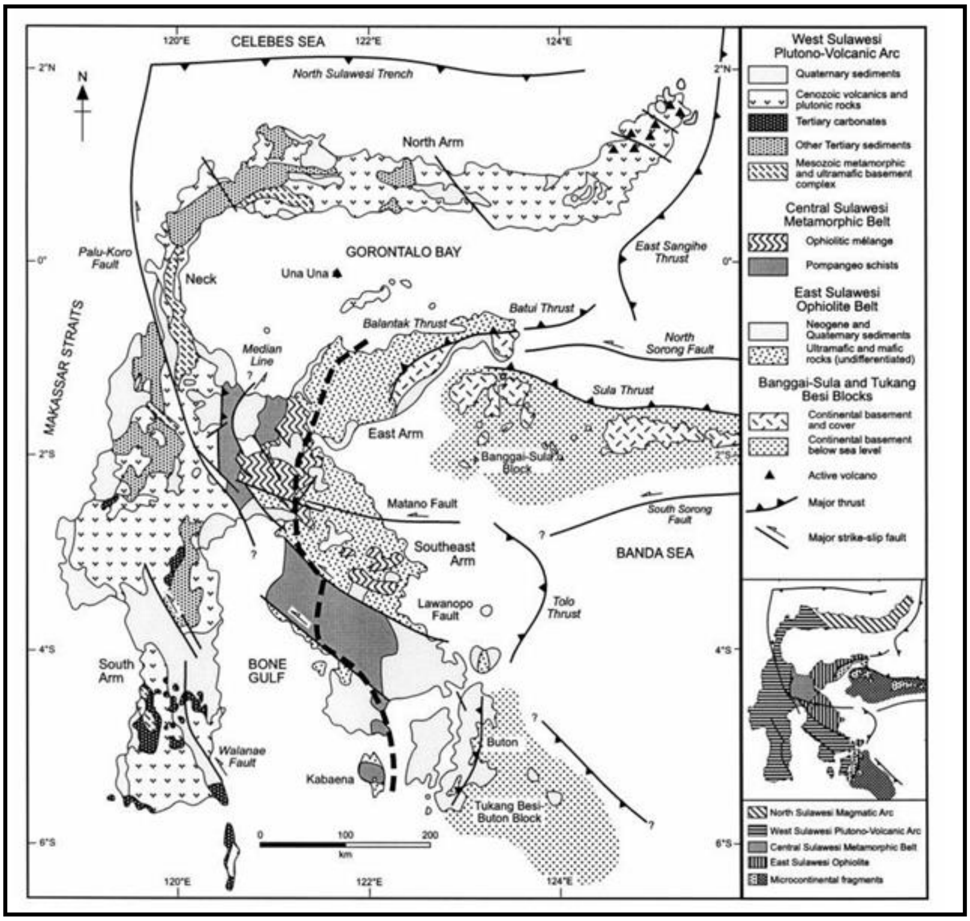

Figure 2. Geology Map of Sulawesi (Hall and Wilson, 2000)

The main fault that develops in the Bone basin is dominated by moderate subduction angles with a fault field that varies from planar to curved. The main faults that are formed are inseparable from the overall tectonic influence of Sulawesi, so changes in the Bone basin configuration are very likely to occur in the course of the evolution of the tics. The main magnitude that develops in the northern Kabaena sub-basin is seen from the seismic cross section BN07 BN07-09 _ PRCMIG (Figure 5) with a slope of the medium fault area which is relatively constant. However, it can be seen in the seismic cross section BN07 BN07-11 _ PRCMIG (Figure 5) that some of the main faults of the northern Kabaena sub-basin are reactivated and cause deformations in younger sediments.

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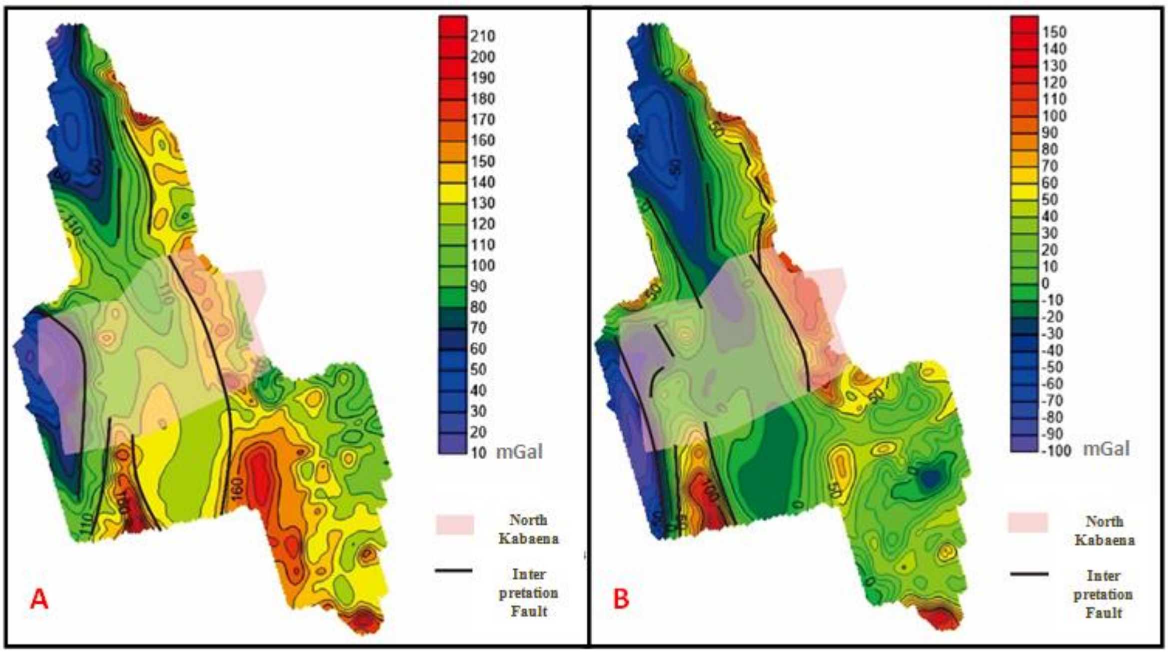

Figure 3. (A) Interpetation of Contrast limit of Complete Bouguer Anomaly (B) Free Air Anomaly

Figure 4. Petrel 14 window; Number 1,2, and 3 is the Major Fault across North – South Part of research area

The main fault reactivation seen in the seismic cross section BN07 BN07-11_PCMIG (Figure 5) can be caused by changes in the force affecting the fault. Old faults in the sub-basin of northern Kabaena that penetrate the young sedimentary layer can be said to occur due to changes in style. The change in force that is intended is extensional to be compressional, the extraneous style of being compressional is indicated by a change in direction of the movement of the fault (down-up) and its effect on young sediments. Changes in the direction of movement of this cesarean section occurred in the middle Miocene - late Miocene age range, which changed normal faults to a fault (Camplin & Hall, 2014). However, the compressional force is changed back to the conventional force at the time of the initial Pliocene, this event causes the change in the fault to be a normal fault again (Camplin & Hall, 2014).

The force changes that occur cause the sediments formed during the Miocene-Pliocene to be deformed due to the reactivation of the main fault forming the northern Kabaena sub-basin. But it is not yet known exactly whether the linking of young sediment by major faults

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(faults that penetrate the basement) is a result of regional or local compressional forces. However, according to Camplin & Hall (2013), reactivity of west bone fault systems only causes the formation of local upward faults. So that it can be said that reactivation movement is caused by a local force that only changes the movement of the fault field (local). According to Camplin & Hall (2014), limiting faults existed in the two sub-basins of the padamar including the west bone fault system which migrated westward. But the bounding fault on the Kabaena sub-basin north turns into a bonerate fault zone. This is related to rifting movements as a result of the relative counter-clockwise (anti clockwise) playback of the southeast Sulawesi arm to the southern arm of Sulawesi. Rifting movements that occur in the Bone basin cause widening of the basin to the south.

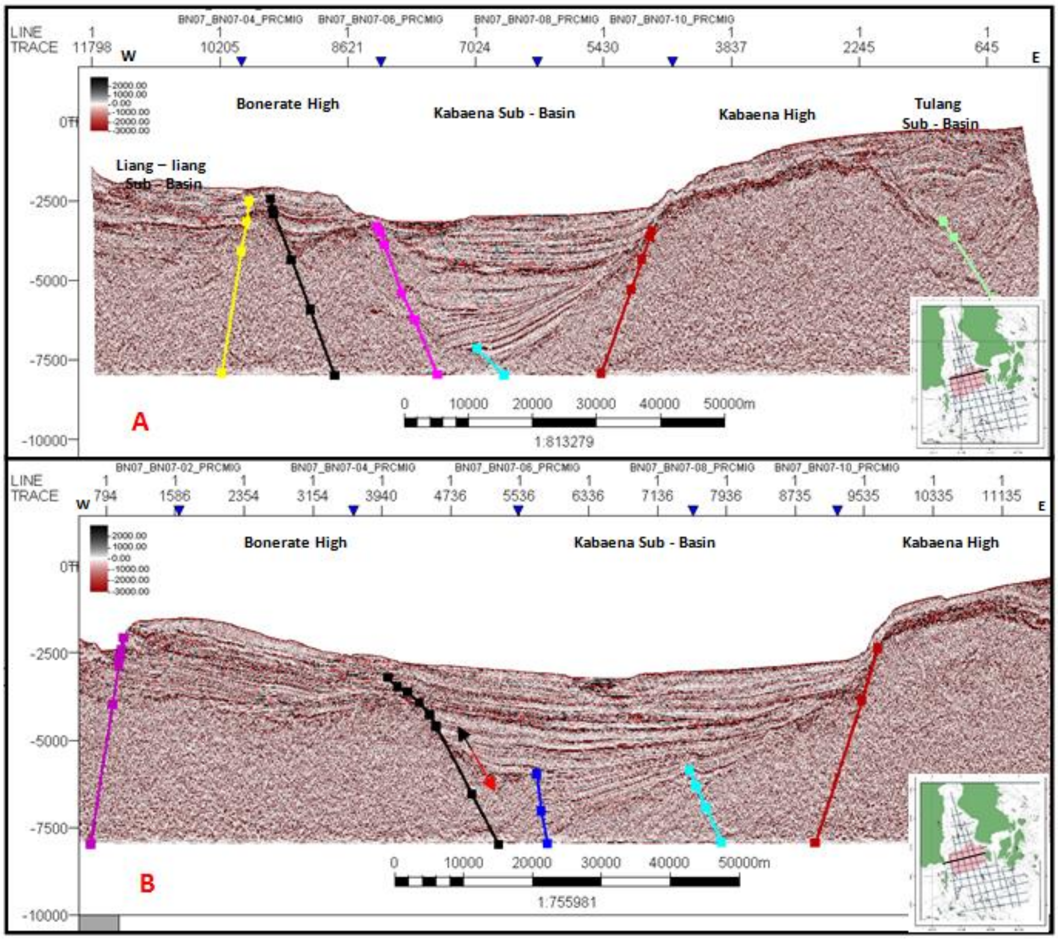

Figure 5. (A) Seismic Cross Section BN07 _ BN07 - 09 _ PRCMIG (B) BN07 _ BN07 – 11 _ PRCMIG

This expansion causes a westward movement from the bounding fault to the northern Kabaena sub-basin deposenter. Seen from Figure 5 (**A**) the bounding fault is a west bone zone fault, and is interpreted as the main bounding fault that is first formed in the rifting phase. The bounding fault formed on the Northern Kabaena sub-basin then increasingly experiences external movement causing a very large decrease. This decrease causes the formation of a sedimentary sedimentary accommodation space and west bone fault movement towards the center of the basin. Furthermore, the fault which is to the west of the west bone fault zone is the bounding fault seen at this time. In the seismic cross section (Figure 5, **B**), it can be seen that the black line is a bounding fault and identified as a bonerate fault by Camplin & Hall (2014). Meanwhile the westbone fault zone is in the middle of the northern Kabaena sub-basin, as a result of the development of the width of the Bone basin to the south. In the picture above also shows the east bone fault (red line in Figure 5 **A** & **B**) with the same movement and fault area as west bone fault and bonerate fault. Limiting

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faults in the northern Kabaena sub-basin form a basin setting into an asymmetrical rift-basin.

ROCK UNIT

In this research, the horizon interpretation process and the distribution of rock packages are carried out based on the configuration of boundary shape and seismic reflectors. Based on the results of the research in the northern Kabaena sub-basin, there are 5 packages of rock from old to young are unit X rock packages, unit A rock packages, unit B rock packages, unit C rock packages, and unit D rock packages.

UNIT X

Unit X has the characteristics of a chaotic seismic reflector configuration (Figure 6) or cannot be identified as a horizon alignment below the surface. The chatotic characteristic of a seismic reflector causes the author to call it a basement. Unit X is spread throughout the northern Kabaena sub-basin as the lowest rock unit and is assumed to be bedrock with inconsistent age and lithology (Camplin & Hall, 2014). The rock package above unit X has a seismic reflector configuration that can be identified by the straightness – the horizon alignment in it. Some rock packages above unit X have a continuous and non-continuous seismic reflector configuration, this will be related to the division of tectonostratigraphic units that are in order more than unit X. In addition, the boundaries of younger rock package interactions vary from on-lapping to down-lapping against unit X. Limits formed can be influenced by tectonics that develop during the deposition process of rock packages that are above unit X. Unit X is spread as high and low which restricts or becomes base rock where younger rock packages are deposited. Unit X is estimated to be composed of meta-sedimentary rocks which are considered as pre-Miocene economic basements, this age assumption is derived from estimates of Yulianto's basement picking (2004) which was revised by Camplin & Hall (2014). According to Sukamto (1975), rock diversity along Sulawesi caused rock variations in the Bone basin, which Camplin & Hall (2014) mentioned basements in Bone basins had inconsistent lithology and age.

UNIT A

Unit A has a seismic reflector configuration that varies from parallel reflectors to divergent reflectors. Unit A is interpreted as sediment deposits associated with the initial process of opening a basin. In the northern Kabaena sub-basin it can be seen that unit A downlap (Figure 6) of unit X at the bottom of the depocenter (the bottom of the bounding fault). The unit A rock package has a wedge shape or thickens towards the Bonerate fault zone, with changes in parallel seismic reflector configuration to divergent (Hammocky). Unit A is a rock package that is deposited during the initial process of opening the basin so that basically sedimentation affecting the northern Kabaena sub-basin originates on two sides. During the opening of the Bone basin, new normal faults will be formed and provide new accommodation space for the sedimentation process. The process of identifying the upper limit of unit A refers to the configuration of sequence boundaries (downlap, onlap, and toplap) which are located younger. Along the height of Kabaena, it can be seen that unit A is attached to unit X (upper limit of interpretation as unit X). In the same place, the younger onlap rock package (Figure 6) of unit A. The limit of the onlap of younger rock packages to unit A is interpreted as the upper limit of unit A. Unit A is interpreted to have the age of the initial Miocene assumption based on BBA well correlation - 1 X conducted by Camplin & Hall (2014). If correlated with the Eastern of sengkang basin stratigraphic column, the possibility of the rocks in Unit A are carbonaceous shale, shallow marine sediment with a small amount of shallow marine carbonate content (east Sengkang - Bone basin stratigraphic table by Barlian Yulihanto, 2004).

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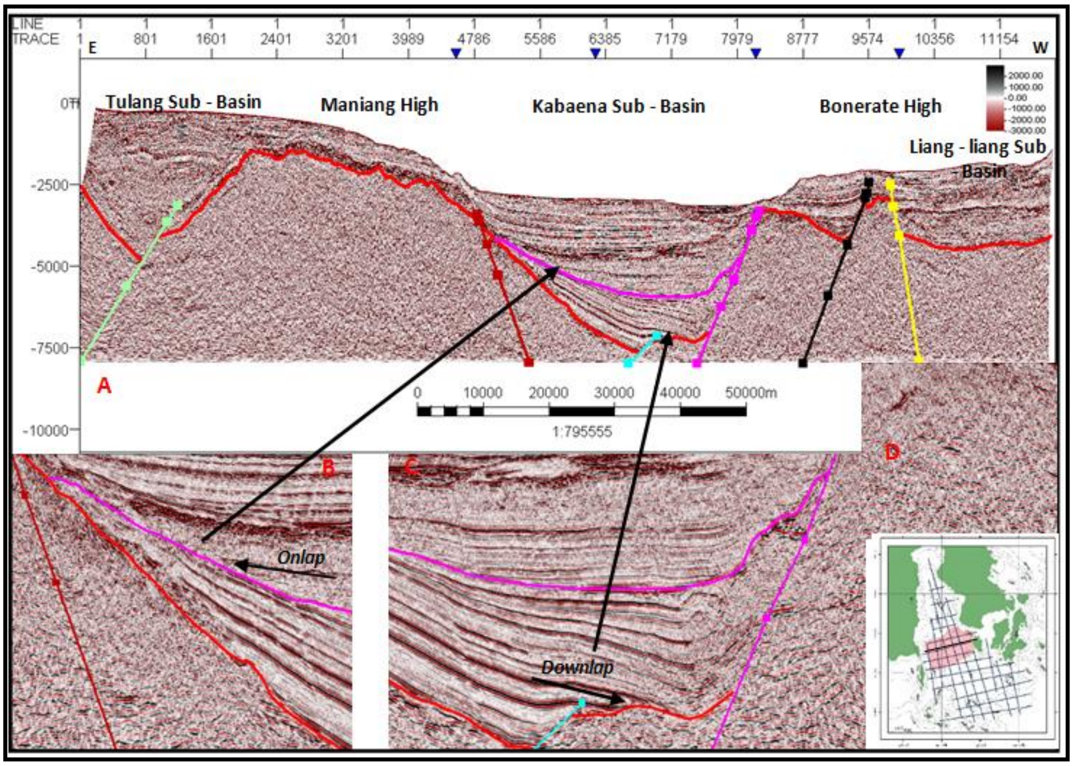

Figure 6. (A) Seismic Cross Section BN07 _ BN07 - 09 _ PRCMIG; (B) *Onlap* Boundary of unit A; (C) *Downlap* Boundary of unit A; (D) Seismic Reflection of unit X

UNIT B

The process of identifying the upper boundary of unit B is done by looking at the configuration of sequence boundary, the upper limit of the identified unit B is wavy and shows a boundary that is not planar. The upper limit of unit B can be related to one of the configuration of force boundaries, which is erotional truncation (Figure 7 **D**). Camplin & Hall (2014) also states that there is an erosion limit in the Bone basin, it connects the erosion boundary between squares to erosion barriers between rocks found in BBA-1X wells (located in Bulupulu), this erosion boundary connection is useful as a marker of age of each unit identified. The erosional limit of unit B can be caused by several things such as the cessation of the sedimentation process which results in a vacuum of occupancy space. The process of sedimentation that stops causes erosion at the top of unit B, so that the seismic cross section of this boundary looks bumpy. Based on the erosion boundary correlation that exists in 2D seismic crossings of BBA-1X wells (Camplin & Hall, 2014), the age of rock layers that are above the erosion field in BBA-1X wells are Pliocene (sandstone to conglomerate) with rocks that are in the old erosional lower limit Middle Miocene to late Miocene (calcareous claystone and thin limestone; Sudarmono, 2000). Meanwhile if it is associated with the Eastern of sengkang basin stratigraphic table (east Sengkang - Bone basin stratigraphic table by Barlian Yulihanto, 2004), then the middle Miocene to the end rocks are Camba formation rocks with little limestone and calcareous mudstone.

UNIT C & D

In the BN07_BN07-09_PRCMIG seismic cross section, it is seen that Buildup Carbonate (Figure 7 **B**) grows in the middle part of the basin followed by Carbonate platform (Figure 7 **C**) in the eastern part. Carbonate growth is followed by raising the sea level which causes the formation of the Carbonate platform along Maniang's high. Carbonate platforms and carbonate buildups identified through seismic devices are named as units C. Carbonate platforms and Carbonate buildup units C have slightly different characteristics, Carbonate platforms have a longitudinal shape with seismic features that form small mountain shapes. Some Carbonate platforms have faded

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internal seismic structures, while carbonate buildups grow isolated with faded internal seismic structures. In this phase the deposited rock package does not have a form of spreading, this is related to tectonic processes that have stabilized so that the deposited sediments do not have regional tectonic disturbances. The sea level rise continues to precipitate other rock packages, these rock packages are named as unit D. The deposited rock package as a whole has a continuous parallel seismic reflector configuration, this sediment package is deposited extensively and not thickening towards the main depocentre (Bonerate bounding fault) North Kabaena sub-basin. Minor faults are formed along the body of this rock package, but in this study no minor faults were formed (faults that deformed sedimentary rocks only). The process of degrading the footwall peak of Bonerate fault has reached its final stage, this process leaves the formation that we see today (Figure 8 **B**).

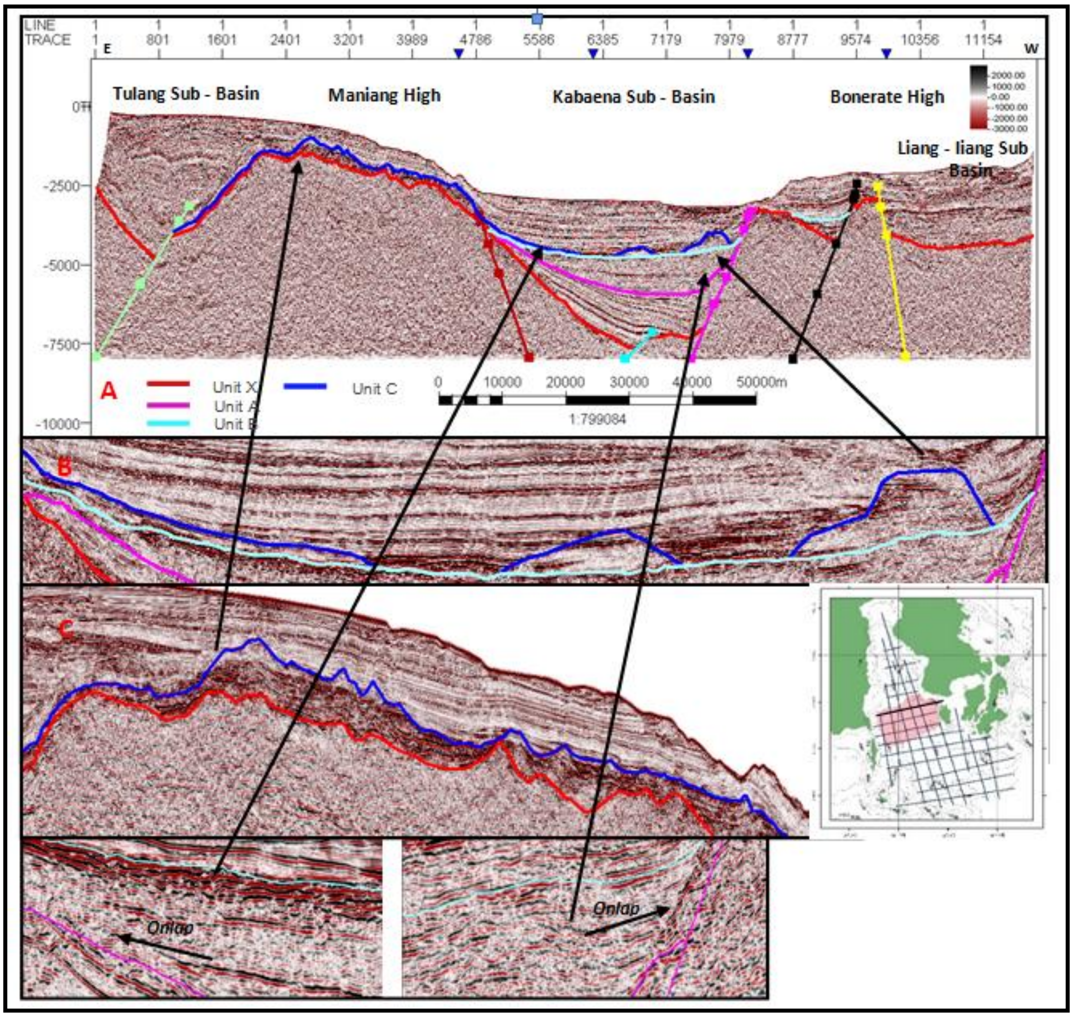

Figure 7.(A) Seismic Cross Section BN07 _ BN07 - 09 _ PRCMIG; (B) *Carbonate Platform* in unit C; (C) *Carbonate Buildup* in Unit C; (D) Erosional Boundary in Unit B; (E) *Onlap* Boundary in Unit

Erosion and degradation of footwall appearances from Bonerate faults cause sediment deposition that occurs to be dominated by fine-grained particles (Prosser, 1993). According to Camplin & Hall (2014), the Carbonate platform and Carbonate build-up found in the Bone basin are equivalent to the formation of Tacipi which is late Miocene - Pliocene. Whereas according to the interpretation of sediment unit D using the Prosser (1993) reference, unit D is composed of fine grained sedimentary rocks, it can be correlated with the Eastern of sengkang basin stratigraphic table (east Sengkang - Bone

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basin stratigraphic table by Barlian Yulihanto, 2004) as Walanae formation. Seismic cross section correlations of BBA-1X wells made by Camplin & Hall (2014) also show that rocks found above the erosion field (in wells BBA-1X) are gradual bedding conglomerates to sandstone (Pliocene) and covered in harmony by fine sands and silty glauconitic clay (Pliosen-Resen). So the authors draw the conclusion that the age assumption of unit C and unit D is the final Miocene - Pliocene.

SUBSURFACE CONTOURS MAP

Map of subsurface contours is generated after interpreting faults and horizons. In this study, the results of the interpretation of the horizon and fault are packaged in the form of time structure maps and time thickness maps. The time domain is still the only choice he does not know into the seismic cross section. Data limitations (no well data intersected with 2D seismic crossings of the Bone basin) make the writer only use the time domain in the map-making process. But basically the subsurface contour map is used to determine subsurface conditions, so the author tries to identify the information recorded in the time contour map.

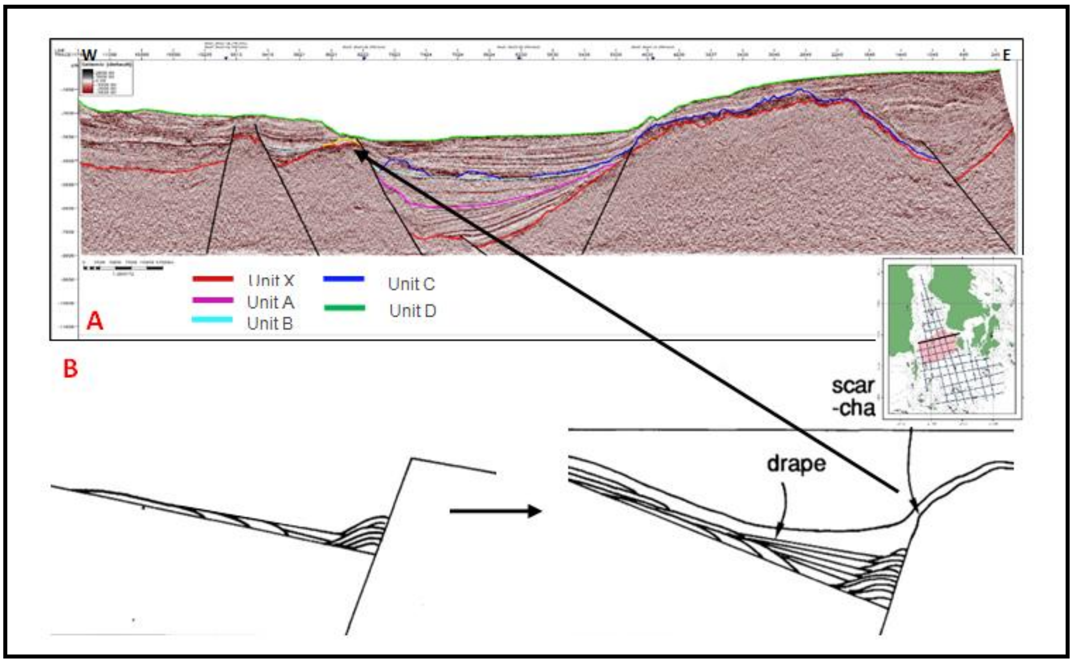

Figure 8. (A) Seismic Cross Section BN07 _ BN07 - 09 _ PRCMIG; (B) Degradation of fault block (Prosser, 1993)

LEAD'S

The process of interpreting faults and the subsurface horizon of the northern Kabaena sub-basin has been discussed in the previous sub-chapter. The process of interpreting the horizon is done using the reflector configuration characteristics and sequence boundary configuration. The interpretation of the horizon is then used as the basis for making a map of the time structure of each unit that has been identified. The time structure map generated from the interpretation of each unit is used as the basis for making time thickness maps. Time thickness maps provide information that is quite important in the process of oil and gas exploration. The author interpreted the time thickness map, which resulted in a possible interpretation of the presence of oil and gas in the northern Kabaena sub-basin. Based on the results of the interpretation of the time thickness map, there are two leads on one of the rock packages that have been interpreted. Lead's interpretation is derived from the rock package unit C, where the rock package is composed of carbonate platforms and carbonate buildup which is equivalent to the Tacipi formation in the eastern Sengkang sub-basin (Camplin & Hall, 2014). The lead that is

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identified in unit C is *carbonate build up*. The decision to take the lead above is based on the interpretation of the possible lithology of the northern Kabaena sub-basin rock package and correlated with the regional stratigraphy of the eastern Sengkang basin (east Sengkang - Bone basin stratigraphic table by Barlian Yulihanto, 2004). The age markers used in this study are the results of the unconformity boundaries that are in 2D seismic crossings against the inconsistency boundary at the BBA-1X well (Bulupulu sub-basin). Based on the analysis that has been done, each unit has an age assumption and the type of lithology that is associated with the process of forming the rock package. The rock A package is assumed to be equivalent to a shallow marine sediment lithology with little shallow marine carbonate content, the B rock package is assumed to be equivalent to the Camba formation and few limestone and calcareous mudstone, the C rock package is assumed to be equivalent to the Tacipi formation in the eastern Sengkang basin, and the D rock package is assumed equivalent to gradual bedding conglomerates to sandstone (Pliocene) and fine sands and glauconitic silt. Carbonate buildup can have good porosity and permeability, porosity formed on carbonate rocks can be grouped into connected porosity, unconnected porosity, and fracture porosity. Porosity in carbonate buildup is said to be good because at the time of its formation, the sediment material is blocked by the growth process so that the sediment will be difficult to enter into the pores. During the initial formation process, carbonate can have porosity reaching 35% - 75%, but the percentage of porosity will decrease along with the diagenesis process. Relationship between reservoir aspects of identified rock packages is carried out at the time of lead determination. Taking into account aspects of reservoir rock, it was decided to determine the carbonate build-up of unit C as a lead. Unit C is interpreted to be equivalent to the Tacipi formation in the eastern Sengkang basin. According to other researchers, the Tacipi formation meteoric dissolution of the aragonite material it contains and has several fractures due to receptive tectonics. Based on the above explanation the author decided to make the carbonate build up unit C as a lead with the possibility of a stratigraphic trap.

CONCLUSION

1. From the results of the study, rock units are divided into 5 based on seismic reflector configuration and sequence boundary configuration. Rock units from old to young are unit X, unit A, unit B, and C & D units.

2. From the results of the study, the three lead were identified. Lead's identification aims to analyze the potential presence of oil and gas in the research area. The identified lead is seen in the BN07_BN07-09_PRCMIG & BN07_BN07-11_PRCMIG seismic cross section as a carbonate build-up unit C.

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