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ESTIMATION OF LIMESTONE RESOURCES AT PT SEMEN BATURAJA TBK SOUTH SUMATERA PROVINCE

ESTIMASI SUMBERDAYA BATUGAMPING DI PT SEMEN BATURAJA TBK PROVINSI SUMATERA SELATAN

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Abstract. Limestone is a rock that is generally whitish, fine-grained, composed of calcium carbonate, and formed below sea level. The Sumatra region, especially in the South Sumatra region, has potential mineral resources in the form of limestone located in the Ogan Komering Ulu district. The study area is included in the Baturaja Formation (Nmb) with the Baturaja limestone unit and the Gumai Formation (Nmg) with the Gumai limestone unit, which are stratigraphically deposited in harmony. The formation of origin in the study area is divided into 2, namely the form of structural origin consisting of structural valley landforms (S1), and the form of anthropogenic origin consisting of non-mine landforms (A1), mine slope landforms (A2) and sump landforms (A3). In the research area in the field observations, there is a geological structure in the form of a right horizontal fault. With field observations and the presence of limestone resources in the research area, mining can be carried out in the area. In limestone mining, estimation is needed to be able to calculate resources before the mining process takes place. In this study, the depth of the limestone layer is modelled with a block model with the aim of being able to see the distribution of layers to be estimated. The estimation of limestone resources uses the Inverse Distance Weighting (IDW) method by estimating the value of the area that does not have an inferred value.

Abstrak. *Batu gamping atau coughapur merupakan batuan yang umumnya berwarna keputihan, berbutir halus, tersusun atas kalsium karbonat, dan terbentuk di bawah permukaan laut. Wilayah Sumatera, khususnya wilayah Sumatera Selatan, memiliki potensi sumber daya mineral berupa batu gamping yang terletak di Kabupaten Ogan Komering Ulu. Daerah penelitian termasuk dalam Formasi Baturaja (Nmb) dengan satuan batu gamping Baturaja dan Formasi Gumai (Nmg) dengan satuan batu gamping Gumai, yang secara stratigrafi diendapkan secara selaras. Asal formasi pada daerah penelitian terbagi menjadi dua, yaitu bentuk asal struktural yang* *terdiri dari bentuk lahan lembah struktural (S1), dan bentuk asal antropogenik yang terdiri dari bentuk lahan non tambang (A1), bentuk lahan lereng tambang (A2) dan bentuk lahan bah (A3). Pada daerah penelitian pada pengamatan lapangan terdapat struktur geologi berupa sesar mendatar tegak lurus. Dengan pengamatan lapangan dan keberadaan sumber daya batu gamping pada daerah penelitian, maka penambangan dapat dilakukan di daerah tersebut. Dalam penambangan batu kapur, estimasi diperlukan untuk menghitung sumber daya sebelum proses penambangan berlangsung. Dalam studi ini, kedalaman lapisan batu kapur dimodelkan dengan model blok agar dapat melihat distribusi lapisan yang akan diestimasi. Estimasi sumber daya batu kapur menggunakan metode Inverse Distance Weighting (IDW) dengan mengestimasi nilai area yang tidak memiliki nilai inferensi.*

1. INTRODUCTION

Limestone is a mineral that can be used as a raw material for cement. Cement is a commodity that utilises natural resources in the form of limestone, clay, iron sand and silica sand. Baturaja Formation and Gumai Formation in the research area exposed many rocks in the form of limestone. Limestone has more than 50% carbonate minerals ($CaCO_3$). Limestone, or known by local people as limestone, is formed from organic sedimentary rock, which is the result of a collection of shell, coral, and algae remains. The shell will accumulate and form sediment, and the lithification process will occur to form limestone. One of the benefits of limestone is as a raw material for the cement industry. The characteristics of limestone can affect the quality of the cement produced. So it is necessary to conduct research on the characteristics of limestone that is good for use as raw material for the cement industry (Wakila et al., 2021).

Cement is referred to as a hydrolysis adhesive because the compounds contained in the cement can react with water and form new substances that bond to rocks. The raw material for cement is a mineral that contains the main components of cement, namely CaO, SiO_2, Al_2O_3, and Fe_2O_3. Raw materials with high CaO levels are called limestone components. Meanwhile, raw materials with high levels of silica, alumina and iron oxide are called clay components (Duda, 1976). The main limestone compound used as raw material for cement is the CaO compound.

In Sumatra Region, especially South Sumatra, has potential mineral resources in the form of limestone, which is located in Ogan Komering Ulu Regency. In limestone mining, estimates are needed to be able to calculate resources before the mining process takes place. Resource modeling and estimation aim to determine the quantity and quality of limestone. With the required value of CaO content as raw material for cement that has been determined by the company, modeling and estimating this resource is very important so that a resource block model can be obtained based on the quality of CaO content. According to the Indonesian National Standardisation (SNI) classification (amendment to SNI 4726:2011), limestone resources are classified from all aspects of the feasibility study and exploration stages, so these limestone deposits can be said to be limestone reserves (Dika & Dono, 2021).

This research aims to determine the geological conditions at the PT site. Semen Baturaja TBK. Then, to find out the distribution of limestone based on drilling data at the PT site. Semen Baturaja TBK, and the last one is to find out the estimated limestone resources at the PT site. Semen Baturaja TBK.

2. LITERATURE REVIEW

Based on physiography, the South Sumatra Basin is a Neogene basin with northwest-southeast direction, bounded by the Semangko Fault and Bukit Barisan to the southwest, the Sunda Shelf to the northeast, the Lampung Plateau to the southeast which separates the basin from the Sunda Basin, and the Dua Belas Mountains and the Tigapuluh Mountains to the northwest which separates the South Sumatra Basin from the Central Sumatra Basin. Blake (1989) stated that the South Sumatra Basin is a Neogene back-arc basin which was formed as a result of the interaction between the Sunda Shelf (as part of the Asian continental plate) and the Indian Ocean plate.

According to Pulonggono et al. (1992), the tectonic events that played a role in the development of Sumatra Island and the South Sumatra Basin were the Compression Phase or Rifting Phase (Jura-Cretaceous). This phase lasted from the Early Jurassic to the Cretaceous. These tectonics produce northwest-southeast direction dextral strike-slip faults such as the Lematang, Kepayang, Saka Faults and north-south trending, as well as horizontal movements and intrusions of Jurassic-Cretaceous age granite.

The regional stratigraphy of Ogan Komering Ulu Regency can be known as a large cycle (megacycle) consisting of a transgression followed by a regression. The formations formed in the transgression phase are the Lahat Formation (Nomt), Baturaja Formation (Nmb) and Gumai Formation (Nmg)). Meanwhile, those formed in the regression phase are grouped into the Palembang group (Air Benakat Formation (Nma), Muara Enim Formation (Nmpm) and Kasai Formation (Qtk)). Limestone is found in abundance around Baturaja City. The formations included in the research area are the Baturaja Miocene Neogene (Nmb) and the Gumai Miocene Neogene (Nmg) which are Miocene in age.

Limestone is a carbonate rock, a rock that contains more than 50% carbonate material and is composed of cemented clastic carbonate particles or crystalline carbonate resulting from direct preparation. Rocks contain up to 95% calcium carbonate, so not all carbonate rocks are limestone (Reijers & Hsu, 1986). Based on the Grabau Classification, it only considers the size of the carbonate rock component, regardless of its origin, and defines three classes of limestone, namely Calcirudite consisting of grains > 2 mm (limestone debris) and representing the carbonate parallel of a conglomerate. Some authors use calcirudite regardless of grain rounding, but some authors use lime breccia for limestones with angular clastics. Calcarenite is limestone with sand-sized (0.0625–2 mm) carbonate grains (limestone). Calcilutite is a fine-grained limestone (<0.0625 mm; lime mud). Limestone is one of the main ingredients in the cement-making process, besides clay, silica sand and iron sand. With the relatively abundant presence of limestone in the Buay Sandang Aji District, it is hoped that in the future this limestone can be used as raw material for the cement industry. For this reason, it is necessary to carry out further exploration activities in this area. Based on XRF analysis or the chemical requirements that Portland cement must fulfil (SNI Portland Cement, 2004) it can be divided into several types, namely:

a. Type I Portland cement is Portland cement for general use, which does not require special requirements as required by other types.
b. Type II Portland cement is Portland cement which, in its use, requires moderate sulfate resistance or moderate hydration heat.
c. Type II Portland cement is Portland cement which, in its use requires moderate sulfate resistance or heat of hydration
d. Type IV Portland cement is Portland cement which requires a low heat of hydration to use.
e. Type V Portland cement is Portland cement which, in its use requires high resistance to sulfates.

As a raw material for Portland cement, limestone must have certain requirements, namely:

a. Must have a high carbonate content of approximately 85%.
b. Must not contain the elements Zn and Pb.
c. Contains small amounts of sulfate, sulfite, phosphate and alkali.

Exploration activities aim to further ensure the existence of limestone in nature, including the position, shape, size, direction of distribution, quantity and quality of the limestone. So this modeling uses the Inverse Distance Weighting method (IDW).

Inverse Distance Weighting method (IDW), the IDW method or distance method is an estimation method that takes into account the spatial relationship (distance), which is a linear combination or weighted average of the surrounding data points. Data near the block gets a larger weight, while data far from the block gets a smaller weight. Thus, the weight given to a data point is inversely proportional to the distance of the estimated data block. Data points that influence the estimated block are limited to a certain radius.

3. RESEARCH METHODOLOGY

This research was conducted in the mining area of PT Semen Baturaja Tbk, Ogan Komering Ulu Regency, South Sumatra Province, on a N land lot.

The data collection stages in this research were carried out by direct observation and indirect observation. Direct data collection in the field takes the form of geological condition data such as taking rock unit samples to determine stratigraphy in the research area, geological structure and for petrographic and XRF analysis.

Resource estimation uses the Inverse Distance Weighting (IDW) method. With this method, a limestone resource model can be created for each layer. This modeling is carried out by creating an estimation method that takes into account the relationship between spatial location (distance), which is a linear combination or weighted average of data points in the surrounding area. The stages of this research consist of:

a. The indirect mapping method, the initial method for interpreting the research area, is by analysing the regional geological map sheet of Baturaja to determine the formations in the research area
b. Geological mapping method, carrying out direct observations in the field with several stages, namely geomorphological observations, observing rock outcrops and measuring geological structures
c. Data analysis and processing, this stage is divided into geological analysis in the form of petrographic analysis and XRF analysis, as well as calculating CaO content values and carrying out resource estimates using Surpac Software.
d. Presentation of data, this stage is the final stage, by collecting and processing all the data that has been obtained.

4. RESULT AND CONCLUSSION

4.1. Stratigraphy of the research area

This research was carried out in N land lot at the PT Semen Baturaja Tbk IUP, which is an active IUP where limestone mining activities are still being carried out. This research area is part of the Baturaja Formation (Nmb) and Gumai Formation (Nmg), which are stratigraphically deposited in conformity. There are Gumai limestone units and Baturaja limestone units. The following is a geological map of the Baturaja research area, marked by a red box, namely the location of the IUP of PT Semen Baturaja Tbk (**Figure 1**).

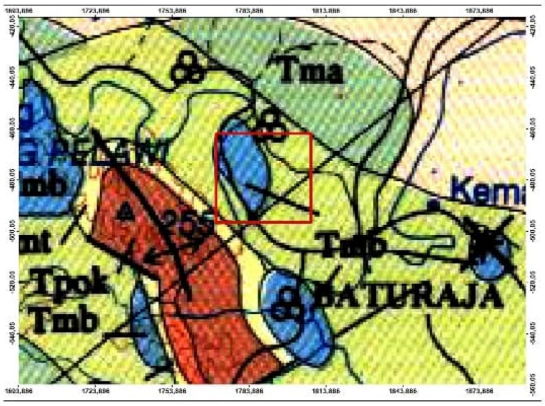

Figure 1. The Geological Map of the Research Area is part of the Baturaja geological map sheet (Gafoer et al., 1993).

4.2. Morphology

Morphology discusses the problem of the shape and origin of the Earth's surface. Based on the original form, the research area is divided into 2 original form formation units, namely structural forms of origin and anthropogenic forms of origin. The original structural form consists of the structural valley landform (S1). Meanwhile, forms of anthropogenic origin consist of mine opening landforms (A1), mine slope landforms (A2) and sump landforms (A3).

In **Figure 2,** according to the geomorphological map of the classification of Verstappen (1985) and David (2000), the Gumai Plantonic Packstone Unit has a fresh blackish gray color and a weathered brownish gray color with a grain size of arenite (0.062 ± 1 mm). The Gumai mudstone unit is found mostly in the east-northeast part of the study area, with strike/dip measurements of N 260-310°E/11-15°.

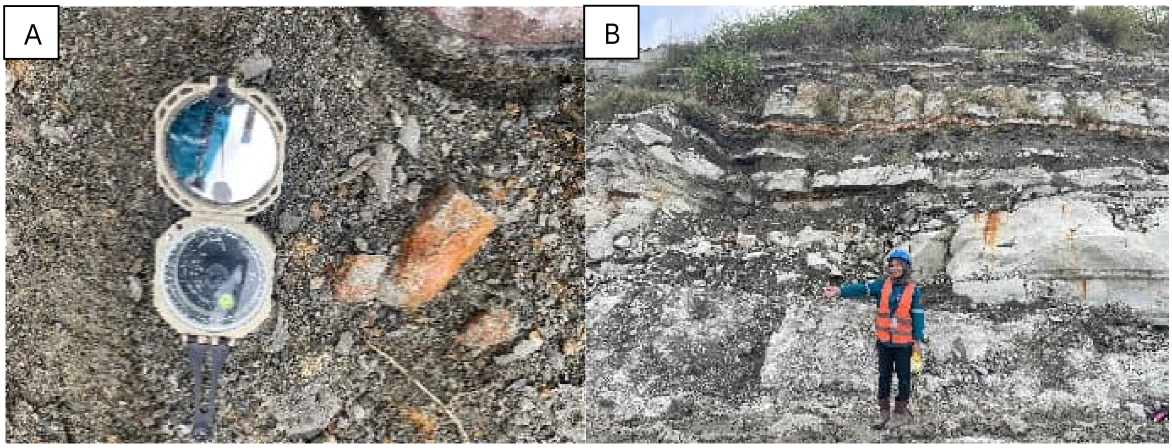

Figure 2. The Outcrop of Gumai Planktonic Packstone (Azimuth N 10°E).

Microscopic results on rock samples with 10x ocular magnification and 4x objective magnification. It has a brownish white color with very fine sand grain size and non-selective fabric porosity (Vug). The composition of the rock is composed of skeletal, micrite and quartz. Composition of skeletal grains (56%) with planktonic foraminifera (41%) dominating and benthonic foraminifera (15%), and quartz (1%). Then the matrix contained in this rock is micrite (43%). This rock is called Plantonic Packstone (Dunham, 1962).

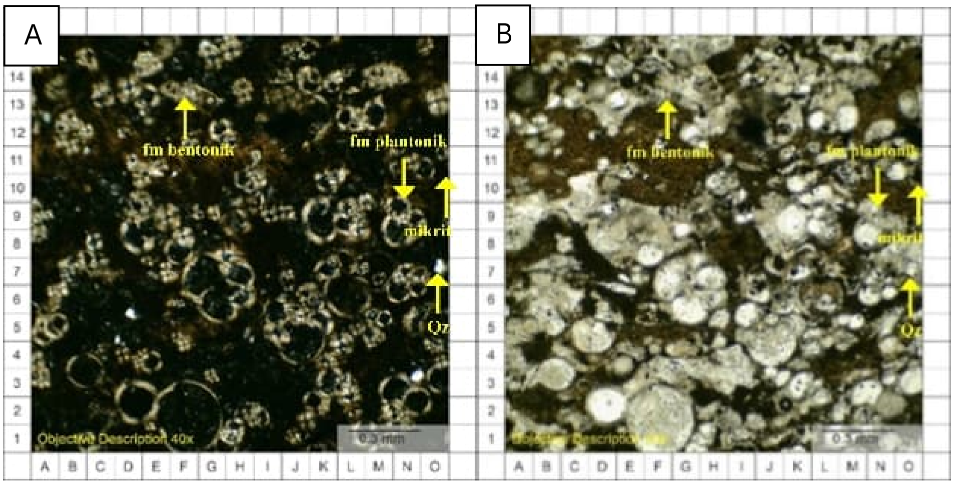

Figure 3. Petrographic Section of Gumai Limestone Sample a). Parallel Nikol (PPL) b). Nikol Silang (XPL).

In **Figure 3**, Petrographic Section of Gumai Limestone Sample. The Baturaja limestone unit has a fresh yellowish white color and a weathered blackish gray color. This rock has a monomineralic carbonate composition with a very high carbonate element (CaCO3) of 90%. The Baturaja limestone unit is often found in the east-northeast part of the study area. In this study area, outcrops are dominated by outcrops that have been disturbed by mining activities.

Based on the results of fossil analysis in the Gumai limestone unit at Observation Location 04 with a 40x magnification appearance, a type of planktonic foraminifera fossil was obtained, which can be used as a reference in determining the age and depositional environment in the research area.

In **Figure 4**, in the Gumai Planktonic Foraminifera Fossil Appearance, the appearance of planktonic fossils was found, namely that there were fossils of (a) Globigerina Praebulloides, (b) Globigerinoides Obliquus, (c) Orbulina Universa, and (d) Sphaeroidinella Subdehiscens.

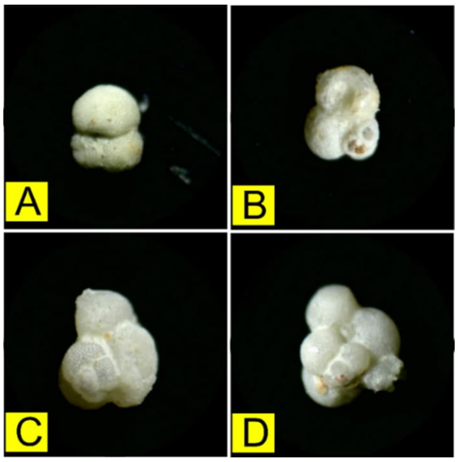

Figure 4. The Highlights of Planktonic Foraminifera Fossils at 40x Magnification.

In **Table 1,** the Results of Depositional Environment Analysis of Gumai Limestone Planktonic Foraminifera Fossils.

Fossil (a) Globigerina praebulloides is a planktonic foraminifera characterised by a trochospiral chamber arrangement and a globular chamber shape. The suture looks strongly curved with a calcareous wall composition, there is an aperture lip/rim decoration with a test surface decoration, namely punctate, and an umbilicus decoration, namely open umbilicus. This species has a relatively long geological age, from the Early Oligocene to the Late Miocene.

Fossil (b) Globigerina Obliquus is a planktonic foraminifera characterised by a trochospiral chamber arrangement and a globular chamber shape. The suture looks strongly curved with a calcareous wall composition, there is an aperture lip/rim decoration with a test surface decoration, namely punctate, and an umbilicus decoration, namely open umbilicus. This species has a geological age, from Early Miocene to Late Miocene.

Tabel 1. Results of Environmental Analysis of Planktonic Foraminifera Fossils in Gumai Limestone.

No. Fosil	Foraminifera Planktonik	Umur																						
		Oligosen			Miosen															Pliosen			Pleistosen	
		Awal		Akhir	Awal					Tengah						Akhir				Awal		Akhir	Kuarter	
		N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	N 11	N 12	N 13	N 14	N 15	N 16	N 17	N 18	N 19	N 20	N 21	N 22	N 23
a.	*Globigerina praebulloides*	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■						
b.	*Globigerinoides obliquus*						■	■	■	■	■	■	■	■	■	■	■	■	■					
c.	*Orbulina universa*									■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
d.	*Sphaeroidinella subdehiscens*													■	■	■	■	■	■	■	■			

Fossil (c) Orbulina Universa is a planktonic foraminifera characterised by a planispiral chamber arrangement and a globular chamber shape, the suture looks strongly curved with a calcareous wall composition, there is a test surface decoration, namely Punctate. This species has a geological age, from Early Miocene to Late Miocene

Fossil (d) Sphaeroidinella Subdehiscens is a planktonic foraminifera characterised by a trochospiral chamber arrangement and a globular chamber shape. the suture looks strongly curved with a calcareous wall composition, there is an aperture lip/rim decoration with a test surface decoration, namely punctate, and an umbilicus decoration, namely open umbilicus. This species has a geological age of Middle Miocene-Early Pliocene.

It can be concluded that the Gumai limestone was formed at the age of N13-N20 in the Middle Miocene - Early Pliocene, which is characterised by the presence of planktonic foraminifera fossils (Blow, 1969).

The Gumai limestone depositional environment is in a shallow marine depositional environment with an inner neritic-outer neritic bathymetric zone (Murray, 1973), so there is the presence of planktonic foraminifera in the Gumai limestone (**Figure 5**).

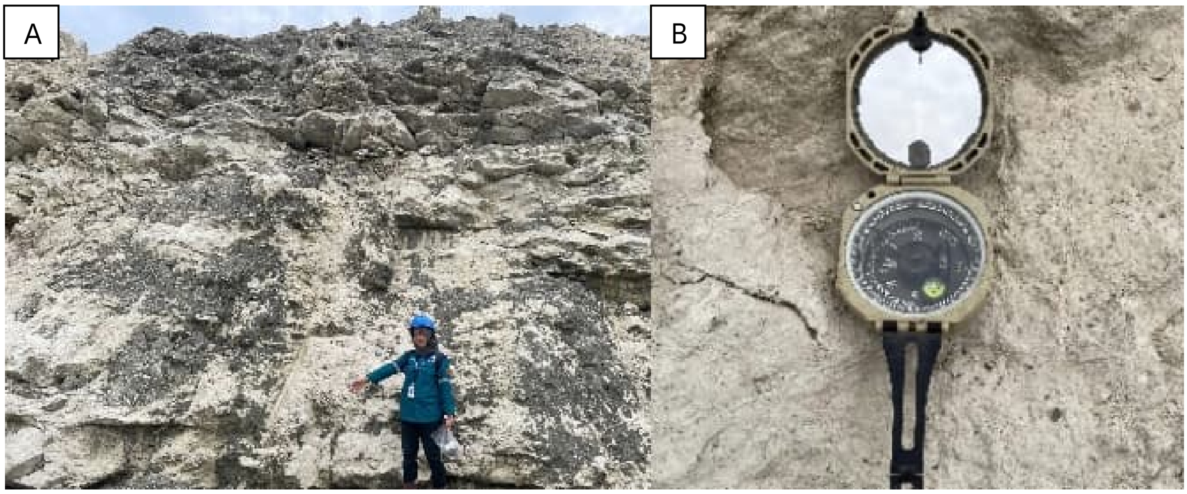

Figure 5. The Outcrop of Baturaja Limestone (Azimuth N 33°).

Microscopic results on rock samples with 10x ocular magnification and 4x objective magnification. It has a brownish white color with fine sand grain size and a selective fabric note (vug) porosity. The composition of the rock is composed of skeletal, sparite, dolomite and quartz. Composition of skeletal grains (61%) with the presence of benthonic foraminifera, dolomite (5%) and quartz (1%). Then the matrix contained in this rock is sparite (25%). According to Dunham (1956), this rock is called packstone.

In **Figure 6**, the petrographic incision of the Baturaja Limestone Sample, microscopic results on the rock sample with 10x ocular magnification and 4x objective magnification. It has a brownish white color with fine sand grain size and a selective fabric note (vug) porosity. The composition of the rock is composed of skeletal, sparite, dolomite (Dol) and quartz (Qz). The composition of the skeletal grain (61%) is dominated by mudstone, dolomite (5%) and quartz (1%). Then the matrix contained in this rock is sparite (25%). This rock is called grainstone (Dunham, 1962).

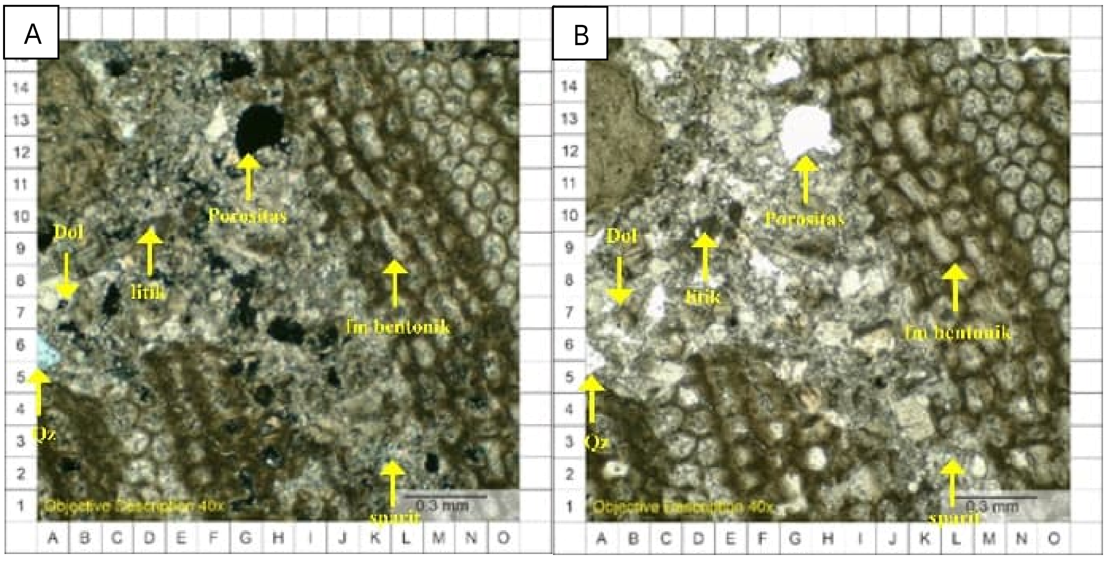

Figure 6. Petrographic Section of Baturaja Limestone Sample a). Parallel Nikol (PPL) b). Nikol Silang (XPL).

4.3. Geological Structures

Geological structures as a reflection of developing tectonic activity can take the form of faults, joints or folds. After carrying out direct geological mapping in the research area, the author obtained the geological structure of the fault. The existence of faults in the field is recognized by several natural characteristics such as changes in topographic shape and damage to rock stratigraphy.

Based on the results of observations in the field, with an azimuth of N 12° E, it shows the hanging wall and foot wall rock areas with a fault movement direction of N 293° E / 37°. As for the scratch-line or slickenside measurements, the plunge data was 62°, bearing N 300 E and rake 9°. From the results of these measurements and stereonet analysis, the name of the right horizontal fault or Right Slip Fault, was obtained based on the classification of Rickard (1972).

Figure 7. Faults in the research area and Stereographic Analysis.

4.4. Historical Geology

In the early compression phase. In the Pre-Tertiary, bedrock (basement) was formed due to intrusion caused by the compression phase. Then rifting activity occurs, which can cause the bedrock to form highs (horsts) and lows (grabens). This is caused by the dominant pulling force having a northeast-southwest direction (Ginger & Fielding, 2005). The rifting activity which has a northwest–southeast direction, has ended, and tectonic activity in a different direction has begun to occur. In the Early Miocene, the sedimentation process of the Baturaja Formation occurred during marine transgression, which submerged the lower delta plain area, causing the development of shallow marine facies limestone. The Baturaja Formation forms harmoniously above the Talang Akar Formation.

In **Figure 8,** experiencing a maximum transgression phase in the South Sumatra basin. Then the continental crust beneath South Sumatra experienced subsidence caused by the thermal lithosphere. The high rate of subsidence (lowering of the basin) and relatively high sea level rise resulted in transgression in the basin until the maximum occurred during the Early Miocene - Middle Miocene, with the entire basin sinking, and the Gumai Formation was deposited during the maximum transgression phase.

In **Figure 9,** sedimentation occurred with the deposition of the Gumai formation. The Gumai Formation, with an Early Miocene - Middle Miocene age, was deposited in harmony on top of the Baturaja Formation with an Early Miocene age. In this phase, sedimentation is a slower process compared to the subsidence of the basin floor, resulting in a sequence of facies that includes non-marine, transitional, shallow marine and deep marine and in the Miocene, the transgression phase ends.

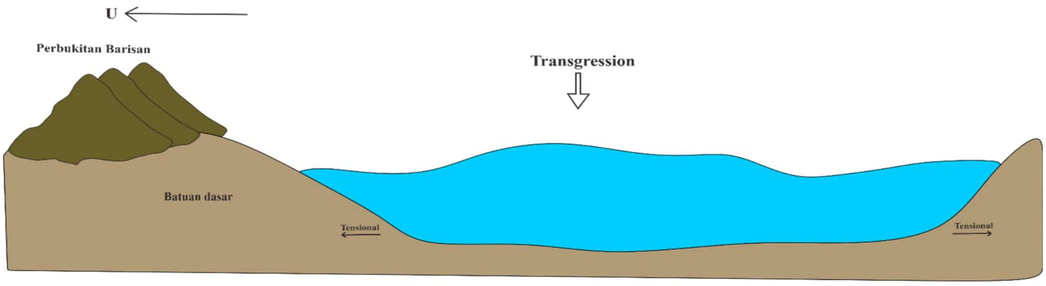

Figure 8. Maximum transgression phase in the South Sumatra basin.

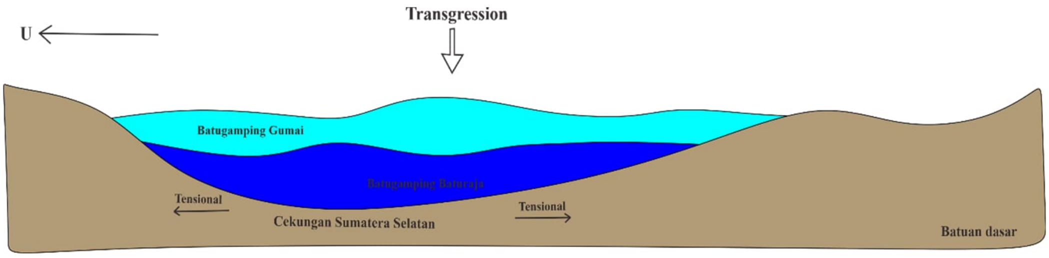

Figure 9. Sedimentation process by deposition of the Gumai Formation.

4.5. Estimation of Limestone Resources at Baturaja Mine Lot "N"

In this study, the depth of the limestone layers was modeled using a block model with the aim of being able to see the distribution of the layers to be estimated. The thickness of the limestone layer is based on the depth and thickness of the drill point. The distribution of drill points has been obtained from database processing, and a grade classification process has been carried out, where the grades are grouped based on the quality of the limestone (layer) by the classification that has been determined at each drill point in order to obtain accurate results.

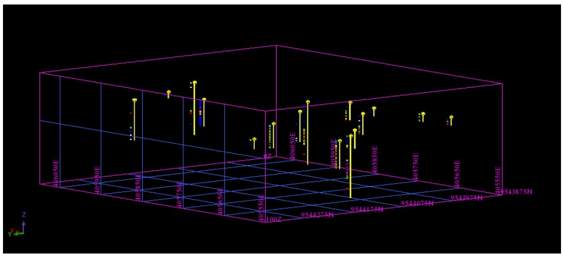

Figure 10. Drillhole.

4.6. The Thickness Layer of Limestone

The thickness of the limestone layer in the research area varies. The thickness of the limestone layer is an important element and is very influential on the calculation of limestone resources. From the distribution of drill points that have been carried out, in the research area, there are 3 types of rock quality, namely high grade (HG) in blue, medium grade (MG) in green, and low grade (LG) in yellow.

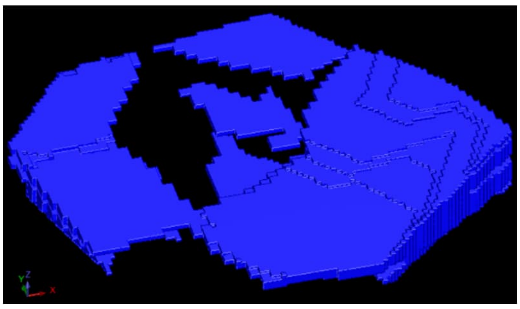

Figure 11. High Grade Layer.

High-grade limestone is a layer of limestone that has very good limestone quality. The CaO content in the high grade limestone layer is 50% - 99%.

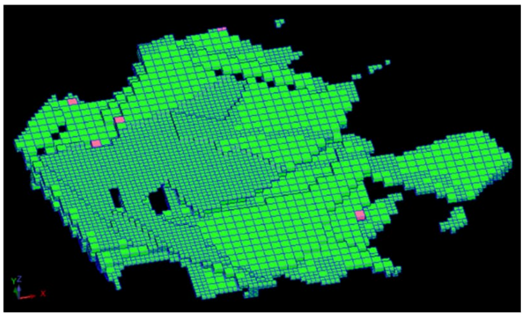

Figure 12. Medium Grade Layer.

Medium-grade limestone is a layer of limestone that has good limestone quality. The CaO content in the medium grade limestone layer is 45% - 50%.

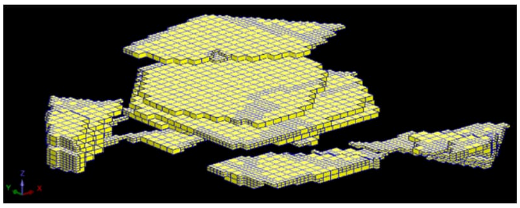

Figure 13. Low Grade Layer.

Low-grade limestone is a layer of limestone that has poor quality. The CaO content in the low-grade limestone layer is 30% - 45%. This provision is to determine the estimated depth and thickness of the resource based on the specified CaO content value.

4.7. Resource Calculation

Before calculating resources, you must first know the parameters that will be used in the estimation so that the results of the estimates will be more accurate. The parameters used in the estimation are Drill Point, Rock Quality based on Assay data and material density. Material density is a parameter used to obtain the tonnage figure for a resource, which is obtained by multiplying the volume by the density of the material itself. The density of limestone material at PT. Semen Baturaja, Tbk, there are 3 types of rock, namely high grade at 2.41 tons/m^3, and medium grade at 2.1 tons/m^3. low grade at 1.8 tons/m^3.

Based on SNI 4762:2011, the calculation of limestone resources at the research location is included in the designated resources. At this research location, thickness and area calculations are used to limit the resources included in the company's IUP.

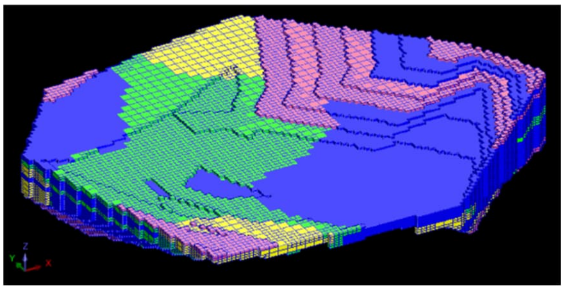

Figure 14. Block Model Limestone.

Through modeling the distribution of rock quality in **Figure 14**, it can be seen that CaO with levels >50% dominates, distributed almost completely throughout the model block distribution. In the blue color it appears very dominant in the distribution of the block above showing a CaO content of 50% - 99%, in the green color it appears quite dominating in the distribution of the block above indicating a CaO content of 45% - 50%, and in yellow it appears less dominant in the distribution of the block above indicating a CaO content of 30% - 45%.

Table 2. Research area resource estimation.

Quality	Volume	Tonnage	Average Cao levels
Low Grade	955.376	1.719.677	40.87
Medium Grade	1.709.250	3.589.425	47.70
High Grade	1.553.000	3.742.730	51.92
Grand Total	4.217.625	9.051.832	47.94

From the analysis results it was found that the resources were obtained with a volume of 4,217,625m^3 and 9,051,832 tons. The Cao content value in the Baturaja Mine 1 Plot "N" resource estimate is at high grade, namely CaO 51.92%, then the Cao content value at medium grade is CaO 47.70%, and the CaO content value at low grade is CaO 40.87%. The average CaO content value obtained was CaO 47.94%. This resource is a resource that meets the criteria for limestone from PT. Semen Baturaja TBK has been determined.

5. CONCLUSSION

The conclusion that can be drawn is that the geological conditions in the research area are geomorphologically divided into 2 forms of origin, namely the form of structural origin and the form of anthropogenic origin. The structural origin form is the structural valley landform (S1), while the anthropogenic origin form consists of the mine opening landform (A1), the slope landform (A2), and the sump landform (A3). The rock units in the study area consist of the Gumai Planktonic Packstone Unit of Middle Miocene age and the Baturaja Bentonic Packstone Unit of Early Miocene age. The geological structure in the research area is a right-slip fault. Then, based on observations in the field, there is a distribution of limestone that has a continuous pattern, namely in a northwest-southeast direction. Limestone continuity is obtained based on data obtained from the field and supported by position data. Then, the total limestone resource estimate at Baturaja Mine 1, namely Lot "N", using the IDW method, was obtained, namely that there was a volume and tonnage of resources of 4,217,625 m^3 and 9,051,832 tonnes.

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