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Triangulation Method for Limestone Estimation in CV. Atang Village, Jemparing: Insights from Long Ikis, Paser District, East Kalimantan

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Abstract
The Atang Are Abadi Firm is a limestone mining company that has carried out further exploration activities to determine the volume, density, and continuity of grades in the exploration area. The exploration activities conducted core drilling at 17 drilling points, a distance of less than 250 meters, and an area of 19.36 ha. This research determined the geological domain of limestone layers with parameters of CaO content greater than 53% through a triangulation (triangle) method. Meanwhile, the cut-and-fill method was used for resource and reserve calculations. The resource acquisition in limestone layers with a content of more than 53% reached 25,682,831.9 BCM, and the acquisition of reserves in limestone layers with a content of more than 53% had 6,788,073.56 BCM. The estimation results of limestone resources and reserves obtained based on the Indonesian National Standard 4726: 2019 are included in the classification of measured limestone resources and proven limestone reserves.

1. Introduction

CV. Atang Are Abadi is engaged in heavy equipment rental, especially excavators and stone crushers. CV. Atang Are Abadi has an office on Jl. Penajam – Kuaro No. 43, Krajan Jaya, Kec. Long Ikis, Paser District, East Kalimantan. Currently in its development CV. Atang Are Abadi ventured into the field of mining operations in the production of limestone as a raw material for cement. A mining business permit is required to carry out production mining operations so that mining can be carried out legally [1]. Management of mining business licenses is required to estimate resources and reserves in order to determine the amount of production [2] and the age of the mine which is then used as a basis or reference for carrying out the next stage of mining operations [3]. Limestone or limestone ($CaCO_3$) is a stone made from the sedimentary mineral aragonite and calcite, these two variations are two different variations of calcium carbonate. The main source of calcite development is marine organic entities [4]. In general, according to SNI (Indonesian National Standards), limestone that has a CaO content of more than 50% can be used as raw material for cement, while limestone that has a CaO content of less than 50% is good for construction materials such as landfills. These standards can of course be different from the standards that exist in mining companies or cement processing companies, of course with the grade limit (CaO) that can be processed or the mining grade limit (CaO) that is considered still profitable or economical to mine [5]. The general types of limestone include chalk limestone, coquina limestone, fossiliferous limestone, lithographic limestone, oolitic limestone and travertine limestone. Several types of limestone have their characteristics [6]. Mining is an area that has the potential to have limestone minerals seen in the regional geological formations included in the Bebulu Formation on the Balikpapan Geological Map Sheet, namely limestone with silt claystone inserts and a little marl [7]. Based on this, it is necessary to carry out further research, namely in the form of detailed exploration to obtain geological continuity data, especially for limestone as a raw material for cement with a CaO content of more than 53% which will then be estimated to determine the amount of resources and reserves of these minerals [8]. Based on the characteristics of the limestone with relatively homogeneous thickness and quality of sediment [9], the appropriate estimation method is the triangular method with the required data including location data, drill data, geotechnical data, namely physical and mechanical properties of the rock, hydrogeological data, and loading factor data. slopes and topographic data of the study area so that later the resources and reserves that have been obtained can be classified according to the parameters of the level of geological confidence and other modifying factors.

2. Methodology

The research approach is carried out using quantitative and qualitative approaches. Quantitative research produces data in the form of data from exploration activities in the form of drill hole data, which consists of topography, geology, and survey data containing numbers that can be analyzed and processed in software. Whereas in qualitative research methods data will be obtained in the form of analytical descriptions [10]. Some of the data generated in this study is in the form of a description of the actual lithology analysis which contains materials such as soil and limestone, as well as an analysis of geotechnical characteristics and hydrogeological analysis at the research location which will be useful as parameters for calculating reserve estimates [11]. Topographic data, the topographic data obtained is topographic data from the results of direct field measurements carried out by the company. After this data is obtained, it is plotted in Autocad software to produce contour lines with coordinates and elevations matching the measurements. Geotechnical data, namely data on physical properties and mechanical properties of rocks as well as slope loading factors, the data that has been obtained will be processed for slope stability analysis with the slide v6.0 application to obtain recommendations for slope height, step width, and slope angle which are then useful for pit design and calculation of estimated reserves. Meanwhile, the hydrogeological data obtained is the depth limit for the emergence of groundwater, the data that has been obtained is processed and used as the basis for determining the lowest mining elevation limit or mining pit limit. Drill log data, processing of drill log data is done with the help of Minescape 5.7 software. Exploration data in the form of existing Geology and Survey data is made into a database as input parameters to determine the distribution of layers and grades of exploration drilling results. Then do drill hole modeling, direction and shape of deposits and grades in 3D form. The level of accuracy of the resources obtained will be influenced by the method used. This time the resource uses the triangulation method, each section that has been made with three points forms a triangle in 2D shape and then its volume is calculated. To get the total resource from limestone deposits, that is by using all the holes that have been calculated from all the existing triangular blocks. After knowing the total resources, it is necessary to design a final mining pit with a slope design based on the geotechnical analysis that has been obtained and determine the highest elevation and lowest elevation limits based on topographical data and hydrogeological data (groundwater) to then recalculate the volume of resources cut off by the pit. so that the total volume is obtained as a limestone reserve.

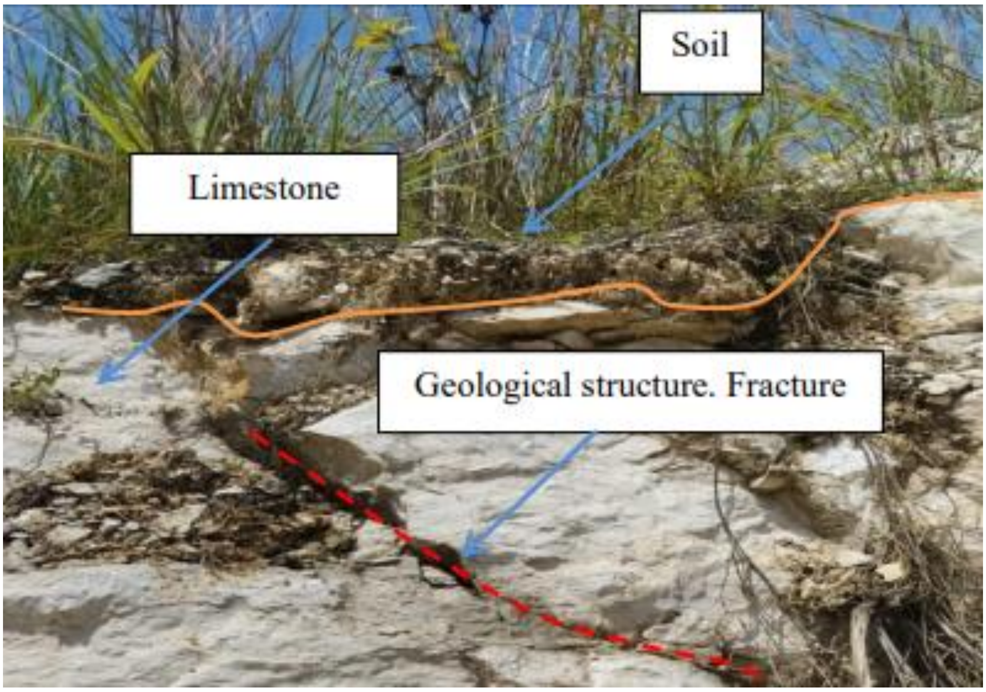

Figure 1. Local geology of the study area

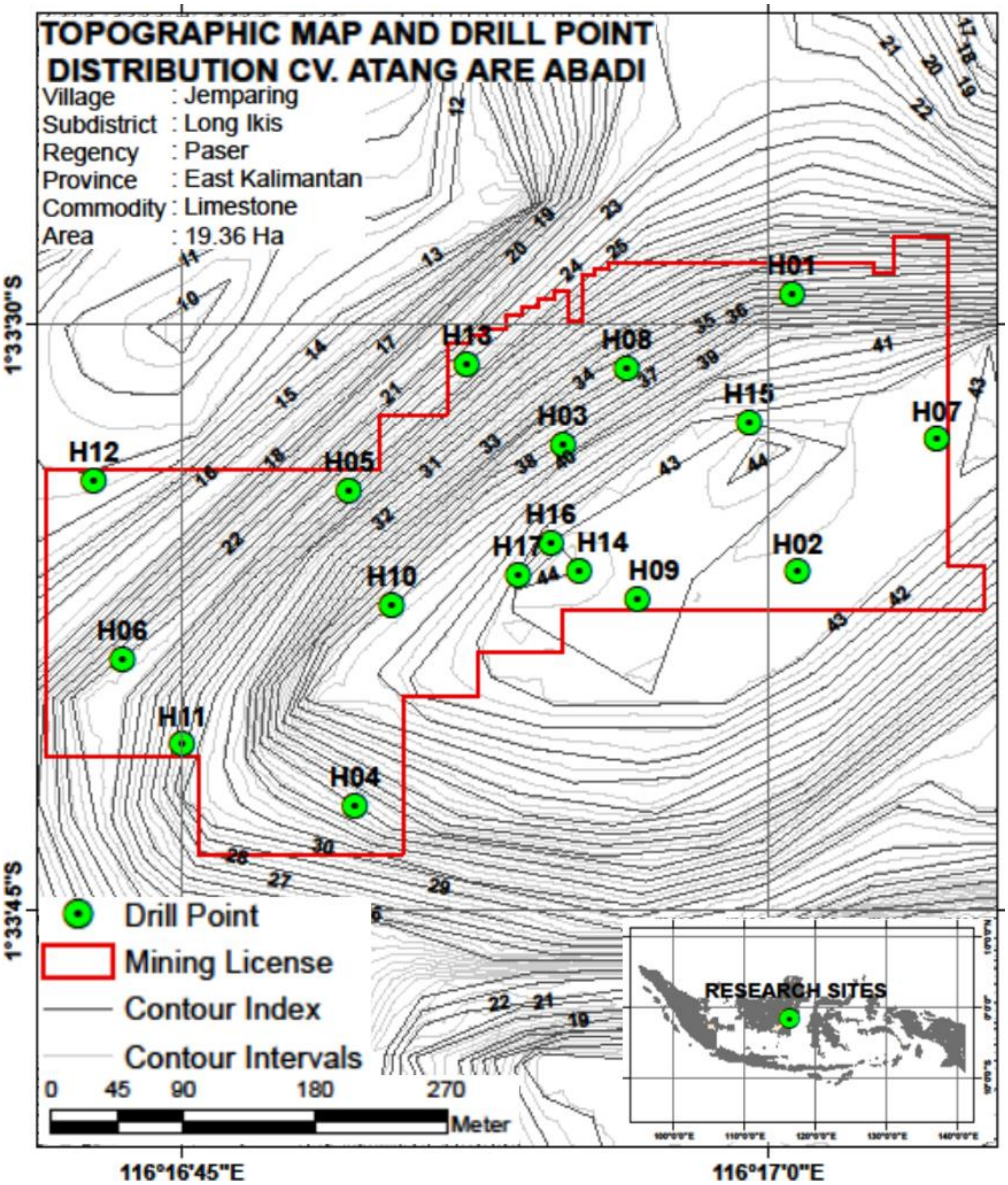

Figure 2. Topographic map and drill point distribution CV. Atang Are Abadi

3. Results and discussions

3.1. Exploration activities

In the exploration area of CV. Atang Are Abadi has an area of 19.36 Ha. In the early stages of exploration, a regional geological map of the balikpapan sheet is needed which is used as a reference for determining areas that have potential resources. From the exploration carried out, it was found that the exploration area has local geological formations with potential for limestone minerals with soil thickness of 10 cm. The exploration activities carried out were detailed exploration, taking core drilling using a drilling machine to determine the lithology and grade distribution in every 50 meters of drilling depth, there were 17 drill holes with a distance of <250 meters and with a depth of 102-154 meters (see Table 1). The topographical data obtained is topographical data from the results of direct field measurements by the company. The data obtained is in the form of coordinates and elevation data (x, y and z) which are then processed and obtained the topography of the study area with the lowest elevation, namely 12 masl to the highest elevation reaching 44 masl.

Table 1. Survey data

Hole_ID	Northing	Easthing	Elevation (Mdpl)	Hole_Depth (meter)
H01	420299	9827767	34,631	143
H02	420303	9827549	43,089	152
H03	420118	9827649	38,113	136
H04	419954	9827365	33,909	151
H05	419949	9827613	25,781	148
H06	419770	9827480	22,666	144
H07	420414	9827653	43	107
H08	420168	9827709	35	110
H09	420177	9827527	43	102
H10	419982	9827523	40	111
H11	419817	9827413	29	121
H12	419747	9827621	12	108
H13	420042	9827712	24	113
H14	420131	9827550	44	128
H15	420265	9827666	43	154
H16	420108	9827572	43	142
H17	420082	9827546	41	153

3.2. Estimation of limestone resources

The COG (Cut-Off Grade) data, painstakingly acquired by the dedicated team of researchers, shines a light on the distinct value attributes of particular companies. This value is paramount, especially when trying to decipher the potential economic benefits of limestone production. The deciding factor for this valuation is intrinsically linked to the CaO (Calcium Oxide) content present in the limestone, more so when its concentration surpasses the 53% mark. Precise laboratory tests and subsequent analyses have revealed a CaO content range that varies between 54.11% and 55.79%. These findings categorically earmark the analyzed limestone as being of a high-grade CaO category, reinforcing its indispensable economic importance in the broader spectrum of mining activities.

The task of establishing a comprehensive database detailing the CaO content is approached with both precision and simplicity. Classifications are kept straightforward and hinge majorly on the high-grade CaO content, which is delineated by values exceeding the 53% benchmark. This methodical and structured approach ensures optimal efficiency. It ensures that when inputting this invaluable data into the specialized Minescape 5.7 software, users are only required to tap into two primary databases: the meticulously compiled survey data and the in-depth geological data.

The survey data is a repository of vital information. It encapsulates crucial details like the unique identification of each drill hole (known as hole id), its meticulously mapped coordinates, the specific elevation of the site, and the depth to which the drilling operation was undertaken. In contrast, the geological data serves as a comprehensive record, providing insights into the hole id, the associated lithology code, and the specific depth measurements corresponding to each individual lithological stratum. For those seeking a more granular understanding and visual representation of this data, Table 2 offers a detailed breakdown.

Table 2. Lithology data

Hole ID	Code	Initial (m)	Final (m)	Overall (m)	Hole ID	Code	Initial (m)	Final (m)	Overall (m)
H01	W	0,2	0,32	0,12	H09	L	0,33	102	101,67
H01	L	0,32	143	142,68	H010	W	0,15	0,27	0,12
H02	W	0,2	0,31	0,11	H010	L	0,27	111	110,73
H02	L	0,31	152	151,69	H011	W	0,14	0,26	0,12
H03	W	0,2	0,33	0,13	H011	L	0,26	121	120,74
H03	L	0,33	136	135,67	H012	W	0,16	0,3	0,14
H04	W	0,15	0,27	0,12	H012	L	0,3	108	107,7
H04	L	0,27	151	150,73	H013	W	0,16	0,3	0,14
H05	W	0,14	0,26	0,12	H013	L	0,3	113	112,7
H05	L	0,26	148	147,74	H014	W	0,16	0,3	0,14
H06	W	0,16	0,3	0,14	H014	L	0,3	128	127,7
H06	L	0,3	144	143,7	H015	W	0,17	0,31	0,14
H07	W	0,2	0,32	0,12	H015	L	0,31	154	153,69
H07	L	0,32	107	106,68	H016	W	0,15	0,28	0,13
H08	W	0,2	0,31	0,11	H016	L	0,28	142	141,72
H08	L	0,31	110	109,69	H017	W	0,21	0,37	0,16
H09	W	0,2	0,33	0,13	H017	L	0,37	153	152,63

The resource calculation is carried out using the triangulation method, which processes the drillhole data that has been obtained, which consists of survey data and lithology/geological data using a software application, namely Minescape 5.7. So that 2 lithologies are obtained, namely soil and limestone in which the solid results from the two layers are obtained in the form of resources in the form of volume (m^3) of top soil and volume (m^3) of limestone (see Table 3).

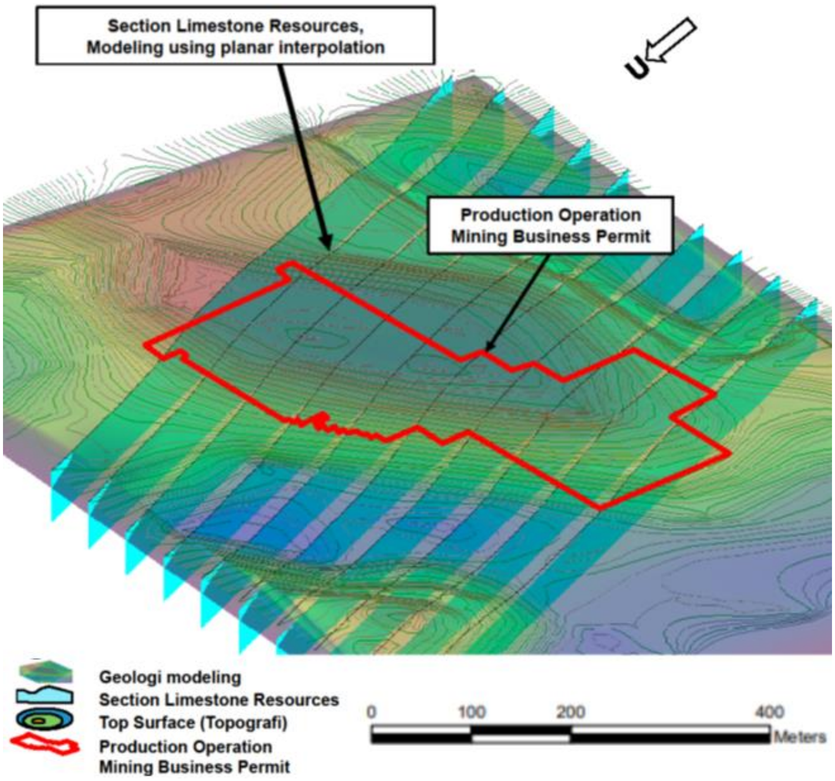

Figure 3. Geological modeling CV. Atang Are Abadi

Table 3. Resource CV. Atang Are Abadi

Material	Sumberdaya	*Swell factor*	Sumberdaya
	Volume (BCM)	(%)	Volume (LCM)
Soil	173.544,14	1.2	208.252,96
Batu gamping	25.682.831,9	1.35	34.671.823,1

First of all, in the Minescape 5.7 software, create a project schema according to the type of mineral deposit to be estimated, then enter and create a topographic data schema, survey data, lithology data and buffer zone boundaries as mining boundaries. After creating the schema, then creating a section for geological modeling and calculations using triangulation to get resource estimates (see Figure 3). The results obtained were then multiplied by the sweel factor values obtained, namely 1,35 for limestone and 1,2 for soil. Geological modeling and resource estimation are based on topography as the upper or surface boundary, drill depth as the lower limit, and IUP OP boundaries as vertical boundaries. The total estimated top soil and limestone resources in the form of volume (m^3) of CV. Atang Are Abadi as mention on the Table 3.

3.3. Hydrogeology and geotechnical

The measurement of the groundwater level with a piezometer is carried out between the boundaries of the mining concession and the quarry. Obtained to the west at coordinates 116016'41.716” E 1033'35.304” S with a groundwater depth limit at an elevation of -29 masl and east at coordinates 116017'3.886” E 1033'27.945” S with a groundwater depth limit at an elevation of -32 masl (see Figure 4). With these results, the pit limit is at an elevation of -25 masl with 6 slope levels in the western pit and 7 slope levels in the eastern pit. The pit limit analysis based on the groundwater level, in addition to optimizing the estimated reserve [12]. Analysis of mine slope stability in slide v.60 software by entering data on the physical and mechanical properties of the rock that have been obtained such as cohesion, internal friction angle, and volumetric weight as well as slope loading factors such as distributed load and seismic load [13]. As for the results of this analysis, it is obtained that the slope safety factor is optimal and is still relatively high based on KEPMEN ESDM No. 1827 K/30/MEM/2018 [1]. On the east slope, it is 1.121 and the value of the safety factor for the slope on the west slope is 1.163 with the following slope geometry: High slope: 10 meters, Bench width: 5 meters, Width of safety bench: 5 meters, Slope: 80^0.

Figure 4. Groundwater drilling 1 (left), groundwater drilling 2 (right)

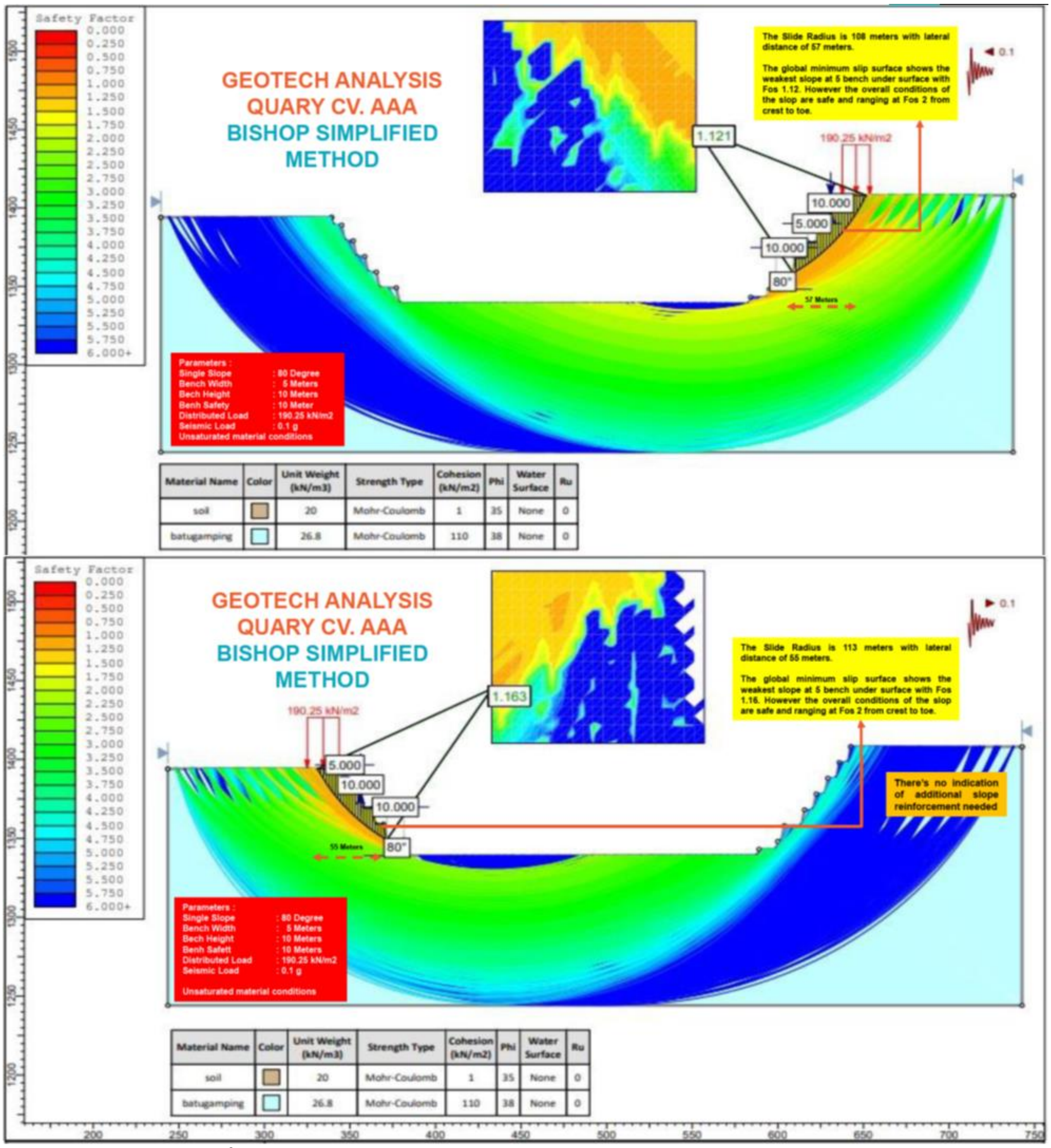

Figure 6. West 80[0] Slope Stability Analysis on the west slope (top), and the east slope (bottom)

3.4. Estimation of limestone reserves

Making a design quarry for estimating limestone reserves is based on recommendations for slope stability for slope design and determination of pit limits based on the depth of the groundwater and for surface limits based on topographical data [14] (see Figure 7). The quarry design was made using Minescape 5.7 software with a dig length of 749 meters and an average dig width of 257 meters. Optimization of the estimated reserves is carried out by constructing a permanent mine road with a standard grade of 7% [15] and a pit limit at an elevation of -25 masl.

Table 4. Reserves CV. Atang Are Abadi

Material	Sumberdaya Volume (BCM)	*Swell factor* (%)	Sumberdaya Volume (LCM)
Soil	157.908,09	1.2	189.489,71
Batu gamping	6.788.073,56	1.35	9.163.899,31

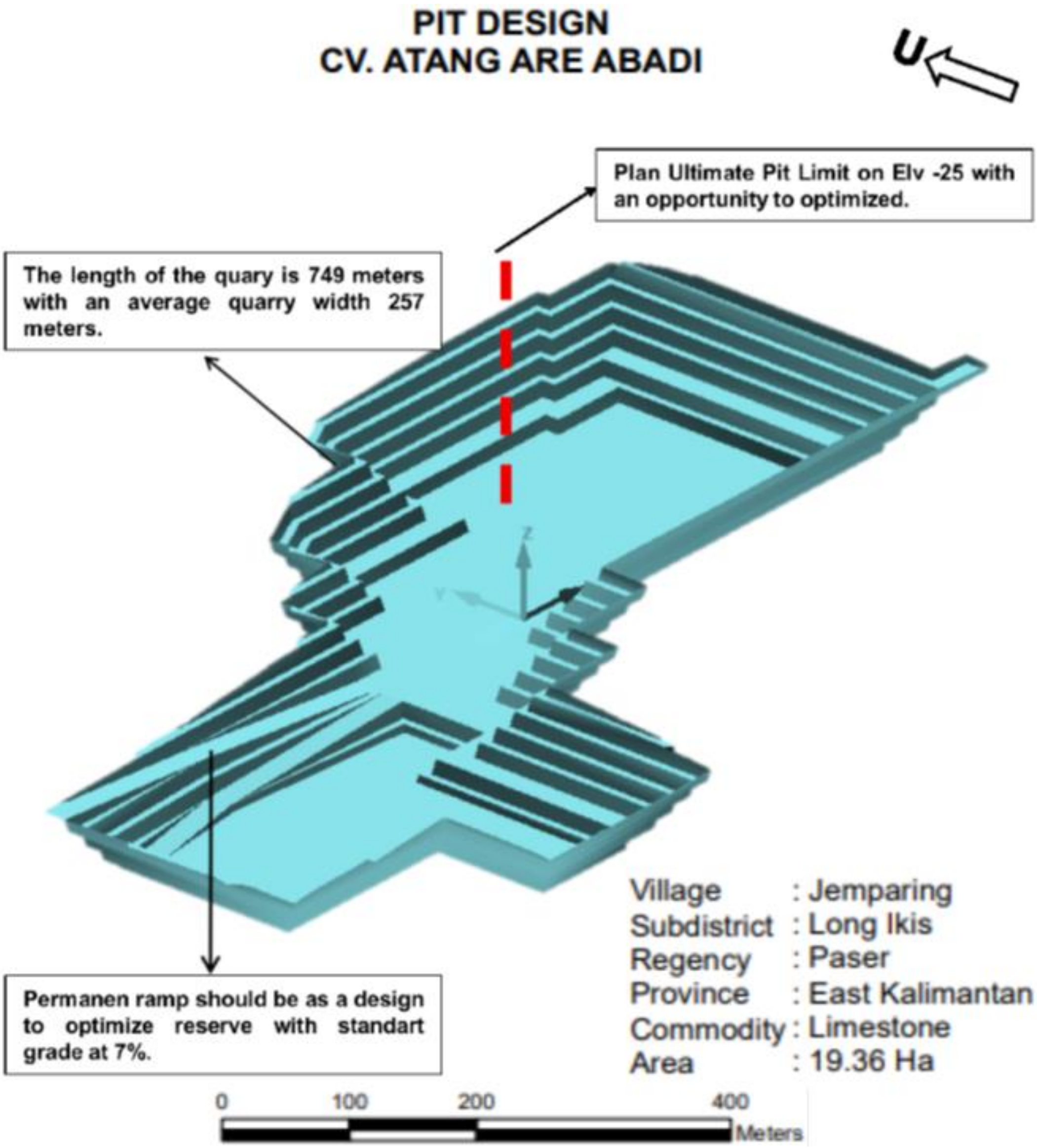

Figure 7. 3D design quarry pit CV. Atang Are Abadi

In estimating limestone reserves, it is necessary to design mining pits as vertical boundaries and bottom pits in Minescape 5.7 software. After that enter and create topographic data schema survey data, lithology data and pit quarry design as mining boundaries. After making the schema is complete, then the calculation uses triangulation to get an estimate of the limestone reserves (see Table 4).

3.5. Clasification of resources and reserves

The classification of resources hinges on the degree of geological confidence. Factors guiding the evaluation of this confidence, grounded in the standards of SNI 4726: 2019 [16], encompass:

1. Topographic and Survey Data: Direct measurements obtained from the study site undergo processing and validation within the AutoCAD and ArcGIS software frameworks. These tools ensure accurate representation by integrating the right survey datum information alongside a structured grid system.
2. Sample Analysis: Samples sourced from observation points predominantly come from core drilling exercises. These samples boast an impressive average core recovery rate of 95%. Moreover, their sourcing occurs within a 50-250 meters vertical range from observation points and a horizontal span of 50 meters.
3. Exploration Data Visualization: The amassed exploration data facilitates the creation of transverse, longitudinal, and horizontal cross-sectional views of CaO mineral deposits within limestone. The Minescape software aids in visualizing these cross-sections, shedding light on the

intricate relationship between limestone mineralization and its geological structure, such as mineral content and thickness.

4. Geological Domain Determination: The demarcation for the geological domain of limestone leans on the preset CaO limit levels established by the organization. Overall, the retrieved CaO content nestles comfortably within the "High grade" category, surpassing the 53% mark. Consequently, this geological domain predominantly houses a limestone lithology featuring a CaO concentration exceeding 53%.
5. Laboratory Test Data: Assay results sourced from laboratory evaluations consistently fall into the high-grade category. Given this uniformity in grade quality, there's no pressing need for a geostatistical analysis when ascertaining the spatial distribution and parameter variability deemed crucial for the deposit.
6. Geological Modeling: The modeling process gets executed using the Minescape 5.7 software. It involves feeding the software with input data derived from boreholes - depth of the material, lithological specifics, and topographical details, which act as modeling surface demarcations. Subsequent interpolation between these datasets employs the triangulation technique for precision.

Based on the completeness of exploration data and appropriate resource estimation techniques that the estimation of limestone resources carried out has fulfilled or is in accordance with the standards for evaluating the parameters of the level of geological confidence, the limestone resources that have been obtained are measurable limestone resources. Based on the Indonesian National Standard 4726:2019, measurable resources that are properly enhanced are included in the classification of proven reserve estimates. The several variables or parameters for increasing reserves that have been carried out are as follows:

1. Geotechnical studies, geotechnical studies have been carried out and recommendations for safe slope geometries for mining designs have been produced.
2. Hydrogeological studies, hydrogeological studies have been carried out by measuring the groundwater level in order to obtain a mining depth limit.
3. Environmental studies, there has been a study and a reclamation plan submitted by the company at the time of obtaining a production business license.
4. Mining technical studies have been carried out or the design of a mining pit quarry is complete with permanent road designs and safety benches as reserves optimization.
5. Economic studies, economic studies are based on the minimum limit content of limestone mining, which is > 53%.
6. Marketing studies, CV. Atang Are Abadi has collaborated with a cement factory so that for the target of marketing or sales of mining products it is sold to the cement factory that has collaborated.

In calculating the estimation of limestone reserves carried out by researchers, they have fulfilled several conditions or variables needed to be converted into proven reserves so that the estimated reserves obtained fall into the category of estimated proven limestone reserves.

4. Conclusion

After thorough examination and quantification of the mineral resources within the region, it's evident that the limestone and soil reserves hold significant potential. The total resources for limestone stand at an impressive 25,682,831.9 BCM, which is equivalent to 34,671,823.1 LCM. In comparison, the soil resources have been determined to be 173,544.14 BCM, translating to 208,252.96 LCM. Delving deeper into the reserves – a subset of resources which are economically viable to extract – limestone has a total of 6,788,073.56 BCM or 9,163,899.31 LCM. Soil reserves, while slightly less in volume, are substantial, registering at 157,908.09 BCM or 189,489.71 LCM. What lends further credibility and assurance to these numbers is the classification methodology utilized. Adhering to the Indonesian National Standard 4726:2019 ensures a rigorous and standardized assessment process. Within this framework, our limestone resources confidently fit into the 'measured resource' category, indicative of a high level of certainty regarding their extent and economic feasibility. Moreover, our limestone reserves have been classified as 'proven reserves', emphasizing their readiness for extraction and use.

As we wrap up this study, the potential for future mining and extraction operations is evident. Such vast reserves not only pave the way for economic growth but also present an opportunity for sustainable practices that can harmonize with local ecosystems and communities. The data presented reaffirms the region's richness and the imperative for strategic planning in utilizing these resources for the benefit of all stakeholders.

References:

[1] ESDM, "Pedoman Pelaksanaan Penyusunan, Evaluasi, Persetujuan Rencana Kerja dan Anggaran Biaya, Serta Laporan pada Kegiatan Usaha Pertambangan Mineral dan Batuba," *Kepmen ESDM RI Nomor 1806 K/30/MEM/2018*, p. 1971, 2018.

[2] H. Faradila, "Izin Usaha Pertambangan Mineral dan Batu Bara dalam Kaitan Dengan Pengelolaan dan Perlindungan Lingkungan Hidup," *Mudarrissuna*, vol. 11, no. 3, pp. 519–525, 2020.

[3] M. Jundi, H. Azis, Y. Fanani, Y. Dwi, and G. Cahyono, "Calculation of coal resources using the cross-section method in the mining plan area of PT . Sentosa Prima Coal in Mersam District , Batang Hari District , Jambi Coal , Model , Resource , Resources , Overburden determining the amount of volume or tonnage ," vol. 3, no. 1, pp. 19–23, 2022.

[4] F. K. Rohmala, D. V. Mamengko, W. Rana, P. A. Kusumo, and J. T. Musu, "Analisis Lingkungan Pengendapan Formasi Batugamping Dayang Distrik Batanta Utara, Kabupaten Raja Ampat, Provinsi Papua Barat," *Lembaran Publ. Miny. dan gas bumi*, vol. 54, no. 3, pp. 127–148, 2020, doi: 10.29017/lpmgb.54.3.567.

[5] V. Martadiastuti, B. Pratiwi, and R. K. Ali, "PT Semen Indonesia (Persero), Tbk ., Kabupaten Rembang , Provinsi Jawa Tengah," *J. Geosains dan Teknol.*, vol. 5, no. 1, pp. 54–60, 2022.

[6] Y. Tabuni, H. Haluk, and N. Alzair, "Karakteristik Batugamping Formasi Maruni Daerah Warmare Dan Sekitarnya Kabupaten Manokwari Provinsi Papua Barat," *INTAN J. Penelit. Tambang*, vol. 4, no. 2, pp. 87–92, 2022, doi: 10.56139/intan.v4i2.88.

[7] G.-S. Sedimentologi Batugamping Formasi Berai di Gunung Talikur dan Sekitarnya, K. Tapin, K. Selatan Berdasarkan Data Petrografi, P. Survei Geologi, B. Geologi, and K. Energi dan Sumber Daya Mineral, "Limestone Sedimentology of the Berai Formation at the Talikur Mountain and Its Surrounding Area, Tapin Regency, South Kalimantan Based on Petrography Data Sigit Maryanto," *J. Geol. dan Sumberd. Miner. oleh LIPI*, vol. 17, no. 2, p. 2, 2016.

[8] SNI 15-0302, "Semen Portland Pozolan," *Standar Nas. Indones.*, p. 9, 2004, [Online]. Available: http://www.bbk.go.id/uploads/media/sni-15-0302-2004_semen-portland-pozolan.pdf

[9] Dika Hadi Anugrah, Dono Guntoro, and Yunus Ashari, "Estimasi Sumberdaya Batugamping di PT X, Kecamatan Palimanan, Kabupaten Cirebon, Provinsi Jawa Barat," *J. Ris. Tek. Pertamb.*, vol. 1, no. 2, pp. 148–154, 2022, doi: 10.29313/jrtp.v1i2.538.

[10] U. Saismana, "Perhitungan Cadangan Terbukti Dan Penjadwalan Penambangan Batugamping Menggunakan Metode Blok Model Pada CV. Annisa Permai Kecamatan Halong Kabupaten Balangan Provinsi Kalimantan Selatan," *J. Geol. Pertamb.*, vol. Vol. 1 No, pp. 29–39, 2017.

[11] P. T. Pertambangan, "Kajian Geoteknik dan Geohidrologi untuk Rencana Pit Extend PT Mandiri Nusa Pratama , Desa Kebur , Kecamatan Merapi Barat , Kabupaten Lahat , Provinsi Sumatera Selatan," pp. 9–15.

[12] U. C. Sari, S. P. R. Wardani, Suharyanto, and W. Partono, "Analisis Tekanan Air Pori Menggunakan Metode Elemen Hingga Dengan Pemodelan Mohr-Coulomb Pada Plaxis," *Konf. Nas. Tek. Sipil 10*, no. 1980, pp. 675–683, 2016.

[13] R. Rekzyanti, S. Balamba, and L. Manaroinsong, "Analisa Kestabilan Lereng Akibat Gempa," *Tekno*, vol. 14, no. 66, pp. 23–33, 2016.

[14] T. Berhitu, F. Yazid, and Y. D. G. Cahyono, "Mining design and short-term production scheduling by using 3D modeler in Coal mining at PT. Internasional Prima Coal, Palaran District, Samarinda City, East Kalimantan Province," *J. Earth Mar. Technol.*, vol. 2, no. 2, pp. 127–137, 2022, doi: 10.31284/j.jemt.2022.v2i2.2885.

[15] *Analisis Geometri Jalan Tambang Pada Penambangan Batubara Pit Central Timur Di PT . Allied Indo Coal Jaya Parambahan Desa Batu Tanjung Kec . Talawi Kota Sawahlunto Cici Wahyuni SEKOLAH TINGGI TEKNOLOGI INDUSTRI (STTIND) PADANG*. 2018.

[16] SNI, "Pedoman Pelaporan Hasil Eksplorasi, Sumber Daya, dan Cadangan Mineral," *Badan Standar Nas.*, 2019.