CHAPTER IV

GEOLOGICAL ASSESSMENT OF POTENTIAL UTILIZATION OF CARBONATES

4.1 Specification of carbonate sediments for industrial uses.

Carbonate rocks including limestone, dolomite, marble are extremely valuable raw materials and are widely used in various throughout industries, although construction and cement manufacturing industries are generally the principal consumers. The processing and major uses of limestone is well illustrated in the spider-web diagram in Fig.4.1.

Dimension limestone, marble, dolomite are widely used as building stones in the form of blocks, slabs, and tiles. It is also used for various ornaments and sculptures. A uniform colour, colour pattern, and texture and relatively low porosity are usually required for dimension stones. Veins and fragments which are harder than the surrounding rock often cause fractures in working dimension limestone.

Enormous quantities of crushed limestone and dolomitic limestone obtained from dense rocks are used as aggregates in concrete; as road; road chippings on asphalt paving and bituminous macadam; as fillers; as rail road ballast; and for use under water-level as a foundation for dams, piers, etc. Crushed stone for the constructional uses must be uniform, non porous, and free from impurities in particularly iron oxides.

Large quantities of limestone with low magnesium content, less than about 3 per cent in terms of MgO, are used for the production of cement. Since the raw materials for cement production also include silica, alumina, and iron oxides, impure limestone such as marl, which already contains some portions of these products, is often used.

In iron and steel production, limestone is used to remove silica and alumina in the slags. It is obvious that the limestone used for this purpose must have a low silica and

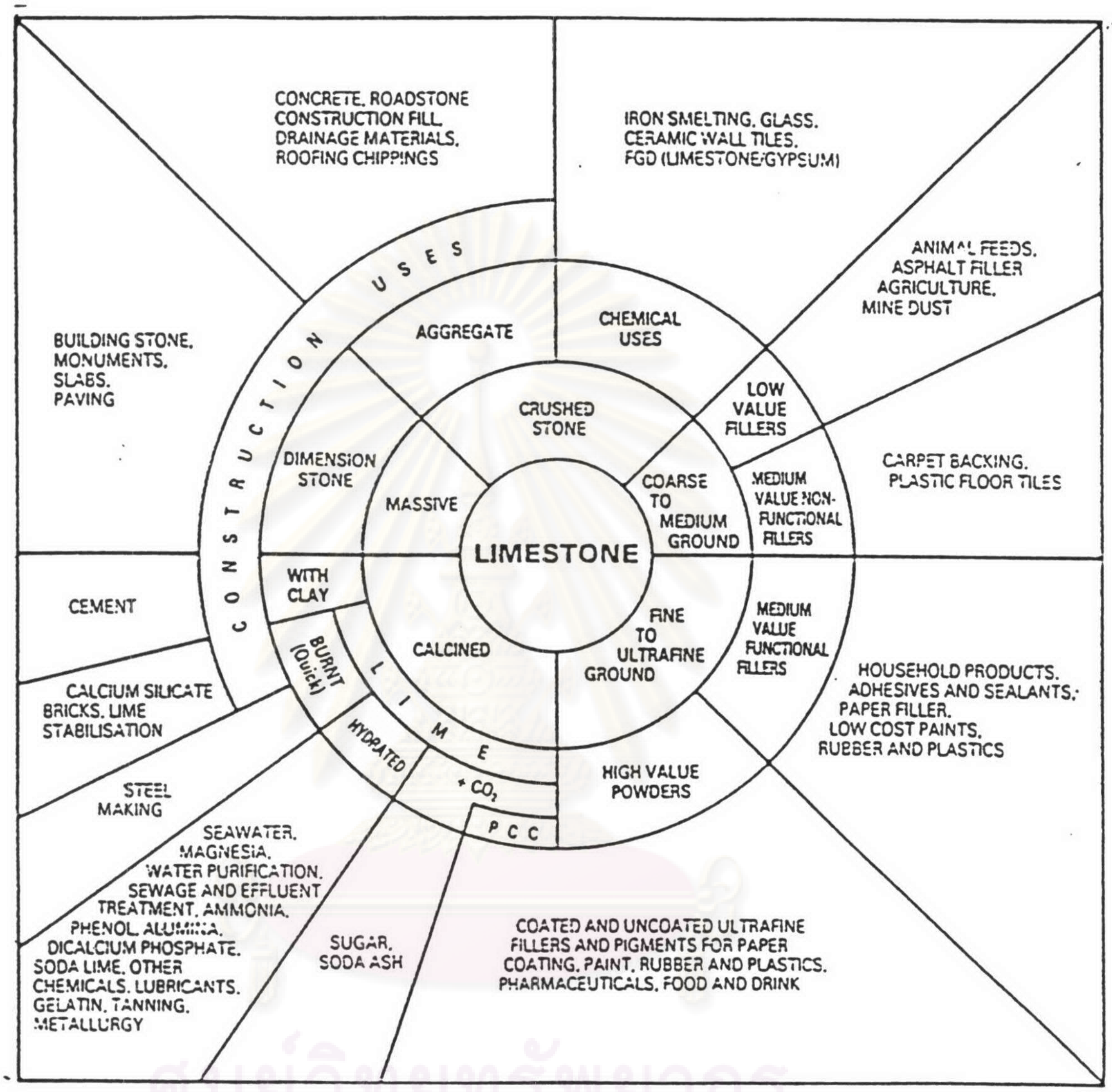


Fig. 4.1 Processing and major uses of limestone (after Harrison, 1992)

Notes: FGD – Flue gas desulphurisation

PCC – Precipitated calcium carbonate

alumina contents. Limestone is also used in refining bauxite for aluminium production and in smelting and refining of copper, lead, manganese, and zinc.

High calcium carbonate is the most important raw materials for the production of lime, sodium carbonate and other chemicals. High calcium carbonate is also used in the glass, paint and paper industries.

Large quantities of carbonate rocks such as limestone and dolomitic limestone are used as soil conditioners, in order to add the essential plant nutrients calcium and magnesium to the soil and to neutralize acid soils.

Other agricultural uses of limestone include the use as a filler in fertilizers, raw materials for mineral food, and poultry grit.

Limestone in the finely divided form, e.g. chalk, is also used as a filter bed in sewage treatment, and as a filler for flooring materials (such as linoleum) paint, paper and rubber. The finest fillers are known as whiting.

In mines, powdered limestone is used as a dust on walls and other surfaces to deactivate the combustible carbon dust.

For strategic evaluation of carbonate resource, it needs to involve systematic geological investigation and should include laboratory determinations of physical, mechanical, chemical and mineralogical properties of the stone. The evaluation also needs to include a comparison with national or international specifications for each potential end use.

Due to limited financial support and time under the present study, the assessment is mainly restricted in determination of chemical properties. With respect to the chemical composition, loss on ignition and moisture have been determined.

In addition to the above described uses, there are so many other industrial uses for limestone, both in its raw and processed forms, that it is hard to name any product which is not required limestones in some phases of its manufacture. Limestone and its products may be regarded as one of the six pillars of mineral resources on which industry and commerce depend, the other five being iron ore, salt, sulphur, petroleum and coal.

4.2 Geochemical properties of carbonates under the present study.

Under the present study, geochemical composition of samples collected from various lithostratigraphic sequences in the study area , namely, unit A, unit B and unit C have been determined using wet chemical analyses (two solutions A,B). The detailed procedure of the determination of chemical composition is shown in the Appendix A. Altogether 30 representative samples have been employed in the geochemical analyses. Besides, 30 representative samples have also been determined for their brightness using facilities at the laboratory of the Department of Mineral Resources (DMR), Bangkok, Thailand.

For chemical analyses, the carbonate samples have been analysed for CaO, MgO, SiO_2, Fe_2O_3, Al_2O_3, P_2O_5 using the atomic absorption spectrophotometry, titration, and colorimetry spectrophotometer at the laboratory of the Department of Geology, Faculty of Science, Chulalongkorn University, and loss on ignition have also been carried out at the DMR.

Geochemical composition

Calcium oxide (CaO)

The carbonate rock of the unit A of approximately 20 metres thick is lithologically characterized as medium-grained, dark gray dolomitic limestone, which are locally exposed in the lowest part of the mountains. Analytical results of 2 representative carbonate samples reveal that the average value of CaO content is 43.95 wt.%, (Table 4.1, Fig. 4.2).

Table 4.1 Chemical composition of representative samples from rock unit A.

Sample No	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	H_2O wt.%	LOI wt.%	Total. wt.%
K2-1	38.50	14.36	0.06	0.45	0.37	0.02	0.16	45.96	99.88
K9-1	49.40	4.53	0.19	0.68	0.20	0.02	0.21	43.55	98.78
Max.	49.40	14.36	0.19	0.68	0.37	0.02	0.21	45.96	99.88
Min.	38.50	4.53	0.06	0.45	0.20	0.02	0.16	43.55	99.02
Mean.	43.95	9.44	0.13	0.57	0.29	0.02	0.18	44.76	99.45

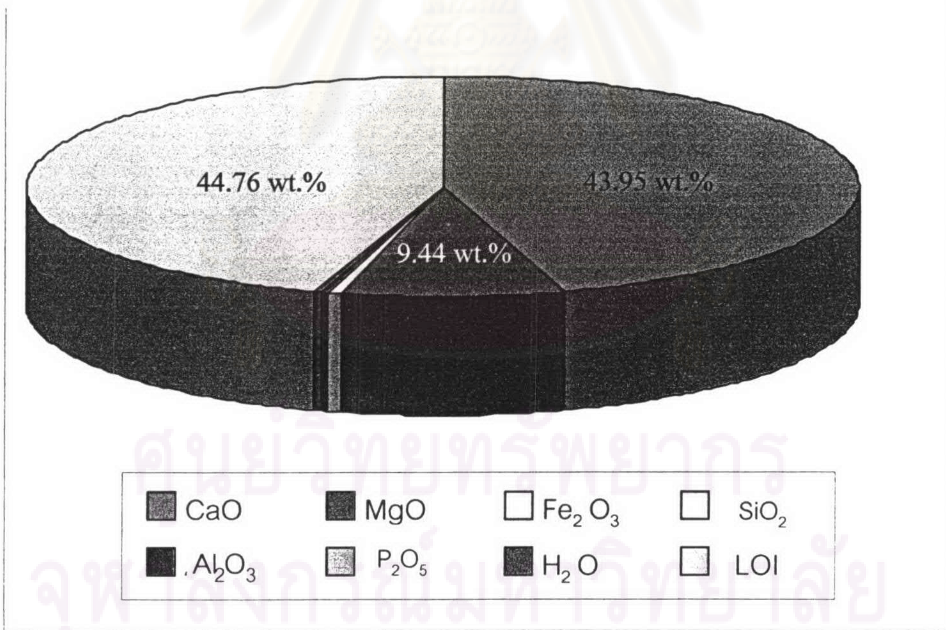


Fig. 4.2 Average chemical composition of rock unit A.

The carbonate rock of the unit B with more than 80 metres thick, is lithologically composed of medium-to-thickly bedded, gray to dark gray limestone intercalated with thin-bedded, brownish gray to dark gray chert. Analytical results of 2 representative carbonate rock samples display that the CaO content varies with in the range of 36.26 to 46.52 wt.%, with the average value of 41.39 wt.%(Table 4.2, Fig.4.3).

The rock unit C of approximately 140 metres thick lithologically, it is fine-grained, light gray to brownish gray limestone with minor calcite veins. Joints are common. Stylolites are also present in some parts. The analytical results of 26 representative rock samples reveal that the CaO content ranges from 51.01 to 55.00 wt.%, with the average value of 54.01 wt.%(Table 4.3, Fig. 4.4).

According to chemical analytical data, carbonate rocks of the unit C contains higher CaO content than rocks of unit A and unit B. This also indicates that carbonate rock of the unit C contain less impurities neither chert nor dolomite.

Magnesium oxide (MgO)

Two representative rock samples from the unit A show that the average value of MgO is 9.44% (Table 4.1).

Two representative rock samples taken from the unit B display that the MgO content varies from 1.70 to 6.50 wt.%, with the average value of 4.10 wt.%(Table 4.2).

Twenty six representative rock samples collected from the unit C show that the MgO content varies in the range of 0.08 to 3.94 wt.%, with average content of 0.80 wt.%(Table 4.3).

Carbonate rocks of the unit A contain the highest content of MgO as compared with those of the unit B and unit C. This implies that stronger dolomitization has taken place in the unit A, while weaker dolomitization occurred in the unit C.

Table 4.2 Chemical composition of representative samples from rock unit B

Sample No	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	H_2O wt.%	LOI wt.%	Total. wt.%
K2-4	46.52	1.70	0.08	10.51	0.48	0.12	0.24	39.00	98.65
K9-2	36.26	6.50	0.27	19.07	0.48	0.05	0.23	42.91	99.77
Max.	46.52	6.50	0.27	19.07	0.48	0.16	0.24	42.91	99.77
Min.	36.26	1.70	0.08	10.51	0.48	0.05	0.23	39.00	98.65
Mean.	41.39	4.10	0.17	14.79	0.48	0.08	0.23	40.95	99.21

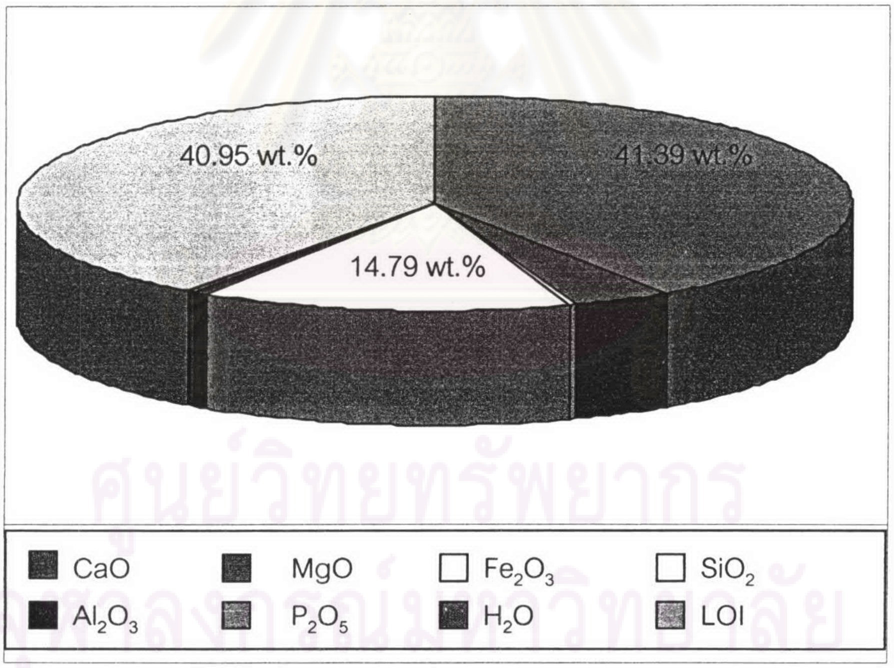


Fig. 4.3 Average chemical composition of rock unit B.

Table 4.3 Chemical composition of representative samples from rock unit C

Sample No	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	H_2O wt.%	LOI wt.%	Total. wt.%
K2-6	53.83	0.72	0.43	0.88	0.60	<0.01	0.20	43.05	99.71
K6-5	54.36	1.59	0.06	0.88	0.01	0.05	0.22	42.61	99.78
K6-7	53.63	0.80	0.08	1.30	0.50	<0.01	0.11	42.65	99.07
K7-2	54.57	0.54	0.03	0.50	0.11	<0.01	0.11	43.09	98.95
K7-5	54.01	0.16	0.04	0.34	0.04	<0.01	0.25	43.04	97.88
K8-2	55.27	0.42	0.03	0.02	0.08	0.01	0.13	43.43	99.39
K9-4	53.56	1.38	0.01	1.04	0.51	0.02	0.21	43.16	99.89
K1-1	55.01	0.56	0.01	0.15	0.29	0.02	0.16	43.52	99.72
K1-4	54.90	0.08	0.08	0.02	0.17	0.04	0.11	43.37	98.77
K2-7	51.01	3.94	<0.01	0.38	0.27	0.02	0.11	43.66	99.39
K3-1	54.16	0.28	0.04	0.20	0.40	0.01	0.15	43.51	98.75
K3-4	55.00	0.28	0.04	0.13	0.24	0.01	<0.01	43.64	99.34
K3-6	55.14	0.57	0.06	0.06	0.19	0.02	0.10	43.02	99.16
K3-9	54.39	0.87	0.14	0.24	0.47	0.01	0.19	43.43	99.65
K3-10	54.05	0.63	0.12	0.63	0.36	0.02	0.17	43.00	98.57
K4-1	54.81	0.50	<0.01	0.34	0.16	0.02	0.29	42.45	98.57
K5-12	52.59	1.55	0.06	0.79	0.36	0.04	0.26	42.97	98.62
K6-9	52.60	0.67	0.04	1.04	0.16	ND	0.11	42.57	97.19
K7-6	54.50	0.44	0.06	0.38	0.07	0.01	0.15	43..15	98.76
K7-8	54.18	0.41	0.08	0.22	0.04	0.02	0.09	43.64	98.68
K8-4	55.18	0.44	0.04	0.16	0.01	0.01	0.27	43.33	99.44
K5-1	53.87	0.69	0.43	1.36	0.76	<0.01	0.48	42.02	99.61
K5-10	54.00	0.89	0.15	0.21	0.45	0.18	0.55	43.00	99.43
K6-1	53.88	0.86	0.04	0.13	0.07	0.04	0.17	43.11	98.30
K6-3	53.05	0.89	0.08	1.34	0.25	0.10	0.39	43.62	99.92
K9-6	55.00	0.40	0.06	0.38	0.21	0.04	0.21	43.14	99.44
Max.	55.00	3.94	0.43	1.36	0.76	0.18	0.55	43.66	99.92
Min.	51.01	0.08	<0.01	0.02	0.01	<0.01	<0.01	42.02	97.19
Mean.	54.01	0.80	0.10	0.60	0.28	0.03	0.23	43.04	99.15

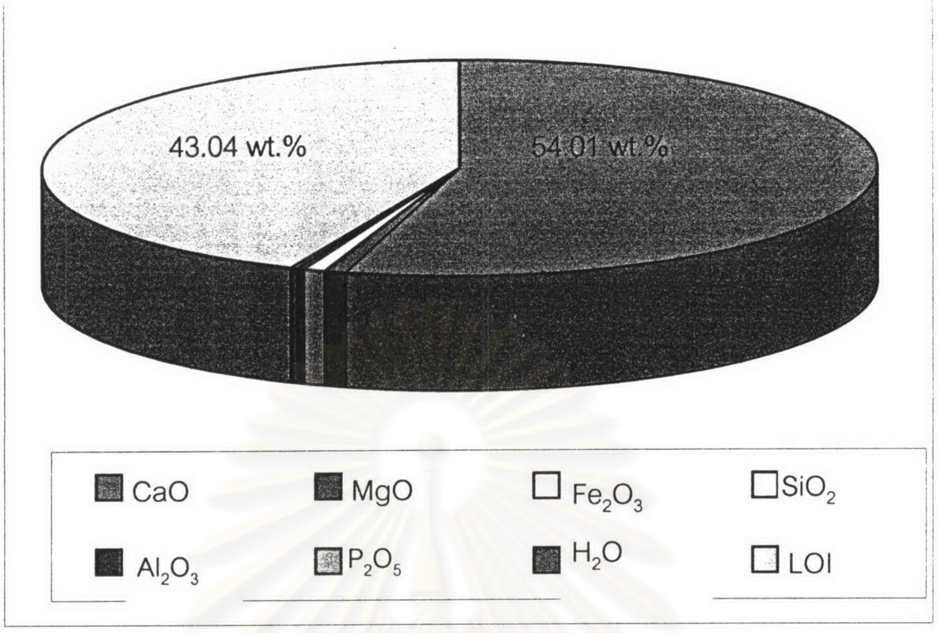


Fig. 4.4 Average chemical composition of rock unit C

Silicon dioxide (SiO_2)

For the rock unit A, the analytical results of 2 representative samples show that the average value of SiO_2 content is relatively low, 0.57 wt.%, (Table 4.1).

On the contrary, analytical results of 2 representative rock samples from the rock unit B display that the SiO_2 content is relatively high in the range of 10.51 to 19.07 wt.%, with the average content of 14.79 wt.%(Table 4.2).

The rocks of unit C also contain relatively low SiO_2 content. Analytical results of 26 rock samples show the range of SiO_2 content from 0.02 to 1.36 wt.%, with the average value of 0.60 wt.%(Table 4.3).

Normally, carbonate rocks contain low SiO_2 content, as in those of unit A and unit C. The high content of SiO_2 in unit B is in consistent with the occurrence of chert nodules or lenses in the unit.

Ferric oxide (Fe_2O_3)

For the rock unit A, analytical results of 2 representative samples show that the average value of iron oxide content is relatively low, 0.13 wt.%, (Table 4.1).

Similarly, the rock unit B, the total iron oxide content varies from 0.08 t0 0.27 wt.%, with the average value of 0.17 wt.% (Table 4.2).

For the rock unit C, analytical results display that the iron oxide content is relatively lower than the other two rock units. It varies from less than 0.01 to 0.43 wt.%, with the average value of 0.10 wt.% (Table 4.3).

The overall Fe_2O_3 content is generally low in all three rock units.

Aluminium oxide (Al_2O_3)

The rock unit A contains the average value of Al_2O_3 content of 0.29 wt.%, (Table 4.1).

The Al_2O_3 content of the rock unit B is relatively higher than that of the rock unit A with the average value of 0.48 wt.%(Table 4.2).

For the rock unit C, the analytical results reveal that the Al_2O_3 content varies from 0.01 to 0.76 wt.%, with the average value of 0.28 wt.%(Table 4.3).

The overall Al_2O_3 content of the all rock units is generally less than 1 wt.%.

Phosphorous penta oxide (P_2O_5)

For the rock unit A, the average value of P_2O_5 content is 0.02 wt.% (Table 4.1).

For the rock unit B, the P_2O_5 content varies from 0.12 to 0.16 wt.%, with the average value of 0.08 wt.% (Table 4.2).

And for the rock unit C, the P_2O_5 content varies in the range of <0.01 to 0.18 wt.%, with the average value of 0.03 wt.% (Table 4.3).

It is clearly shown that the overall P_2O_5 content is less than 1 wt.% in all three rock units.

Loss on ignition

Loss on ignition is one of important chemical properties of carbonate rocks that the content varies according to percentage of volatile matters in the rocks. They include the water content and the carbondioxide which has been dissociated from the carbonate sediments.This is also a clue to determine the accuracy of the analysis. Limestone normally contains loss of ignition of 43-43.5 wt%, while dolomite shows a little higher value of 44 wt% or more. Rocks of unit B contain higher silica content and therefore shows lower loss of ignition value.

For the rock unit A, the average value of loss on ignition is 44.76 wt.% (Table 4.1).

And the rock unit B, the value varies from 39.00 to 42.99 wt.%, with the average value of 40.95 wt.% (Table 4.2).

For the rock unit C, the loss on ignition falls within the range of 42.02 to 43.66 wt.%, with the average value of 43.04 wt.% (Table 4.3).

Brightness

Brightness is the percentage of reflectance of measured material as compared with reflectance of the barium sulfate i.e standard plates. Brightness is also one of very important properties of carbonate rocks, particularly for those used as raw materials for fillers, such as, paper, paint, plastics, glass industries.

The brightness of rock in all units under the present study is lower than 55%(Table 4.4). Therefore, they are not suitable for fillers. Generally, the brightness is required to be greater than 80% for paper, 80 t0 82% for plastics, and 85 to 93% for paper coating (Harrison, 1992).

The average value of brightness of each rock unit is shown in (Table 4.4, Fig. 4.5).

Table 4.4 Showing a average value brightness of each rock units

Rock unit	Average value of brightness(%)	Total number of samples
A	44.1	2
B	29.09	2
C	52.95	26

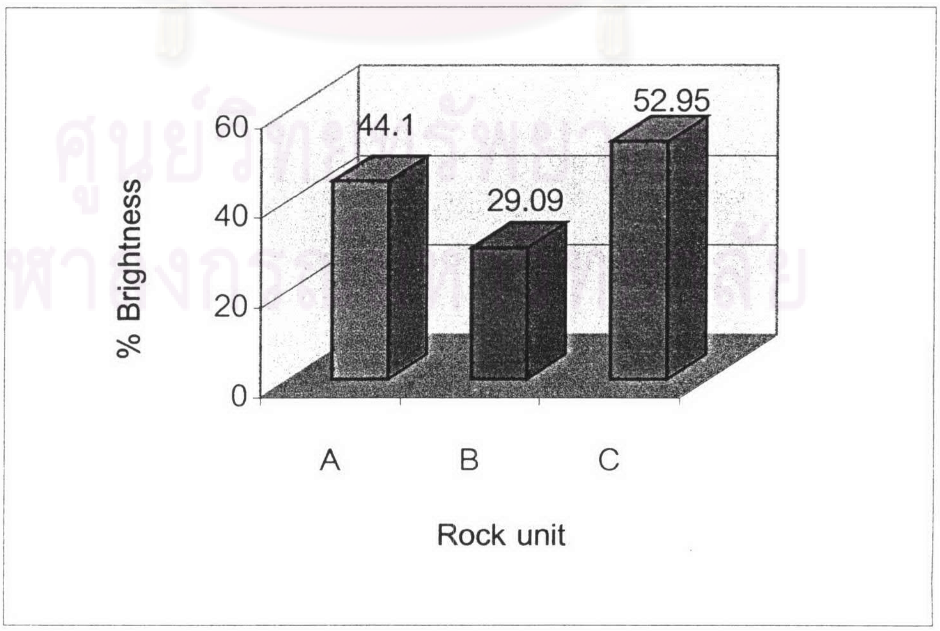


Fig. 4.5 Average brightness of three rock units.

4.3 Quality evaluation for potential uses

4.3.1 Chemical specification of carbonate rocks for industrial uses

Under the present study, a simple classification of limestone resources based on calcium carbonate content from Cox et al. (1977) in Table 4.5, and the quality specifications for the assessment of limestone deposits according to their potential end uses from Lorenz, (1991), and Harrison, (1992) in Tables 4.6; 4.7; 4.8; 4.9; 4.10, have been employed in determining the potential uses as a preliminary assessment.

The system used to determine the purity of limestone is the calcium carbonate content. The advantage is that the distribution of various chemical grades can be easily illustrated on the resource map. Under this classification , the rock units in the study area are classified into five grades ranging from impure to very high purity. Only the rock unit C shows potential use for industries as shown in the geological base map with 1: 50.000 scale (Fig.4.6).

Table 4.5 Classification of limestone by purity (Cox et al.1977).

Category	Percentage ($CaCO_3$)	Percentage (CaO)
Very high purity	>98.5	>55.2
High purity	97.0-98.5	54.3-55.2
Medium purity	93.5-97.0	52.4-54.3
Low purity	85.0-93.5	47.6-52.4
Impure	<85.0	<47.6

Table 4.6 Potential utilization of limestone for cement industry.

Chemical composition	Standards				SCC (1995) (average from 50 samples) wt%	Present study (average from 30 samples) wt%
	Lorenz (1991) wt%	Lamar (1961) wt%	Harrison (1992) wt%	Ubonsri (1994) wt%		
$CaCO_3$	>75	>75	-	>82.0	-	-
CaO	>42	-	-	>46.0	53.06	52.65
MgO	<3	<3	<3	<1.5	1.23	1.52
SiO_2	<15	-	-	-	2.01	1.46
Al_2O_3	-	-	-	<5.0	0.09	0.23
Fe_2O_3	<0.01 (for white cement)	<0.01 (for white cement)	<0.01 (for white cement)	-	0.05	0.09
P_2O_5			<1	<0.4	0.01	0.03
SO_3	<0.5	<0.5	<1	-	-	-
K_2O + Na_2O	-	-	0.6	0.6	0.11	-
LOI	-	-	-	-	42.16	43.08
	-	-				

SCC : Siam Cement Public Company

Table 4.7 Potential utilization of limestone for sugar refining.

Chemical composition	Standards				SCC (average from 50 samples) wt%	Present study (average from 30 samples) wt%
	Lorenz (1991) wt%	Lamar (1961) wt%	Harrison (1992) wt%	Ubonrsi (1994) wt%		
$CaCO_3$	-	>96-97	>96	-	-	-
CaO	55.2	-	-	>50	53.06	52.65
MgO	<4	<1-4	-	>1	1.23	1.52
SiO_2	<1	<1	<1	<2	2.01	1.46
Al_2O_3		-	<0.35	-	0.09	0.23
	}<1.5			}<1.5		
Fe_2O_3	-	<0.5	<0.3	-	0.05	0.09
P_2O_5	-	-	-	-	0.01	0.03
K_2O+Na_2O	-	-	-	-	0.11	-
LOI	-	-	-	<44.0	42.16	43.08

SCC: Siam Cement Public Company

Table 4.8 Potential utilization of limestone for agriculture.

Chemical composition	Standards		SCC (average from 50 samples) wt%	Present study (average from 30 samples) wt%
	Lorenz (1991) wt%	Lamar (1961) wt%		
$CaCO_3$	-	>80	-	-
CaO	>47.6	-	53.06	52.65
MgO	-	-	1.23	1.52
SiO_2	Not too high	-	2.01	1.46
Al_2O_3	<1	-	0.09	0.23
Fe_2O_3	<1	-	0.05	0.09
P_2O_5	-	-	0.01	0.03
K_2O+Na_2O	<0.05	-	0.11	-
LOI	-	-	42.16	43.08

SCC: Siam Cement Public Company

Table 4.9 Potential utilization of limestone for ceramic (grade II) industry.

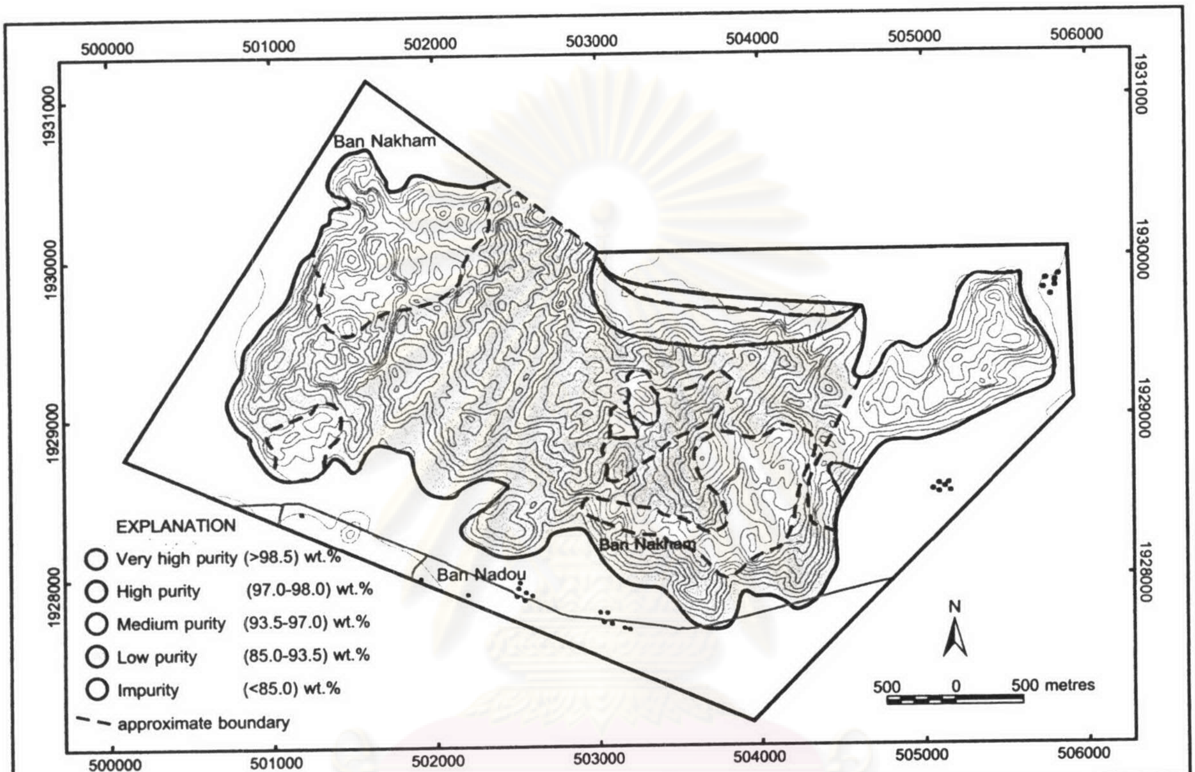
Chemical composition	Standards		SCC (average from 50 samples) wt%	Present study (average from 30 samples) wt%
	Lorenz (1991) wt%	Lamar (1961) wt%		
$CaCO_3$	-	>97	-	-
CaO	>49.9	-	53.06	52.65
MgO	<4	-	1.23	1.52
SiO_2	<2	<2	2.01	1.46
Al_2O_3		-	0.09	0.23
	}<0.03			
Fe_2O_3	-	<0.3	0.05	0.09
P_2O_5	-	-	0.01	0.03
K_2O+Na_2O	-	-	0.11	-
SO_3	<0.1	<0.1	-	-
LOI	-	-	42.16	43.08

SCC: Siam Cement Public Company

Table 4.10 Potential utilization of limestone for quick lime

Chemical composition	Standards			SCC	Present study
	Lorenz (1991) wt.%	Lamar (1961) wt.%	Ubonsi (1994) wt.%	(average from 50 samples) wt.%	(average from 30 samples) wt.%
$CaCO_3$	-	97-98	97-98	-	-
$MgCO_3$	-	<5	-	-	-
Other impurities (for high calcium lime)	-	<3	-	-	-
$MgCO_3$	-	>40	>40	-	-
Other impurities (for high magnesiumlime)	-	<3	-	-	-
CaO	>52.3	-	-	53.06	52.65
MgO	<2	-	-	1.23	1.52
SiO_2	-	-	-	2.01	1.45
Al_2O_3	}<0.09	-	-	0.09	0.23
Fe_2O_3		-	-	0.05	0.09
Other impurities	-	-	<3	-	-
P_2O_5		-	-	0.01	0.03
LOI	-	-	-	42.16	43.08

SCC: Siam Cement Public Company



GEOLOGICAL ASSESSMENT OFSOME PERMO-CARBONIFEROUS CARBONATE SEDIMENTS IN THE SOUTHERN PART OF THE PHA HOUA XANG RANGE, MOUANG THAKHEK, KHAMMOUANE PROVINCE, THE LAO PDR.

Figure 4.6 The limestone purity map of the study area using the purity classification by Cox et. al(1977).

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4.3.2 Chemical quality and potential uses of Pha Houa Xang carbonate rocks

For the evaluation of potential uses of carbonate rocks under the present study, chemical analyses from the Siam Cement Public Company (SCC) with sample symbols of KMD, KMF, KMG, KMW have also been taken into consideration.

The results of chemical analyses of totally 80 samples, including 50 samples from SCC, are employed for quality evaluation of potential end-uses. Location of those samples are shown in Fig. 4.7.

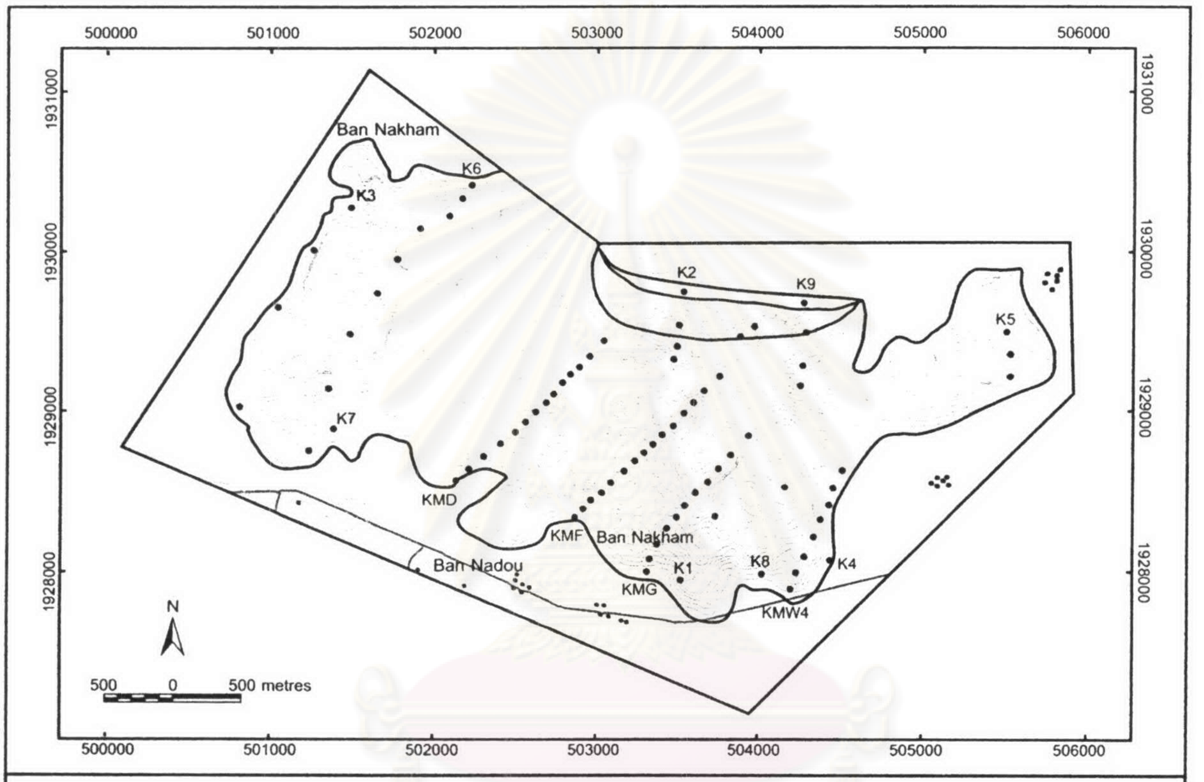
The possible potential end-uses of each rock unit are described as follows:

Unit A

The results of chemical characteristics from 2 representative samples of this unit reveals the relatively high MgO (Table 4.11).The magnesium oxide (MgO) content is ranging from 4.53 to 14.36 wt.%, with the average value of 9.44 wt.%. The relatively high MgO content is contributed by the presence of dolomite in this rock unit. The rock of unit A is not suitable for any industrial use because its magnesium content is higher than all standards. The only possible use is road materials, concrete aggregate and agricultural purposes. Due to the limited aerial extension of the rock of unit A, the reserve is not calculted in the present study.

Table 4.11 Chemical composition of 2 presentative samples from the unit A

Sample No.	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	LOI wt.%	Source
K2-1	38.50	14.36	0.06	0.45	0.37	0.02	45.96	Present study
K9-1	49.40	4.53	0.19	0.68	0.20	0.02	43.55	Present study
Average	43.95	9.44	0.13	0.57	0.29	0.02	44.76	



GEOLOGICAL ASSESSMENT OF SOME PERMO-CARBONIFEROUS CARBONATE SEDIMENTS IN THE SOUTHERN PART OF THE PHA HOUA XANG RANGE, MOUANG THAKHEK, KHAMMOUANE PROVINCE, THE LAO PDR.

Figure 4.7 Sampling location map of the study area.

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Unit B

The chemical characteristics from 4 representative samples of the unit B displays the relatively high silicon oxide (SiO_2) content as compared with all standards. It varies from 10.51 to 78.1 wt.%, with the average value of 30.74 wt.%. The calcium oxide (CaO) content is relatively low, with its average value of 34.80 wt.% as compared with all standards(Table 4.12).

Lithologically, the unit B is composed predominantly of fine-grained limestone intercalated with thinly-bedded, elongated and nodular chert.

The quality of rock unit B is not suitable for industrial purposes. However, it can be used for the purpose of road materials and concrete aggregates.

Table 4.12 Chemical composition of 4 samples from unit B.

Sample No.	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	LOI wt.%	Source
K2-4	46.52	1.70	0.08	10.51	0.48	0.12	39.00	Present study
K9-2	36.26	6.50	0.27	19.07	0.48	0.05	42.91	Present study
KMF-80	10.50	0.27	0.46	78.10	0.75	0.04	8.60	SCC
KMF-85	45.90	0.79	0.20	15.3	0.62	0.03	36.7	SCC
Average	34.80	2.32	0.25	30.74	0.58	0.06	31.8	

SCC : Siam Cement Public Company

Unit C

The rock of unit C shows better quality than that of the unit A and unit B. The chemical characteristics of 74 samples is presented in Table 4.13. The calcium oxide content (CaO) is relatively high as compared with standards, namely its average value is 54.09 wt.%. The magnesium and silicon oxides are lower than standards, therefore this rock unit is most suitable for almost industrial uses.

Table 4.13 Chemical composition of 74 samples from rock unit C

Sample No.	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	LOI wt.%	Source
K1-1	55.01	0.56	0.01	0.15	0.29	0.02	43.52	Present study
K1-4	54.9	0.08	0.08	0.02	0.17	0.04	43.37	Present study
K2-6	53.83	0.72	0.43	0.88	0.60	<0.01	43.05	Present study
K2-7	51.01	3.94	<0.01	0.38	0.27	0.02	43.66	Present study
K3-1	54.16	0.28	0.04	0.20	0.40	0.01	43.51	Present study
K3-4	55.00	0.28	0.04	0.13	0.24	0.01	43.69	Present study
K3-6	55.14	0.57	0.06	0.06	0.19	0.02	43.02	Present study
K3-9	54.39	0.87	0.14	0.24	0.47	0.01	43.43	Present study
K3-10	54.05	0.63	0.12	0.63	0.36	0.02	43.00	Present study
K4-1	54.81	0.50	<0.01	0.34	0.16	0.02	42.25	Present study
K5-1	53.87	0.69	0.43	1.36	0.76	<0.01	42.02	Present study
K5-10	54.00	0.89	0.15	0.21	0.45	0.18	43.00	Present study
K5-12	52.59	1.55	0.06	0.79	0.36	0.04	42.97	Present study
K6-1	53.88	0.86	0.04	0.13	0.07	0.04	43.11	Present study
K6-3	53.05	0.89	0.08	1.34	0.25	0.10	43.62	Present study
K6-5	54.36	1.59	0.06	0.88	0.01	0.05	42.61	Present study
K6-7	53.63	0.80	0.08	1.30	0.50	<0.01	42.65	Present study
K6-9	52.60	0.67	0.04	1.04	0.16	<0.01	42.57	Present study
K7-2	54.57	0.54	0.03	0.50	0.11	<0.01	43.09	Present study
K7-5	54.01	0.16	0.04	0.34	0.04	<0.01	43.04	Present study
K7-6	54.50	0.44	0.06	0.38	0.07	0.01	43.15	Present study
K7-8	54.18	0.41	0.08	0.22	0.04	0.02	43.64	Present study
K8-2	55.27	0.42	0.03	0.02	0.08	0.01	43.43	Present study
K8-4	55.18	0.44	0.04	0.16	0.01	0.01	43.33	Present study
K9-4	53.56	1.38	0.01	1.04	0.51	0.02	43.16	Present study
K9-6	55.00	0.40	0.06	0.38	0.21	0.04	43.14	Present study
KMD-3	54.70	0.55	0.03	0.05	0.12	<0.01	42.60	SCC

Table 4.13 (contd.)

Sample No.	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	LOI wt.%	Source
KMD-7	54.80	0.51	0.03	0.11	0.09	0.02	43.00	SCC
KMD-11	54.90	0.54	0.02	0.15	0.05	<0.01	42.70	SCC
KMD-21	54.80	0.57	0.04	0.07	0.05	0.04	42.70	SCC
KMD-25	54.80	0.56	0.04	0.07	0.04	0.02	42.90	SCC
KMD-29	55.20	0.53	0.04	0.11	0.07	0.01	42.70	SCC
KMD-33	55.10	0.48	0.05	0.07	0.05	0.03	42.80	SCC
KMD-35	55.00	0.56	0.03	0.10	0.02	0.02	42.80	SCC
KMD-39	54.40	0.66	0.03	0.09	0.07	<0.01	42.80	SCC
KMD-43	55.00	0.51	0.03	0.14	0.13	0.03	42.70	SCC
KMD-45	54.90	0.52	0.03	0.11	0.06	<0.01	42.70	SCC
KMD-49	55.00	0.46	0.04	0.10	0.10	<0.01	42.60	SCC
KMD-55	54.70	0.50	0.04	0.13	0.15	<0.01	42.40	SCC
KMD-63	55.10	0.59	0.06	0.12	0.05	<0.01	42.40	SCC
KMF-5	55.00	0.77	0.02	0.07	0.04	<0.01	42.50	SCC
KMF-9	55.30	0.49	0.03	0.10	0.06	<0.01	42.40	SCC
KMF-15	55.00	0.49	0.02	0.08	0.07	<0.01	42.30	SCC
KMF-19	54.80	0.84	0.01	0.08	0.08	0.01	43.20	SCC
KMF-23	49.60	5.35	0.04	0.11	0.10	0.02	43.20	SCC
KMF-25	54.90	0.79	0.03	0.09	0.02	<0.01	43.3	SCC
KMF-31	51.30	3.26	0.05	0.23	0.19	0.02	43.5	SCC
KMF-35	44.80	8.90	0.05	0.16	0.24	0.02	44.5	SCC
KMF-41	52.10	2.95	0.04	0.24	0.13	0.01	43.3	SCC
KMF-45	53.10	2.19	0.04	0.21	0.13	0.02	43.10	SCC
KMF-49	53.30	1.88	0.02	0.08	0.09	0.01	43.10	SCC
KMF-53	53.50	1.45	0.05	0.11	0.10	0.01	43.10	SCC
KMF-61	52.00	2.98	0.05	0.13	0.11	0.01	43.30	SCC
KMF-65	54.90	0.61	0.13	0.45	0.11	0.03	43.00	SCC

Table 4.13 (contd.)

Sample No.	CaO wt.%	MgO wt.%	Fe_2O_3 wt.%	SiO_2 wt.%	Al_2O_3 wt.%	P_2O_5 wt.%	LOI wt.%	Source
KMF-73	55.20	0.50	0.04	0.34	0.09	<0.01	42.60	SCC
KMG-5	55.00	0.57	0.03	0.19	0.10	<0.01	42.90	SCC
KMG-9	55.20	0.56	0.05	0.14	0.07	0.03	43.00	SCC
KMG-15	54.60	0.54	0.02	0.17	0.13	0.06	42.90	SCC
KMG-19	55.40	0.47	0.04	0.16	0.05	0.05	43.00	SCC
KMG-29	55.20	0.48	0.03	0.10	0.09	0.05	43.00	SCC
KMG-33	54.70	1.08	0.03	0.09	0.06	0.01	43.30	SCC
KMG-39	55.10	0.57	0.02	0.10	0.05	<0.01	42.90	SCC
KMG-49	55.40	0.49	0.03	0.06	<0.01	0.01	42.90	SCC
KMG-57	55.60	0.59	0.04	0.24	0.05	0.02	43.10	SCC
KMG-59	54.90	0.70	0.02	0.28	0.04	0.02	43.10	SCC
KMG-65	54.20	1.53	0.05	0.27	0.07	0.01	43.30	SCC
KMWA-1	55.00	0.50	0.04	0.09	<0.01	<0.01	42.90	SCC
KMWA-2	54.70	0.43	0.05	0.06	<0.01	<0.01	43.20	SCC
KMWA-3	54.90	0.49	0.04	0.14	<0.01	<0.01	43.20	SCC
KMWA-4	52.90	1.64	0.09	0.29	0.04	0.02	43.70	SCC
KMWA-5	51.60	3.31	0.07	0.22	<0.01	0.01	43.30	SCC
KMWA-6	53.70	1.06	0.05	0.17	<0.01	<0.01	42.90	SCC
KMWA-7	52.60	2.73	0.03	0.15	<0.01	0.01	43.10	SCC
KMWA-8	52.90	2.16	0.08	0.16	<0.01	0.02	43.10	SCC
Average	54.79	1.11	0.06	0.27	0.15	0.03	43.57	

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The rock of unit C is, most abundant, characterized by very thickly-bedded, fine-grained, light to brownish limestone. It covers most of the study area. According to the utilization standards, the unit C has high potential end-uses for any industries ,such as, portland cement, quicklime, agriculture, ceramic (grade II), sugar refining.

Portland cement

Portland cement is made by calcining a mixture of about 75% limestone and 25% clay to form calcium-silicate clinkers which are then ground and mixed with a small amount of gypsum which acts as a setting retardant.

The quality specification of limestone for portland cement employed in this study is after Lorenz, (1991). It is based on limestone containing at CaO >42%, MgO< 3%, SiO_2 <15%, P_2O_5 <0.5% (Table 4.14).

Table 4.14 Potential utilization for cement industry of carbonate sediments under the present study.

Standard / Chemical Composition	Lorenz (1991) wt%	Rock unit C of the present study	
		average from 26 samples wt%	average from 74 samples wt%
CaO	>42	54.01	54.79
MgO	<3	0.80	1.11
SiO_2	<15	0.60	0.27
Al_2O_3	-	0.28	0.15
Fe_2O_3	<0.01 (for white cement)	0.1	0.06
P_2O_5	<0.5	0.03	0.03
LOI	-	43.04	43.57

The suitable limestone for portland cement industry covers mostly all parts of the study area of approximately 8 square kilometres. The rock unit C is considered to be most suitable for this purpose as determined from its chemical characteristics. The lithology of unit C is consists of light gray to brownish gay, fine grained very thick-bedded limestone with minor calcite veins and veinlets.

Limestone quality resource map for the portland cement is illustrated in Fig 4.8.

Quick-lime

There are two types of quick-lime, high calcium quick-lime, and high magnesium quick-lime. For high calcium quick-lime, generally the calcium carbonate content ($CaCO_3$) is higher than 90%, preferably (97-98%), the magnesium carbonate content ($MgCO_3$) is less than 5%, and other impurities is less than 3%. Whereas for the high magnesium quick-lime, the magnesium carbonate content (MgCO3) is higher than 40%, and other impurities is less than 3%. For this present study, the quick-lime is only referred to high calcium quick-lime.

Quick-lime is essential industrial chemical, with a tremendous list of uses. It is used as a flux in smelting; soda ash, in alkalies, and other chemical products; in treating pulp for paper manufacture; sugar refining; water purification and effluent treatment, etc.

Lime is obtained by calcination of high calcium carbonate in a shaft or rotary kiln with requirement temperature 1000°-1100°C.

The reaction is reversible

$$CaCO_3 \rightleftharpoons CaO + CO_2$$

Quick-lime consists mainly of amorphous calcium oxide, CaO. It forms lumps which have a strong affinity for water, either as liquid, vapor, or ice; it crumbles as the lime 'slake' and heat is released, then calcium hydroxide $Ca(OH)_2$ is formed.

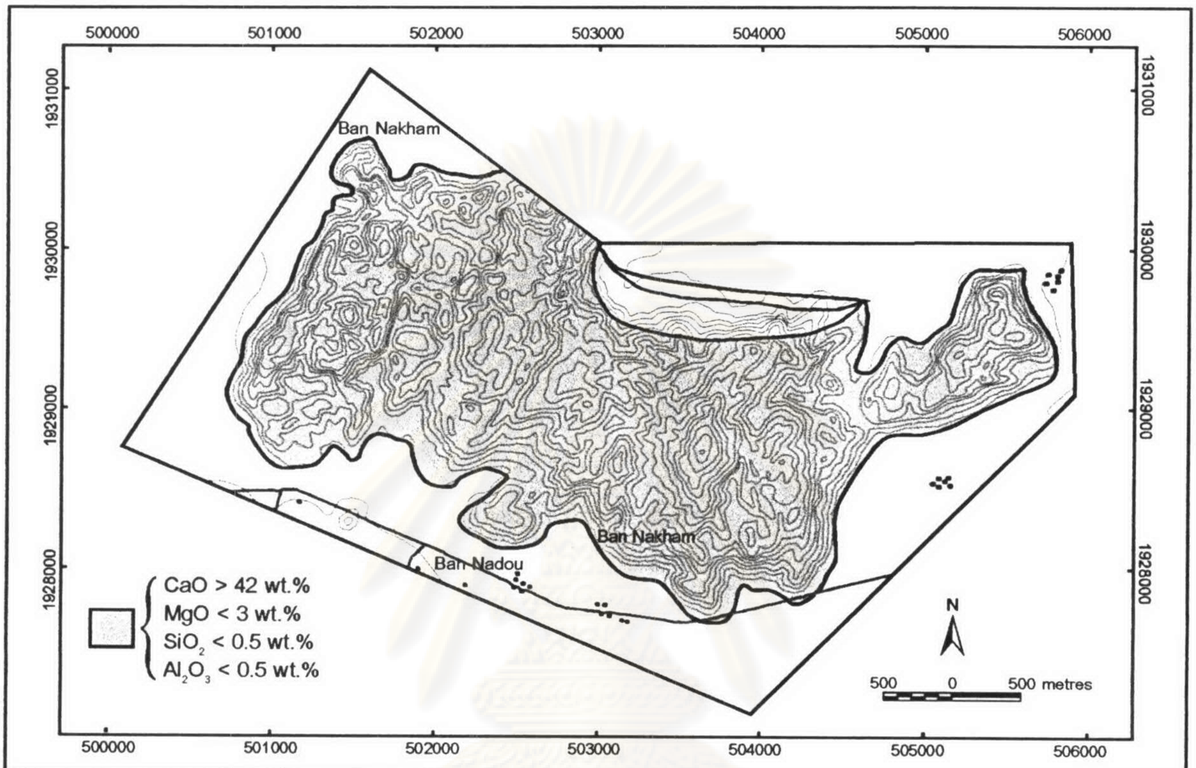

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Figure 4.8 Limestone quality resource map for cement production

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$$CaO + H_2O \longrightarrow Ca(OH)_2$$

The limestone which is suitable for quick lime in terms of chemical compositions are as follows: CaO>53.2%, MgO<2%, SiO_2<1.2 and Al_2O_3 +Fe_2O_3<0.9% (Lorenz,1991). The evaluation of limestone under the present study for the quick lime production is presented in Table 4.15.

Table 4.15 Potential utilization for quick lime of carbonate sediments under the present study.

Standard / Chemical Composition	Lorenz (1991) wt%	Rock unit C of the present study	
		average from 26 samples wt%	average from 74 samples wt%
CaO	>53.2	54.01	54.79
MgO	<2	0.80	1.11
SiO_2	<1.2	0.60	0.27
Al_2O_3	-	0.28	0.15
	}<0.9		
Fe_2O_3	-	0.10	0.06
P_2O_5	-	0.03	0.03
LOI	-	43.04	43.57

The limestone resource suitable for quick lime covers large part of the study area of approximately 8 square kilometres. Only the rock unit C is considered to be suitable for this purpose. The limestone quality resources map for the quick lime production is illustrated in Fig 4.9.

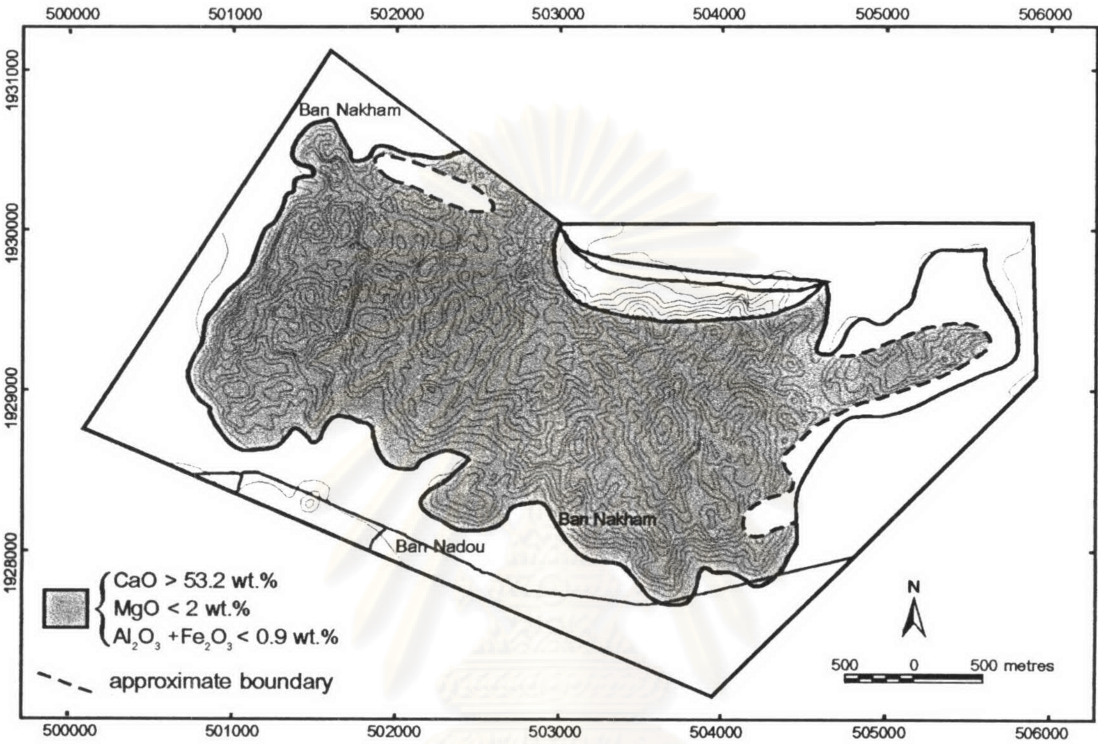

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Figure 4.9 Limestone quality resource map for quick lime production.

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Agriculture

A vast tonnage of limestone enters the agriculture field as direct application to soil, as a filler and conditioner for mixed fertilizer, animal mineral feeds, poultry grit, and in a few miscellaneous minor uses.

The limestone for agriculture in the study area is specified by chemical grade based on quality specification of limestone according to their potential end-uses of Lorenz (1991). This typical specification demand that CaO>47.6%, SiO_2 not too high, Al_2O_3<1%, Fe_2O_3<1%.(Table 4.16)

Table 4.16 Potential utilization for agriculture of carbonate sediments under the present study.

Standard / Chemical Composition	Lorenz (1991) wt%	Rock unit C of the present study	
		average from 26 samples wt%	average from 74 samples wt%
$CaCO_3$	-	-	-
CaO	>47.6	54.01	54.79
MgO	-	0.80	1.11
SiO_2	Not too high	0.60	0.27
Al_2O_3	<1	0.28	0.15
Fe_2O_3	<1	0.1	0.06
P_2O_5	-	0.03	0.03
K_2O+Na_2O	<0.05	-	-
LOI		43.04	43.57

Under the present study, the identified potential end-use of limestone for agriculture covers relatively large part of the study area of about 9 square kilometres. It is underlain mainly by rock units C and A.

Limestone quality resource map for agricultural uses is shown in (Fig.4.10).

Ceramic (grade II)

Finely pulverized limestone is an ingredient of many formulas for glazes and enamels that it might be regarded as a type of filler, but its function is more towards chemical, since when these clay products are burned in kilns, the $CaCO_3$ converts to CaO and is an active fluxing material.

For this classified limestone for ceramic (grade II) is specified following from their potential end-uses (Lorenz, 1991). It is based on some chemical grade such as CaO>49.9%, MgO<4%, SiO_2<2%, Fe_2O_3<0.3%(Table 4.17).

The limestone resource for ceramic (grade II) covers almost all part of the study area of approximately 8 square kilometres. The limestone for ceramic (grade II) is mainly composed of rock unit c.

The limestone quality resource map for ceramic (grade II) is presented in Fig.4.11.

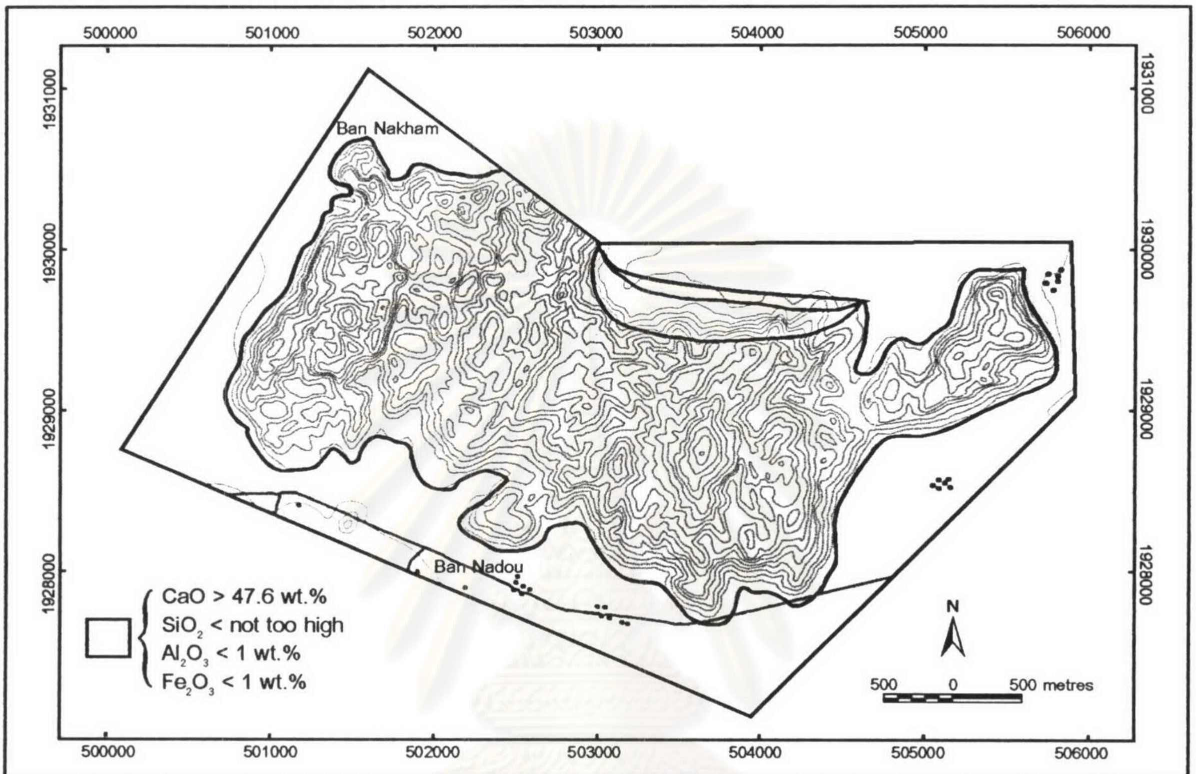

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Figure 4.10 Limestone quality resources map for agricultural uses.

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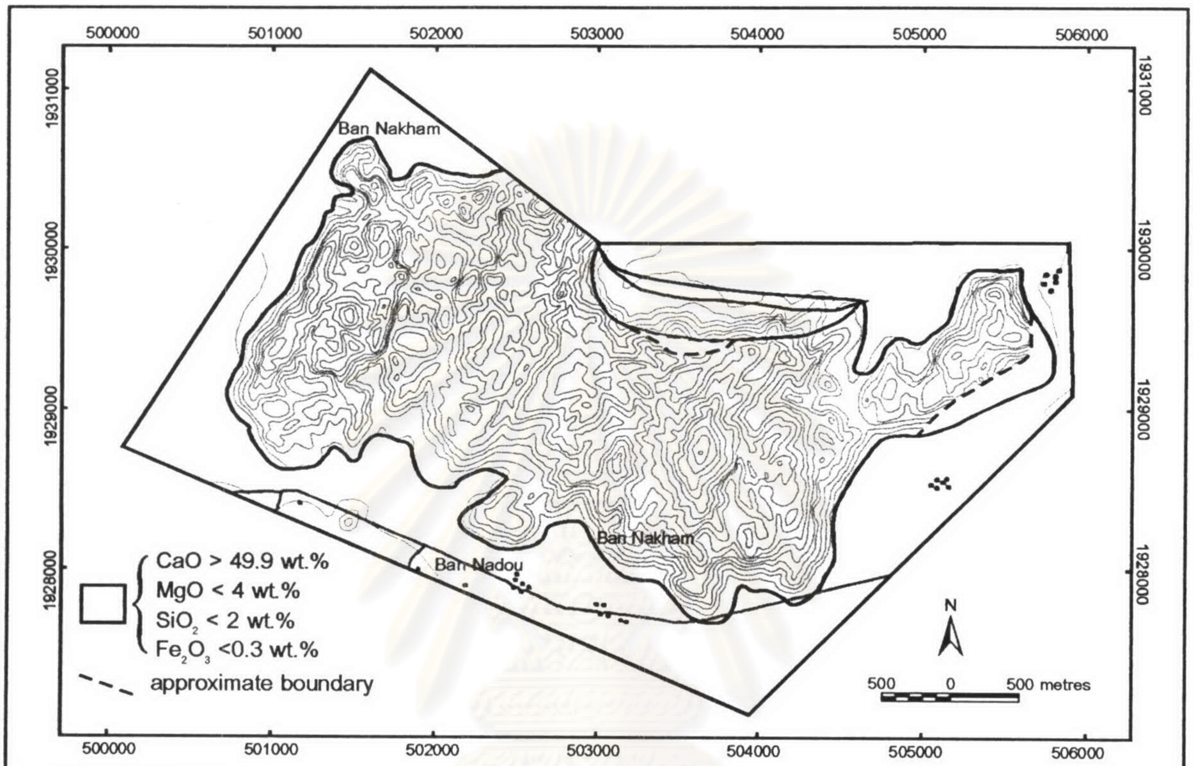

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Figure 4.11 Limestone quality resource map for ceramic (grade II)

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Table 4.17 Potential utilization for ceramic (grade II) of carbonate sediments in the present study.

Standard / Chemical Composition	Lorenz (1991) wt%	Rock unit C of the present study	
		average from 26 samples wt%	average from 74 samples wt%
$CaCO_3$	-	-	-
CaO	<49.9	54.01	54.79
MgO	<4	0.80	1.11
SiO_2	<2	0.60	0.27
Al_2O_3	-	0.28	0.15
Fe_2O_3	<0.3	0.1	0.06
P_2O_5	-	0.03	0.03
SO_3	<0.1	-	-
LOI	-	43.04	43.57

Sugar refining

Limestone and lime are used in the sugar industry as part of the purification process. The classification of limestone for sugar refining is specified based on standard from Technical Report WG /92/ 29, (Harrison, 1992). This specification is determined on chemical grade as follows: $CaCO_3$>96%, MgO<4%, Al_2O_3<0.35%, SiO_2<1%, Fe_2O_3<0.3%.(Table 4.18).

Table 4.18 Potential utilization for sugar refining of carbonate sediments in the study area.

Standard / Chemical Composition	Harrison (1992) wt%	Rock unit C of the present study	
		average from 26 samples wt%	average from 74 samples wt%
$CaCO_3$	>96	-	-
CaO	-	54.01	54.79
MgO	-	0.80	1.11
SiO_2	<1	0.60	0.27
Al_2O_3	<0.35	0.28	0.15
Fe_2O_3	<0.3	0.10	0.06
P_2O_5	-	0.03	0.03
LOI	-	43.04	43.57

The limestone which is suitably used for sugar refining consists of the rock unit C is mainly composed of light gray to brownish gray fine-grained very thick-bedded limestone with calcite veins and veinlets. It covers approximately 5 square kilometres.

The limestone quality resource map for sugar refining is presented in Fig.4.12.

4.4 Quantity of limestone resources.

The possible geological limestone resources have been calculated with program Surfur V. 6.04 which is commonly used for geological modeling as well as for mining design.

All the topographic data are issued from the digitization of regional 1:50.000 scale map, and the geological data are derived from the field work.

For the present study, the specific gravity used in the calculation has been fixed at 2.6 g/cm^3 and the geological safety factor of 30% due to the presence of some sinkholes.

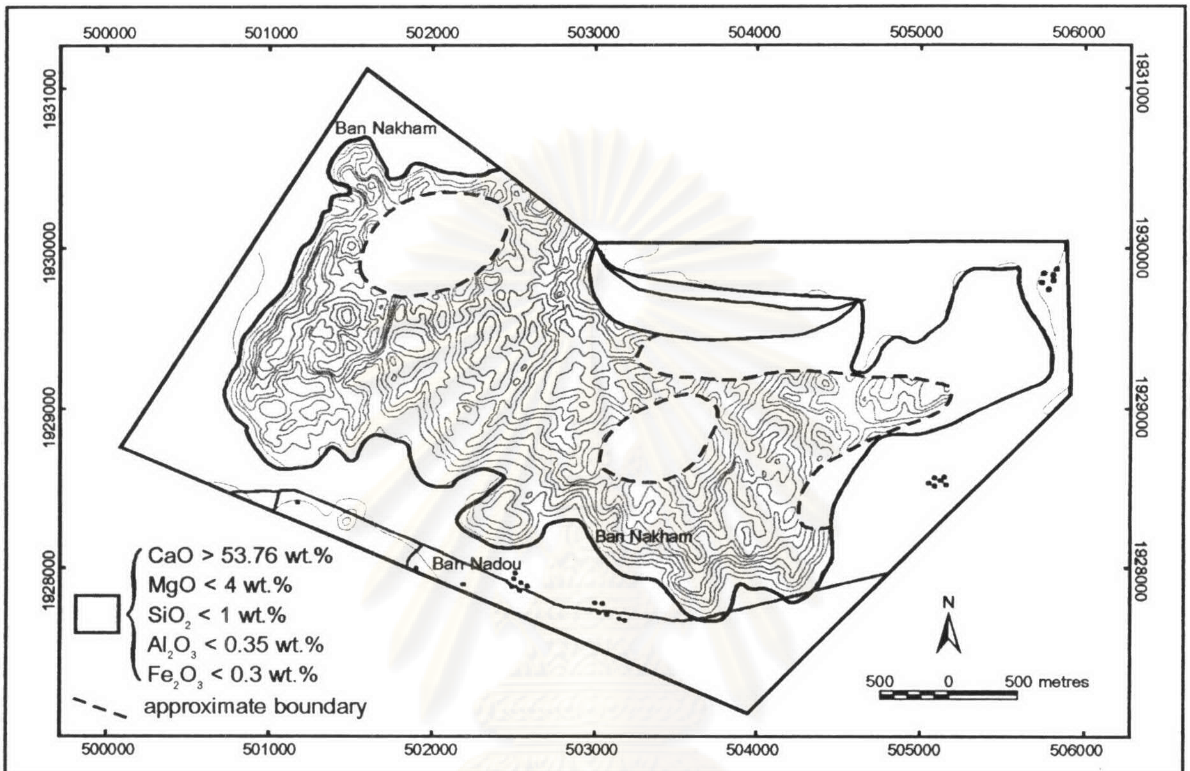

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Figure 4.12 Limestone quality resource map for sugar industry.

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The lower level of topographic map is calculated at160 metres (MSL) and upper level is at 480 metres.

The resources, which have been calculated for end-used limestone are shown in Table 4.19.

Table 4.19 End-used limestone resources of study area.

N°	Limestone	Resources (mill. cubic metres)	Resources (mill. metric tons)
1	Portland cement	531.51	1381.93
2	Quick lime	505.4	1314.04
3	Agriculture	531.51	1381.92
4	Ceramic, grade II	524.72	1364.27
5	Sugar refining	418.18	1087.26