Estimation of limestone deposits calcium carbonate source for industrial applications in some area of Lahej Governorate- Yemen

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DOI: https://doi.org/10.47372/uajnas.2020.n2.a10

Abstract

The area of the study is at Lahej Governorate, Yemen, which is about 110 km to the north from Aden**.**

Limestone deposits at the study area belongs to Amran Group of Jurassic Age. Three main formations composed Amran Group; Lower: Shugrah Formation, Middle: Madbi Formation and Upper:Nayfa Formation. Nayfa Formation is characterized by thickly bedded and massive limestones of which having between them ahigh quality, interestingly pure thick limestone, atdepths from nearly 40 m to75m, which is studied early by the National Company of Cement (NCC), at the areas ofWadi Faltah,Wadi Nakhleen and between Ar-Raqah and Wadi Asaq. These limestones are classified as high and very high pure limestones according to the results of chemical analysis, the spatial contour maps of percentages of $CaCO_3$ and CaO attributes. Limestone is considered as raw materials for proper industries. Accordingly, the limestones could be used for glass manufacture. High and very high limestone is the suitable for Soda ash manufacturing, for iron and steel industry.

Keywords: Geology, Chemistry, Purity, industrial application, Calcium Carbonate, Nayfa, Jurassic, Lahej Governorate.

Introduction

Limestone rocks are the main geological source of calcium in the form of chemical component known as calcium carbonate ($CaCO_3$), which arrive to 98%, slightly more or less, in general , Other chemical elements, such as magnesium , potassium , sodium , aluminum , ferruginous elements and titanium , are in little percentages .

Chemical specifications of limestones are important for many required industries where the calcium is the essential requirement. The purity of limestones is determined upon the percentage of calcium carbonate content ($CaCO_3$%), asindicated by the results of chemical analysis of limestone deposits. These results occur also in the form of calcium oxide percentage (CaO%), where the content of the purest limestone reaches 56%. Using these indices, counting limestones as a raw material for industrial requirements is done. Accordingly and upon the results of which having from chemical analysis for samples collected from limestone deposits in the study area extending from Ar-Raqah Wadi Nakhleen at the west to WadiMahaar at theeast. The preliminary outline purity assessment, quality and potentials of these deposits as raw materials for some required industries was estimated as the primary object of this study at first, in addition to the geological setting of the deposits of limestones at the study area.

Previous studies

The study area was part of the integrated regional geological mapping and mineral prospecting on scale 1:100000, carried out by Czechoslovakian team ,in the period 1981-1985 ,in the western part of the P.D.R. of Yemen .

Detailed works were done previously by the National Company of Cement (NCC); in parts geological works including mapping,sampling and drilling of bore holes were carried out in the area in the period 2001-2005 for cement production by the geologists of the Geological Survey and Mineral Resources Board /Aden .

Location of study area

The study area is located at Lahej Governorate, Yemen. It is extending between Ar-RaqahWadiNakhleen at theWest and Wadi Mahaar to theeast , about 110 km to north from Aden. It is connected by the asphaltic road of Aden – Sana'a at Almelah center of which the branch of asphaltic road to Jaar Abyan has begun, about 20 km south east to study area. Administratively, it is belonging to Almelah district. In UTM , international geographical position system is located between the coordinates 497850 to 510000 E and 1470000 to 1475000 N.

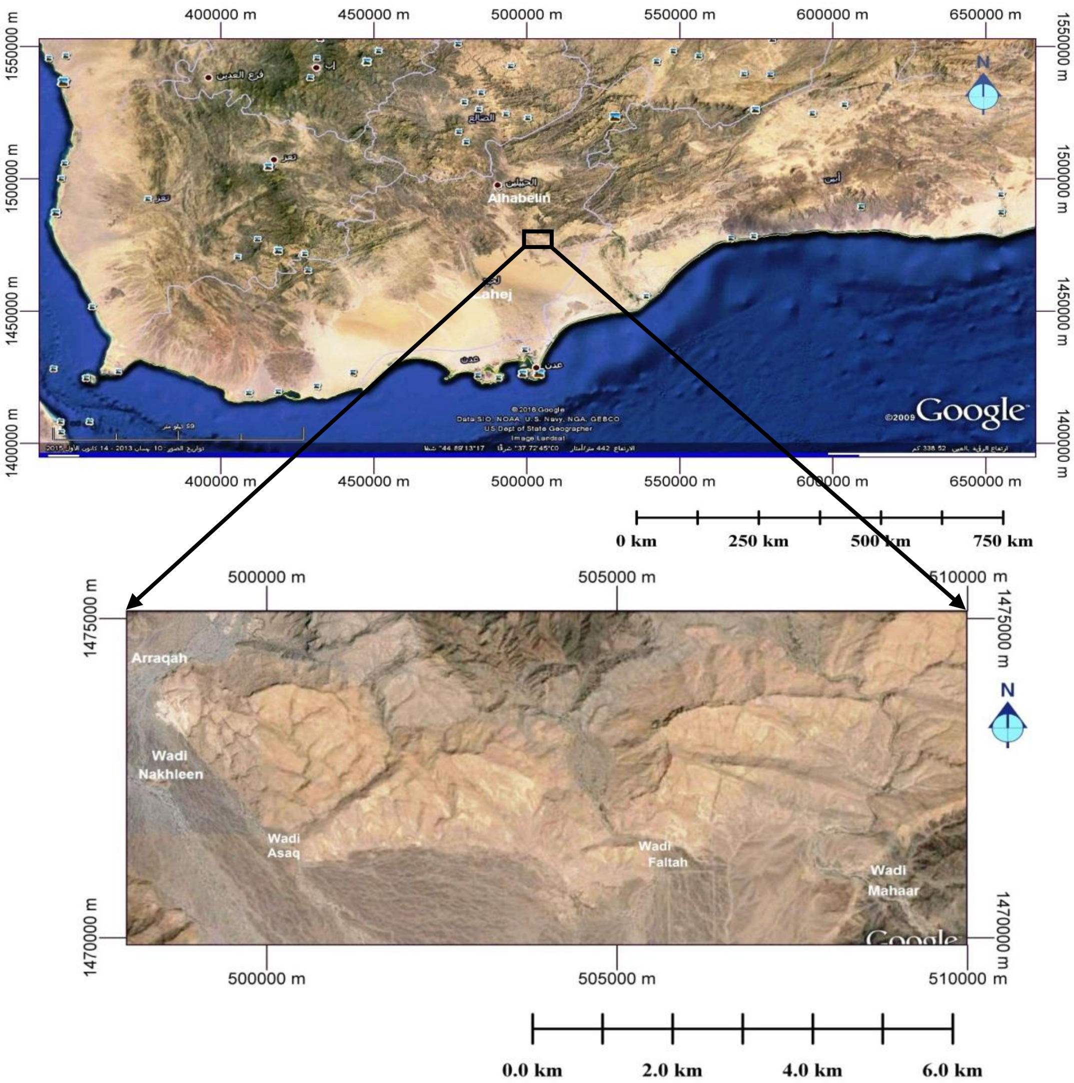

Fig. 1 : Location map of Lahej Governorate and surroundings - Yemen : study area at Almelah District [13].

Methodology and Objectives

Non-systematically areal distribution sampling from outcrop surfaces, some small sections, faults and wadi cuttings were the method applied in collecting, documentation and description. Borehole systematic sampling and description was done only in the areas of detailed works.

In the laboratory , the chemical full silicate analysis for the collected samples was done. The results are taken in this study were analytically and statistically processed , zoned and simplified for the best order of industry.

The main object of this study is to classify limestones of the study area according to its purity, which makes them of good potential for specified requirements for chemical industries. This can be viewed and outlined on a source map.

Brief Geology of the area

Rocks occurred as outcrop formations or exposures in the study area which extend in age from Proterozoic to Recent [3, 4, 9,10]. Proterozoic rocks occurred at small exposures north and south east of geological map (see fig. 2), metamorphic rocks of crystalline basement, mainly composed of gneisses, schists and amphibolites of different colors and textures, other minor components of metamorphics are there too. Crystalline basement rocks are belonging to Yaffa Group . These rocks are covered by overlaying sedimentary rocks of Jurassic age which belong to Amran group and composed of limestone deposits and marl interbeds, Limestone is the dominant and more extensive in the study area (east – west extending belt at the middle part of geological map fig. 2) . By tectonics and fault associated works, limestone rocks, generally form a monocline , and dipped in most to south and south west and bordered southerly and south west by two main fault systems, these faults generally take orientations east – west , north west – south east . Overlying the limestone deposits of Amran Group in stratigraphic position, occur the sandstones of Cretaceous age belonging to Tawillah Group ; it also occurs at small remnant form on limestone rocks at the eastern border of geological map (Fig. 2) near Wadi Mahaar and also outcropping at the south western corner of the map. To the south and south west area of the geological map represented by(Fig. 2), the younger Quaternary proluvial deposits of gravels and sandy gravels are the main cover of which the underlay Jurassic and Cretaceous rocks plunge.

Geology of limestone deposits

This study is concerned mainly on limestone deposits of Jurassic Amran Group , ideally Nayfa Formation, which takes its form as three main bodies characterized by J3nf sign at geological map(Fig. 2), these bodies are laterally separated by some wadis, named Asaq and Faltah (Fig. 1). All wadis crossed limestone bodies drain to the south.

The deposits of Jurassic Nayfa limestone are described at the field at several time visits , by the stratigraphic serial deposition as layers; noticed and classified as rock units according to its variability with depth . It occurs as layered rocks having variable thicknesses ranging from thinly bedded to thick and massive. Sometimes, these variable thicknesses appear alternated with small and thin interlayers of marl and shale, at the upper parts of these deposits the alternations of marl and marly limestone with thick and massive limestone are common. Geological cross section represents the position of limestone deposits at study area was drawn and presented at(Fig. 3).

Taking its variability as rock units, it can be classified from bottom to top as follows:

Limestone and shale- lower unit

Thinly bedded limestone , fine and fine to medium grained , dark grey, with interbeds of shale and calcareous shalylimestone ; this part of the unit forms the transition between Nayfa Formation with underlay Madbi Formation. Upper on this part the chalky medium to coarse grained , sparite limestone of light grey to cream color occurs , generally thick and massive , rich by microfossils and of cavernous character ; this part reaches up to 50 m thick, approximately. Overlay, other part of concretionalmarly limestone , coral massive limestone and cherty limestone layers are serially deposited with thickness of about 25 to 30 m

Oolithic and bioclastic limestone- middle unit

The fossil dominant represented the main character of this unit , the limestone series are generally thin, some thick , medium to coarse grained and light grey to beige , some layers rosy coloured also occur , up to 30 m thick.

Micritic limestone , marly limestone and marl- upper unit

Alternations of thin and thickly bedded limestone with shaly and marly layers. Other limestone beds are the main character of this unit, generally fine and fine to medium grained limestone (micritic) of grey and dark grey color . This unit of high thick series up to 50 – 70 m ;sometimes up to 100m ,but locally deposited form in some occurrences.

Sampling and chemical analysis Results

Unsystematic distribution method of sampling from outcrop surfaces was carried out. Some small geological sections, fault zones and Wadi cuttings was used in sample collection; sample size ranged from 4 – 5 kg in weight.

All samples are crushed , grinded, and pulverized to 0.07 mm grain size ,200 gm from each sample was taken for chemicall analysis . All samples were analyzed in the laboratories of Geological Survey and Mineral Resources Board /Aden.Atypical chemical analysis of limestones includes: CaO,MgO,SiO_2 ,Al_2O_3, Fe_2O_3, Na_2O, K_2O, P_2O_5, MnO, and S, F, Cu, Pb and Zn [5] . Full silicate analysis of 40 samples collected from limestone deposits at the area presented in Table No:1 ,including major oxides of CaO, MgO, SiO_2, Al_2O_3, Fe_2O_3, Na_2O, K_2O, SO_3, Mn and loss of ignition. A brief description of the chemical results of major oxides (wt%), for the limestones is given below :
The chemical composition of samples collected from Ar-Raqah village limestone denoted RAQ (11), characterized by contentes of CaO varying from 51.80 – 55.72 % (mean 54.81%), Fe_2O_3 mainly 0.2% (mean 0.2%), MgO 0.2-3.23% (mean 0.67%),K_2O from 0.015%-0.025% (mean 0.023), Na_2O from 0.18- 0.21% (mean 0.19%), SO_3 0.02-0.83% (mean 0.11%), Al_2O_3 0.12-0.25% (mean 0.09%),SiO_2 is not detected.

Samples collected from the area between Ar-Raqah village and Wadi Asaq, a total of 11 samples having the following results, and are denoted by RA.

The contents of SiO_2 from 0.35-1.45% (mean 0.9%), CaO 53.5-54.9% (mean 53.951), Fe_2O_3 from 0.4-1.6% (mean 0.8%), MgO 0.2-2.42% (mean 0.79%), K_2O 0.03-0.06% (mean 0.04%), Na_2O 0.1-0.13%) mean (0.11%), SO_3 0.03-0.28% (mean 0.21%).

The samples of WadiAsaq (Asq) limestone, a total of 13 samples analyzed having the following , SiO_2 from 0.13 -0.75%) (mean 0.271%),CaO 54.04-55.72% (mean55.17%), MgO 0.2-0.81% (0.28%), K_2O 0.03-0.08% (mean0.04%) , Na_2O 0.21- 0.23% (mean 0.21%), SO_3 0.02-0.16 % (mean 0.04%).

Five samples from WadiFaltah denoted FTH contained : SiO_2 varying from 0.25-0.5% (mean 0.2%), CaO 54.32-55.44% (mean 54.82%) , Al_2O_3 0.2-1% (mean 0.2%), MgO 0.1-0.4% (mean 0.24%), K_2O 0.03-0.08% (mean 0.04%), Na_2O 0.21-0.23% (mean 1.88%), SO_3 0.06-0.2% (mean 0.08%) .

As a result of chemical analysis ,it is obvious that the content of CaO greater than 55.2% is found within the extent of Ar-Raqah –W.Saq and W.Faltah, from 51.8-55.72% is distributed in both areas. with less amounts or negligble of content Al_2O_3,MnO, Fe_2O_3 and SiO_2.The limestones could be classified as very high to medium purity, rarely low purity of calcium carbonate, as indicated in Table No 2.

Many industrial applications of limestone impos constrains on the levels of specific impurities (such as SiO_2,MgO and Fe_2O_3), and therefore chemical analysis of limestone raw materials are necessary to assess its grade . However, the carbonate content of limestone is fundamental in most industrial uses and a simple laboratory method for determining this component is a valuable procedure for determining its chemical purity. Ideally, the method should be rapid, simple, accurate and capable of giving reproducible results[7].

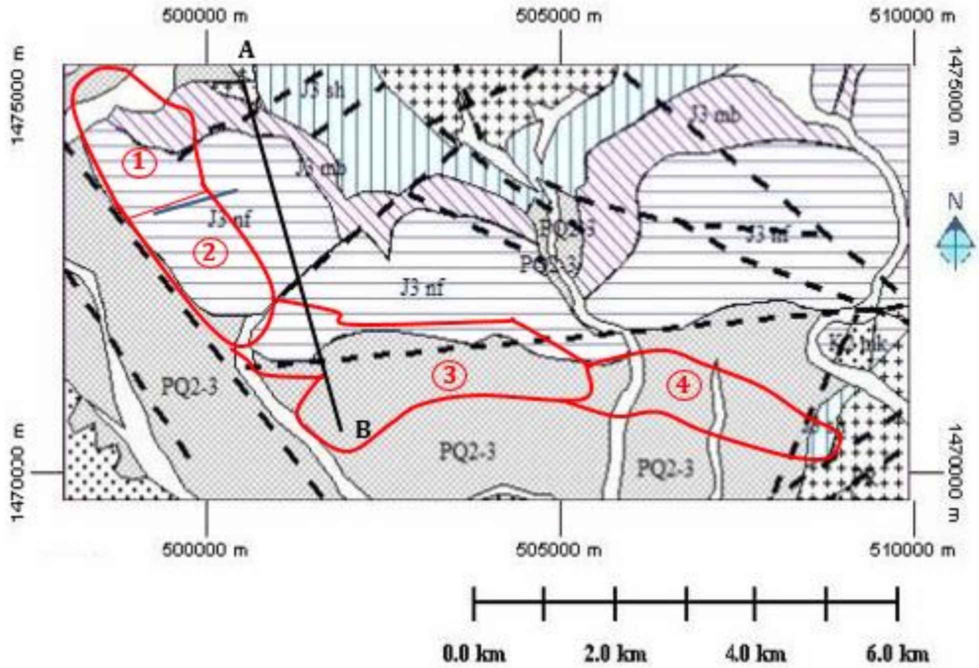

Fig.2: Geological map of study area [3,4,13,10,].

LEGEND

Concealed faults.

Major location of study area: 1. RAQ – Ar-Raqah village. 2. R-A- Ar-Raqah village-W.Asaq. 3. ASQ - W.Asaq. 4. FTH - W.Faltah.

Line of geological cross- section (fig 3.).

Recent: wadi sediments at channel wadis, clays, Silt & sand.

PQ 2-3 :Proluvial quaternary deposits, gravel & sand.

K2 mk :Cretaceous Sandstone, Mukalla formation.

JURASSIC AMRAN GROUP

J3 nf :Limestone, marl & marly limestone, fossiliferous, lower part with thin shale interlayers Nayfa formation.

J3 mb :Limestone, marl and marly limestone with sandstone interlayers, Madbi formation.

J3 sh : Thinly bedded limestone, bituminous, Shqrah formation.

Proterozoic rocks, gneisses, schists and amphibolites.

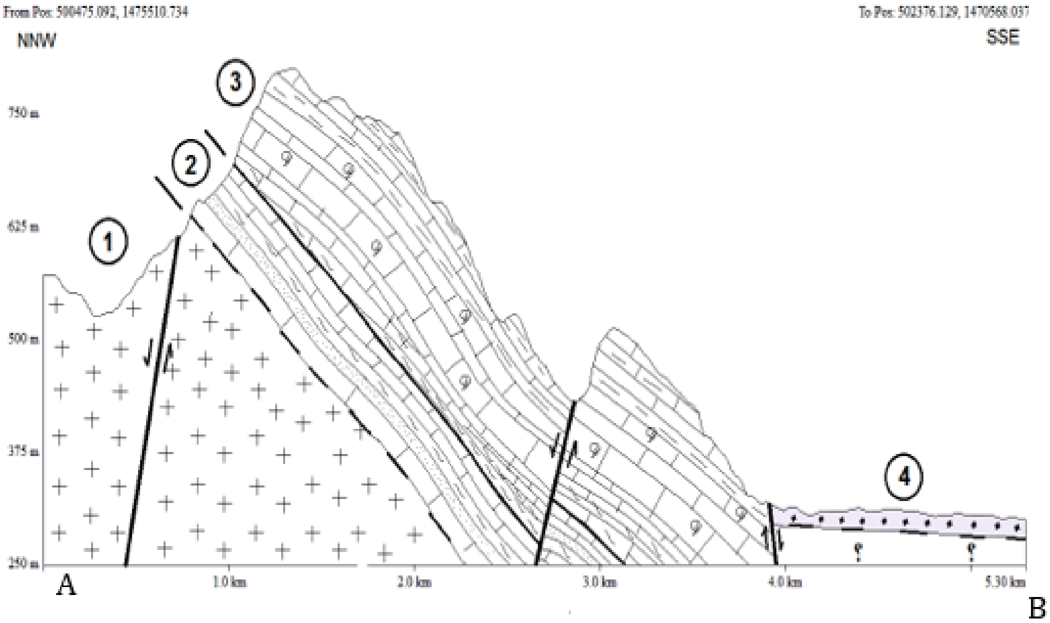

Fig. 3: Geological cross section represent position of limestone deposits overlaying basement rocks and dipping to south in general.

LEGEND:

Fossils.

Faults.

Unconformity.

4 Proluvial quaternary deposits, gravel & sand.

3 Limestone, marl & marly limestone, fossiliferous, lower part with thin shale interlayers Nayfa formation .

2 Limestone , marl and marly limestone with shale & sandstone interlayers, Madbi formation.

1 Proterozoic rocks, gneisses, schists and amphibolites.

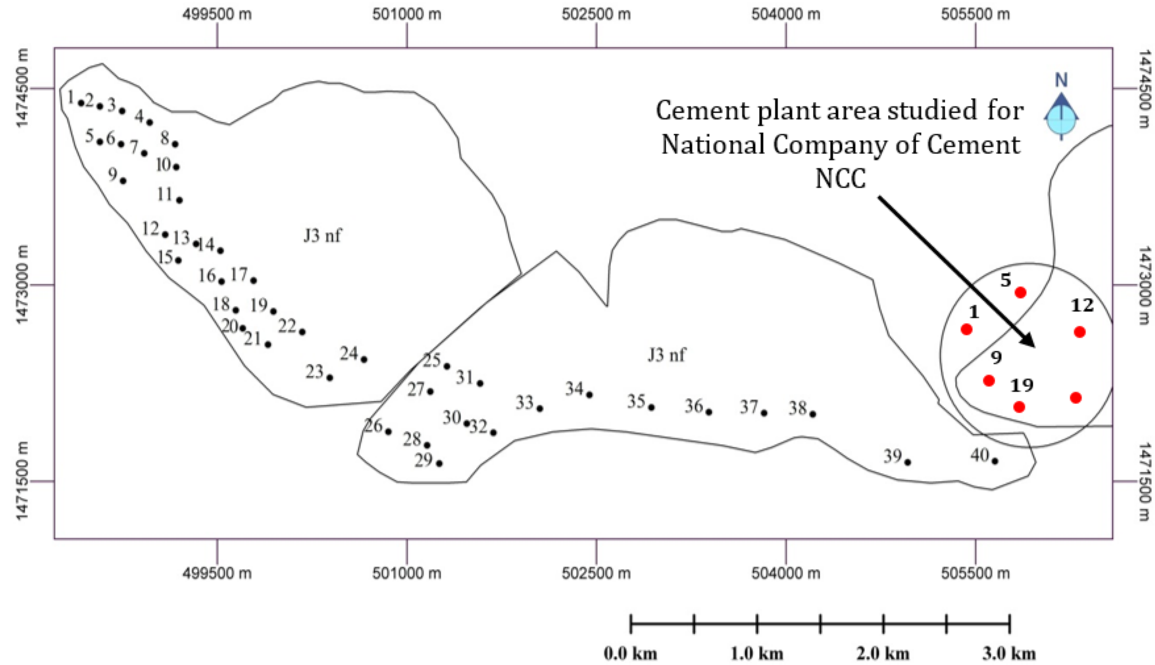

Fig. 4: Sample location map of study area ,using serial number of Table 1.

LEGEND:

- Serial number of the samples and its location.
- Location of bore holes.

Table No 1: Results of chemical analysis of limestone samples from study area ,After geological, Survey & Mineral Resources Board of Aden [14].

Ser. No.	Sample No.	CONTENT % AFTER DRYING THE SAMPLES AT 110° C										
		SiO_2	$Al_2 0_3$	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	SO_3	L.O.I.	Sum
1	RAQ-1	0.00	0.25	0.2	-	55.44	0.2	0.025	0.18	0.05	42.78	99.13
2	RAQ-2	-	0.12	-	-	55.44	0.2	0.025	0.19	0.02	42.11	98.11
3	RAQ-3	-	-	0.2	-	55.44	0.2	0.025	0.21	0.04	42.72	98.84
4	RAQ-4	-	-	0.2	-	55.16	0.51	0.025	0.19	0.83	42.95	99.07
5	RAQ-5	-	-	0.2	-	55.44	0.2	0.025	0.19	0.07	43.04	99.17
6	RAQ-6	-	-	0.2	-	55.44	0.2	0.025	0.19	-	42.14	98.20
7	RAQ-7	-	-	0.2	-	55.72	0.2	0.025	0.2	0.08	42.43	98.86
8	RAQ-8	-	-	0.2	-	53.2	1.92	0.025	0.21	0.06	43.04	98.66
9	RAQ-9	-	0.12	-	-	55.44	0.2	0.015	0.18	0.04	42.51	98.51
10	RAQ-10	-	0.25	0.2	-	51.80	3.23	0.015	0.19	0.1	43.33	99.12
11	RAQ-11	-	0.25	0.2	-	55.16	0.4	0.025	0.19	0.03	42.43	98.69
12	R-A-1	0.9	-	1.2	-	54.3	0.61	0.04	0.11	0.08	42.06	99.3
13	R-A-2	0.62	-	1.6	-	54.04	2.42	0.04	0.12	0.11	42.62	101.5
14	R-A-3	1.0	-	0.4	-	53.5	0.61	0.03	0.11	0.13	42.72	98.5
15	R-A-4	1.17	-	0.8	-	53.8	0.61	0.06	0.13	0.08	42.52	99.17
16	R-A-5	1.11	-	0.8	-	53.8	0.61	0.03	0.12	0.4	42.62	99.49
17	R-A-6	1.17	-	0.8	-	53.8	0.61	0.03	0.13	0.28	42.57	98.39
18	R-A-7	0.72	-	0.4	-	54.6	0.2	0.03	0.1	0.04	42.47	98.56
19	R-A-8	1.45	-	0.4	-	53.8	0.61	0.05	0.11	0.07	42.52	99.01
20	R-A-9	0.35	-	0.8	-	53.5	1.4	0.05	0.11	0.03	42.61	98.85
21	R-A-10	0.74	-	0.8	-	53.5	0.81	0.05	0.12	0.6	42.44	98.52
22	R-A-11	0.67	-	0.8	-	54.9	0.2	0.04	0.1	0.5	42.57	99.33
23	ASQ- 1	0.25	0.2	-	-	55.16	0.4	0.03	0.21	-	42.44	98.69
24	ASQ- 2	0.25	0.2	-	-	55.16	0.4	0.03	0.23	0.16	42.78	99.21
25	ASQ- 3	-	0.2	-	-	55.72	0.2	0.05	0.23	-	42.62	99.02
26	ASQ- 4	0.5	0.2	-	-	55.16	0.4	0.03	0.21	0.04	42.62	99.16
27	ASQ- 5	0.5	0.2	-	-	55.72	0.2	0.03	0.23	-	42.60	99.08
28	ASQ-6	0.25	0.2	-	-	55.16	0.4	0.03	0.22	0.05	42.35	98.66

Table 1: Continued.

Ser. No.	Sample No.	CONTENT % AFTER DRYING THE SAMPLES AT 110° C										
		SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	Mg O	K_2O	Na_2O	SO_3	L.O.I.	Sum
29	ASQ-7	0.25	0.2	-	-	54.04	0.4	0.1	0.22	0.08	42.12	98.95
30	ASQ-8	0.13	0.2	-	-	55.44	-	0.05	0.21	0.07	42.15	98.25
31	ASQ-9	0.13	0.2	-	-	55.72	0.2	0.05	0.21	-	42.95	99.46
32	ASQ-10	0.75	0.2	-	-	55.44	-	0.05	0.22	0.06	43.00	99.72
33	ASQ-11	0.13	0.2	-	-	55.16	-	0.05	0.21	0.05	43.02	98.82
34	ASQ-12	0.25	0.2	-	-	55.30	0.3	0.05	0.21	0.03	43.02	99.3
35	ASQ-13	0.13	0.2	-	-	54.04	0.81	0.05	0.21	0.02	43.11	98.0
36	FTH-1	-	0.2	-	-	54.32	0.4	0.05	0.21	0.01	42.48	98.03
37	FTH-2	-	0.2	-	-	54.46	0.1	0.08	0.21	0.07	42.89	98.01
38	FTH-3	0.5	0.2	-	-	54.6	0.4	0.03	0.16	0.06	42.83	98.87
39	FTH-4	0.25	0.2	-	-	55.30	0.1	0.03	0.18	0.06	42.52	97.64
40	FTH-5	0.25	0.2	-	-	55.44	0.2	0.03	0.18	0.2	42.89	99.39

Assessment of chemical-grade and classification of the limestone of study area

The determination of carbonate content can then be used to classify chemical – grade limestones (Coxetal. 1977) (9) (Table 2). Such a definition of chemical purity is relatively simple and can be easily used to illustrate the distribution of limestone purity on a map. The classification is also suitable for comparison of chemical data for limestones of different geological origins,(Table 3) on page 18 gives a good example [6].

Table 2: Classification of limestones by calcium carbonate content [9,10]

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

Focusing on $CaCO_3$ percentages resulted from the chemical analysis of the samples from limestones of study area , of which equal the summation of CaO& L.O.I., and using Tables 2 and 3 as a guide for classification, the results are compared, classified and used as an index to estimate the potential of high purity limestones at the study area. Accordingly,the source map of limestone deposits as raw materials for therequired industry based on purity potential as reliable, as is drawn.

Spatial distribution map of the percentages of $CaCO_3$ on limestones of study area was drawn and presented in Fig. 5, It can be seen clearly the variety of distribution according to the content of $CaCO_3$ percentages. Refering back to Table 2 as a guide, the very high pure limestones are spotted on the area at wadiAsaq by a value of 98.506% and locally surrounding this value a contour line of 98.6% also of very high pure limestone. High pure limestones of $CaCO_3$% between 97.0 – 98.5 occurred largely at the area surrounding wadiAsaq and local on the north west of the map Fig. 5 near Ar-Raqh village at wadiNakhleen , these areas bordered by heavy line in Fig. 5. Areas of medium purity limestones of which $CaCO_3$% between 93.5 and 97.0 are bordered by dissected heavy line.

The National Company of Cement (NCC) also studied the limestones at the area near wadiFaltah[1], the area is marked by a circle in Figs. 4 , 5 and 6 . Reviewing the study of NCC, it can be seen that chemical analysis of core samples from boreholes drilled for study could explain great variety of limestones with depth, mostly of low purity limestones, except the limestones at the interval of depth between 40 to 75 m are near high to medium purity limestones . These limestones are described as chalky and crossed by some boreholes [1,2] , typically on borehole numbered on study of NCC by No. 22, in this borehole $CaCO_3$ percentage averaged 97.8 at depth from 47.4 to 76.4 m , at this average value the limestones of high purity, whereas other borehole numbered 19 takes average of 96.5 for $CaCO_3$% of which medium pure[1].

Using CaO percentage, the spatial distribution map was drawn and presented in Fig. 6, the distribution shows $CaCO_3$% . According to Table 2, limestones have CaO % greater than 55.2 % clearly occurrs at wadiAsaq and surroundins, with highest value of 55.698 % and at the corner part of limestone deposit near Ar-Raqah village north west of the spatial distribution map of CaO percentage Fig. 6; these main two areas of high and very high purity limestones, according to CaO percentage (>55.2%), are clearly distinguished at Fig. 6. Contour lines represent CaO percentages in the areas at the sides bordering high and very high purest ones are having values of which categorized of medium purity limestones.

Although the spatial forms of $CaCO_3$ and CaO percentages are like the same to occur, the slight differences are there, especially in the areas between and surrounding the main two areas of high and very high purity limestones; these differences occur due to heterogeneity of CO_2 contents.

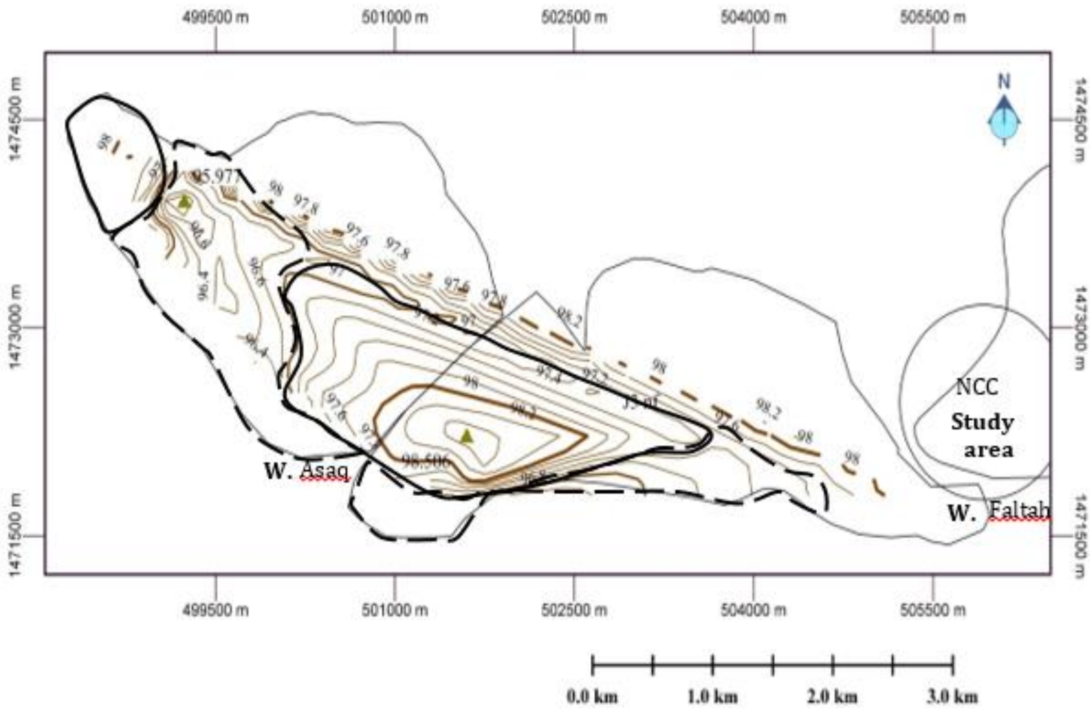

Fig. 5: Spatial distribution contour map CaCO3 percentages for limestone deposits of study area

LEGEND

Isohyets contour lines represent $CaCO_3$ %.

Spot inform highest (98.506) and lowest (95.977) values of CaCO3% in the area

Border line of areas estimated as of high & very high purity limestones.

Border line of areas estimated as of medium purity limestones.

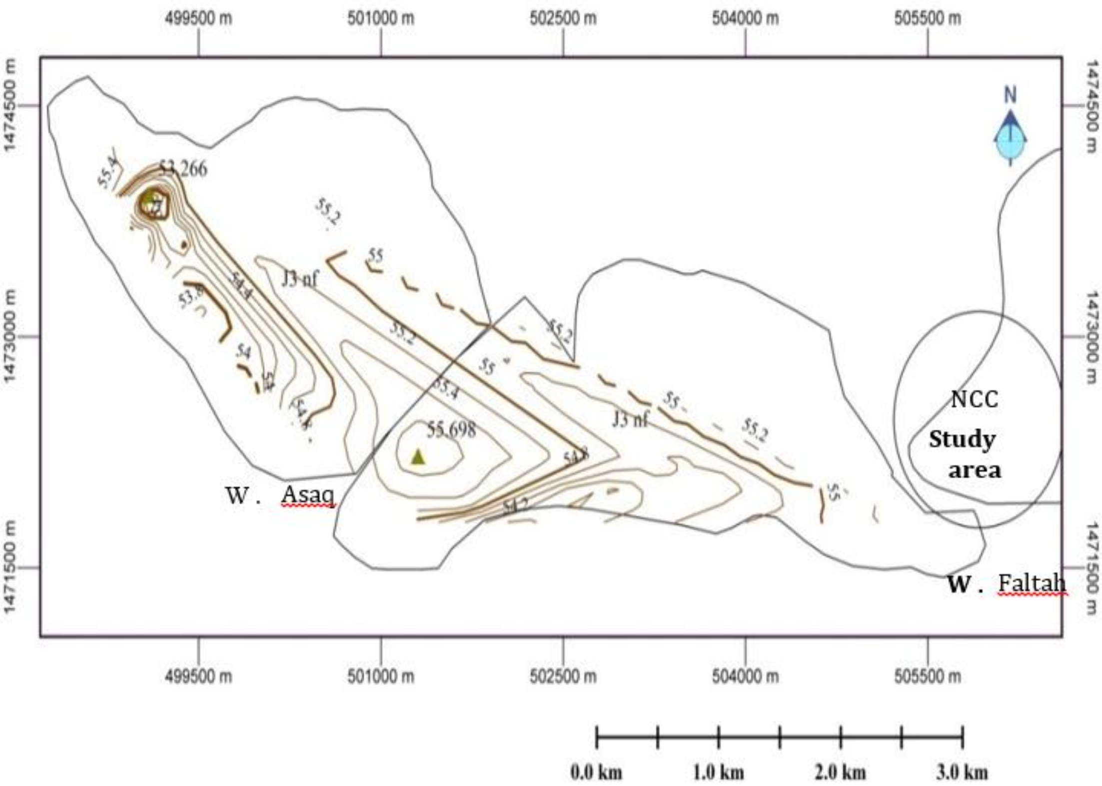

Fig. 6: Spatial distribution contour map CaO percentages for limestone deposits of study area

LEGEND

Isohyets contour lines represent CaO %.

Spot inform highest (55.698) and lowest (53.266) of CaO % in the area.

Potential appraisal for high grade limestone for industrial applications

Although the primary use of carbonate rocks is in construction, as aggregate or in the production of cement, they are also extensively used in iron and steel industry, the chemicals industry, the manufacture of glass and in many more specialized uses. In these non – constructional or ' high purity ' applications, limestone (or lime) may be used either as a chemically – reactive raw material or as an inert filler or pigment. So, limestones, especiallyare high and very highly pure, used, or have potential used, in a wide range of industrial applications including glass manufacture, production of soda ash, sea water magnesia, sugar refining, iron and steel industry and high grade fillers[1]. For the purposes of industrial applications , the following chemically classificationscan be mentionedfor the limestonesto become suitable for the purpose. For glass manufacture, in particular, amounts of impurities which may color the glass such as iron (varies from <0.05 to <0.02% depending on the type of glass), generally, very high purity limestones (>98.5% $CaCO_3$ or 55.2% CaO) are required for this application. For soda ash manufacture, the lime and carbon dioxide consumed in the process are obtained by calcining limestone, which should be of high purity (<98.5% $CaCO_3$). For sea water magnesia, typically specifications demand low SiO_2 (<0.15%), Al_2O_3 (<0.05%) and Fe_2O_3 (<0.15%). On sugar refining , high grade limestone containing at least 96% $CaCO_3$ and <1% SiO_2, <0.35% Al_2O_3 and <0.3% Fe_2O_3 is usually specified. Lime is also used as a flux in the steel industry and is required to remove silica and phosphorus from pig iron, specifications demand high purity limestone with low silica (less than 1% to 0.25%) and sulphur (less than 0.1%), particle size, surface area and density of the lime are also important. Limestone powders are extensively used as fillers or pigments in a diverse range of industries, specifications for limestone powders used as fillers in paper, plastics and paints typically require closely controlled particle size distribution and high brightness values[6].

According to the specifications mentioned above and reviewing the results generated from chemical analysis of samples from limestones of study area (Table 1), we can deduce the link between these results and industry require as follows ; for glass manufacture, the limestones of very high purity in the study area are suitable, the iron contents isn't contained within the chemical results of samples covering the area of very high pure limestones (samples from ASQ-3 to ASQ- 9 of which serially numbered from 25 to 31), but in considering the Fe_2O_3% of much samples surrounding, which generally take 0.8% (generally greater than specific requirement of which between <0.05 to <0.02%), Accordingly, these impurities may occur, so the source for colored glass manufacture requirement is regarded and probable. Soda ash manufacture requires the suitable high and very high pure limestones within the area. Most limestones of the study area aren't suitable for sea water magnesia according to high aluminum content impurity. For sugar refining silica and aluminum contents is very high than the specified requirements.As well as iron and steel industry, limestones of study area of high and very high purity are possible. Using limestones from study area as powders for fillers in paper, plastics and paints aren't regarded, in the domain of these applications; more investigations of which the closely controlled particle size distribution and high brightness values are typically required.In this reform the tests and investigations wasn't done.

Table 3: Chemical analysis of high - purity limestones.(Comparative analyses)

Wt.%	Derbyshire, UK[13] Bee Low Limestones	North Pennines, UK[13] Malham Formation	Guanacaste, Costa Rica[14] Barra Honda Limestone
CaO	55.09	55.54	55.71
MgO	0.37	0.26	0.21
SiO_3	0.64	0.26	0.04
Fe_2O_3	0.05	0.08	0.05
Al_2O_3	0.11	0.13	0.02
Na_2O	0.00	0.01	0.00
K_2O	0.02	0.05	0.00
P_2O_5	0.02	0.01	0.02
MnO	0.02	0.01	0.00
SO_3	0.18	0.02	0.03
Loss	43.44	43.40	43.70

High purity limestoneisn't required incement industry , medium and low purity limestones are suitable as raw materials , while, impurities in the raw materials may affect the quality of cement including magnesium, fluorine, phosphorus, lead, zinc, alkalies and sulphides. Most national specifications for ordinary Portland cement require that the cement should not contain more than 6% MgO (less than 3% in the limestone). Other chemical specifications may limit SO_3 and P_2O_5 to less than 1% and total alkalies to less than 0.6%. Additional specifications may be applied to specialty cement types, such as sulphate – resisting cement, oil – well cement and white cement (less than 0.01% Fe_2O_3)[6].

Conclusions

- Limestone deposits at the study area belong to Amran Group of Jurassic age. Nayfa formation is characterized by thickly bedded and massive limestones of which having between them an interestingly pure limestones. Limestone thickly and massive bedded of chalky main character is marked by the light color of cream to white , slightly hard and compact. These limestones occur at depths from nearly 40 m to 75m at WadiFaltah of which the limestone was studied for the National Cement Company (NCC).
- Limestone deposits classified as high and very high pure limestones according to the results of the chemical analysis are done for the samples collected from Ar-Raqah,Asaq,WadiFaltah and WadiMakhleen (40 samples). Most other limestones in the study area are of medium purity.
- According to the sampling method adapted(unsystematic distribution) and the results of the chemical analysis, the spatial contour maps of the percentages of $CaCO_3$ and CaO attributes were produced . Limestone deposits are characterized and classified into subareas according to their purity character.
- The limestones of very high purity are suitable for glass industry, but the high contents of iron mayoccur , of which colored glass manufacture is applicable .
- High and very high pure limestones is suitable for soda ash manufacture .
- For iron and steel industry, limestones of high and very high purity are possible.
- Limestones are not suitable for sea water magnesia production due to high aluminum content impurity.
- Using Limestones for plastics ,paints and powders.
- Using Limestones from study area as powders for fillers in papers, plastics and paints require more investigations to determine, particle size and brightness values.

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تقييم رواسب الحجر الجيري كمصدر لكربونات الكالسيوم ومدى ملائمتها للصناعة في بعض مناطق محافظة لحج – اليمن

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DOI: https://doi.org/10.47372/uajnas.2020.n2.a10

الملخص

أثبتت الدراسات وجود كميات كبيرة ذات نوعية جيده من صخور الحجر الجيري التي يمكن استخدامها في صناعات متعددة. من خلال الدراسة التي اجريت على التوضعات التابعة لتكوين نايفه من مجموعة عمران المنتمية للعصر الجوراسي المتوضعة في المنطقة المنحصرة ما بين قرية الرقة– وادي نخلين غربًا ووادي مهار شرقًا في محافظة لحج، تبين أن طبقات الحجر الجيري النقي تكون صلبه، متماسكة، دقيقة الحبيبات، بيضاء اللون، حاويه على المستحاثات ومختلفة السماكة من موقع لآخر.

تم تنفيذ بعض الدراسات الجيولوجية المختلفة التي شملت حفر عدة آبار تتراوح أعماقها بين 40-65 مترًا، مع الأخذ بعين الاعتبار جمع العينات الصخرية السطحية واللبية للدراسات الكيميائية.

أظهرت التحاليل الكيميائية أن نسبة أكسيد الكالسيوم في الصخور تتراوح بين 51.8-55.64 %. يتواجد الحجر الجيري بدرجات نقاوة مختلفة تتراوح من عالي النقاوة إلى متدني النقاوة التي يمكن استخدامه في العديد من الصناعات اعتمادًا على خصائصه الكيميائية والفيزيائية، مثل صناعة الاسمنت العادي والاسمنت الأبيض او كمواد مالئه في صناعة الدهانات، وتنقية الغازات، وكذلك صناعة الأعلاف، الصودا الكاوية، صناعة الزجاج الأبيض والملون بالإضافة إلى كونه أحد مدخلات صناعة الحديد، وهي صناعات اساسيه للتنمية الاقتصادية.

الكلمات المفتاحية: جيولوجيا، كيمياء، النقاوة، الصناعية، كربونات الكالسيوم، تكوين نايفه، العصر الجوراسي، محافظة لحج.