Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 22 (2016) 211 – 218

Procedia Technology

9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu-Mures, Romania

Geochemical Assessment of Limestone for Cement Manufacturing

Noureddine Bouazza[a,]*, Abdelaziz El Mrihi[a], Ali Maâte[a]

[a]*Department of Earth Sciences, Faculty of Sciences of Tetouan, P.B 2121, Mhannech II, 93002, Tetouan, Morocco*

Abstract

The El Mashar Unit of Triassic-Quaternary successions from limestone deposit of Cement Lafarge quarry (North, Morocco) is characterized by the occurrence of several sedimentary rocks. This study, based on chemical composition of more than 1600 samples of drill cuttings provides insight into the chemical parameters controlling the use of limestone in cement making. El Mashar formation can subdivided into twelve facies based on the chemical composition and geological position of different lithostratigraphic successions, being: dolomite Triassic limestone, Rhaetian limestone marl, Hettangian nodular limestone, Hettangian limestone with low magnesium, Hettangian limestone with silica, Hettangian limestone with high magnesium, Sinemurian brecciated limestone, basal Sinemurian limestone, central Sinemurian limestone, sommital Sinemurian limestone, Eocene marl and Quaternary topsoil. This study documents the importance of geochemical assessment of limestone for cement manufacturing.

Keywords: EL Mashar Unit; geochemistry; limestone; cement.

1. Introduction

Limestones are one of the most important of all the sedimentary rocks. Limestones are composed mostly of the mineral calcite ($CaCO_3$). They may also contain some other carbonates minerals and several non-carbonate impurities. Limestones are the raw materials widely used by throughout industry, although the limestone is the first raw materials for cement making industry where chemical properties are important. Portland cement is produced by

* Corresponding author. Tel.: +212-656-595-118; fax: +212-539-994-500.
E-mail address: bouazzanor@yahoo.fr

doi:10.1016/j.protcy.2016.01.046

calcining finely ground raw meal consisting of a mixture of about 75% limestone and 25% of clay, at about 1450°C in a rotary kiln to form a calcium silicate clinker which is then ground and mixed with a small amount of gypsum which acts as a setting retardant. The compositional chemistry of cement depends largely on geochemistry of its raw materials, i.e., limestone. Approximately 75% of the cement's raw material consists of lime (CaO)-bearing material [1]. Representative sampling of the raw materials used to make Portland cement [2], Chemical Study of the Raw Material [3-5], Raw mix designing [6], correct calculations for the possible clinker mixtures, sufficient reserves of the raw materials and selection of the correct infrastructure for the location of a cement factory [2], are essential to the protection of the great investment in the factory. The Moroccan cement industry is a major player in the development of the country because growing needs for cementing products for the construction of buildings and communication infrastructures are considerable. According to the specifications of the Moroccan standard NM 10.1.004 [7], Portland cement clinker is a hydraulic material which must be composed of at least two-thirds by mass of calcium silicate [$(CaO)_3.SiO_2$], [$(CaO)_2.SiO_2$], containing the remaining part of iron oxide (Fe_2O_3), aluminum oxide (Al_2O_3) and other oxides. The mass ratio (CaO)/ (SiO_2) should not be less than two. The magnesium oxide (MgO) must not exceed 5% by mass. Evaluation of limestone deposits for cement manufacturing involve study of the geological setting and determination of the physical, mechanical, mineralogical and chemical properties of the stone. However, the content of limestone is fundamental in cement making, although geochemical assessment should, therefore begin with an initial field investigation involving field mapping, section measuring and sampling. In this paper we evaluate the geochemical contents of majors oxides in limestones from northwest Tetouan (Morocco) in order to assessment their suitability for use in the cement manufacturing.

2. Geology

The study area is a limestone quarry of the cement plant in at Tetouan, north of Morocco located near the Saddina village, and belongs to El Mashar Unit of the Dorsale Calcaire Complex (Fig. 1a). Earlier researches have provided a first geological background on these rocks, established the first geological maps and defined all units in the calcareous ridge [8]. Later, research work was mainly focused on sedimentology, biostratigraphy, depositional environments of the dolomitic, calcareous successions and structural geology [9-11].

El Mashar Unit displays a stratigraphic succession mainly made of: Triassic dolomite followed by Rhaetian marl-limestone alternations and dolomitic, which are covered by Hettagian massive limestones, followed by Sinemurian thin-bedded cherty limestone succession overlying the external platform and finaly topped of siliciclasticmarls, conglomerates and Eocene-Oligocene breccias and quaternary topsoil (Fig. 1b). Many tectonic structures such as faults and folds are clearly visible in the El Mashar Unit well as numerous structures to small dimension such as fractures and folding. The average dip of the stratigraphy (Sinemurian, Hettangian and Rhaetian) is about 45 degrees to the northeast; its direction is 140 degrees north. The sedimentary formations in the study area are represented by two distinct scales separated by a major tectonic thrust. The sedimentary formations of El Mashar deposit, is in places, covered with topsoil exceeding 2 meters thick. Also the Karstic structures characterize the surface of these formations which often extend to a depth of over 20 meters especially in the Hettangian limestone. These karst structures are frequently filled with clay sediments. However, the volume of karstification is very difficult to assess in this deposit. We can also see that the sedimentary formation represented in the deposit of El Mashar was strongly affected tectonically. Since few studies have attempted the geochemical assessment of limestone from The Haouz Dorsale Calcaire, the goal of this research is first to determine if discrimination between different bedrock is possible, using geochemical analyses samples. Consequently These limestone formations has been assessed to elaborate their geochemical characteristics.

3. Methodology

More than 1600 drilling limestone samples were collected at different stratigraphic levels along the sampled stratigraphic succession of El masher Unit (Fig. 1a). The samples collected during field work were taken to laboratory for treatment and standard laboratory preparation prior to analysis. Geochemical analysis of major elements was done using an X-Ray Fluorescence Spectrophotometer (XRF) at the Portland Cement LAFARGE factory Laboratory, Tetouan. Analytical precision is better than 3% for the major oxides. Total iron was expressed as

Fe_2O_3. Total loss on ignition (L.O.I.) was determined after heating the samples for 3h at 900°C. The geochemical results are presented in Table 1.

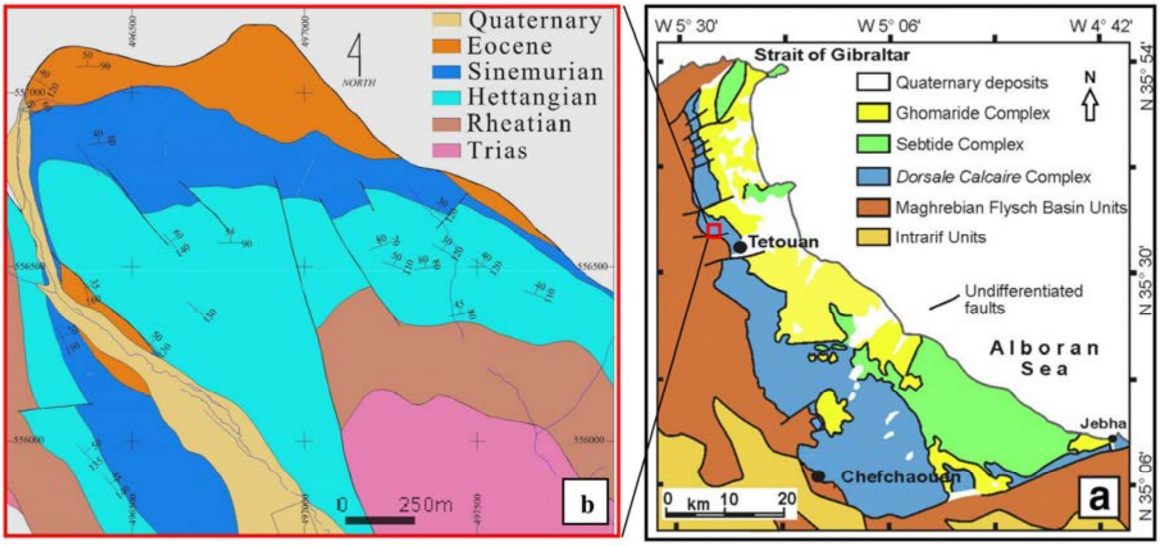

Fig. 1. (a) Schematic geological map of northern Rif showing the study area (from [9]); (b) geological map showing stratigraphic succession of El Mashar Unit (study area).

4. Results and discussion

4.1. Chemical compositions of limestone

On based in SiO_2 and MgO contents for Traisic, Hettangian, Sinemurian , nine types of rocks (F_3 to F_{10}) characterized by different chemical composition ranges are defined in Table 1. On based only on their geological position compared to other formations, dolomite Triassic limestone (F_1), Rhaetian limestone marl (F_2), Eocene marl (F_{11}) and topsoil Quaternary (F_{12}) were characterized separately. Geochemical discrimination between elements are generally used as a tool for geochemical interpretation and correlation. For the study area, as will be illustrated from the variation of their chemical composition and as exhibited in Table 1, reflecting varying environments of deposition for the recorded facies in the Elmashar quarry (Fig. 1a). The distribution of values of major oxides varies greatly, which proves and indicated the lateral and vertical irregularity of the limestone deposit. Despite the variation of minor oxides include alkali (Na_2O and K_2O) and SO_3, they present in low concentrations.

4.2. Chemistry of dolomite Triassic limestone (F_1)

Yellowish to brownish color, these dolomites are organized in decimetric benches (0.5 to 1m) alternating locally with inter-stratified dolomitic interval or in the form of gutters. The soft Triassic formation in the study area were discarded by this geochemical assessment study, because the complete chemical analyses of the dolomite samples showed that it contained a very high MgO ratio of 16.34% (the MgO ratio should be less than 5% in general and should be less than 3% in some cements).

Table 1. Chemical analyses of the El Mashar Unit

Facies		F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}
Number of samples		13	166	232	34	121	174	167	101	408	198	5	18
SiO_2 (%)	Mean	1.57	10.44	1.26	0.91	3.01	0.77	4.19	8.50	15.06	8.24	42.03	51.03
	Min	0.91	0.44	0.00	0.00	2.01	0.00	2.02	6.10	11.00	6.01	27.30	25.29
	Max	3.44	51.70	1.99	1.85	5.93	1.97	5.98	10.99	19.97	10.99	66.92	74.63
	Stdev	0.73	8.89	0.50	0.51	0.94	0.57	1.17	1.50	2.51	1.51	15.88	15.55
Al_2O_3 (%)	Mean	0.41	2.43	0.58	0.42	0.96	0.38	1.12	1.88	2.30	1.87	3.24	11.58
	Min	0.26	0.15	0.22	0.23	0.36	0.04	0.37	0.94	0.98	0.85	1.95	1.72
	Max	0.77	12.14	1.19	0.75	2.32	0.82	3.83	3.45	5.21	3.63	4.68	18.10
	Stdev	0.16	2.31	0.15	0.15	0.34	0.14	0.49	0.55	0.52	0.67	1.23	4.94
Fe_2O_3 (%)	Mean	0.18	1.04	0.25	0.21	0.39	0.21	0.51	0.84	1.00	0.83	1.84	5.50
	Min	0.09	0.09	0.00	0.02	0.06	0.01	0.03	0.41	0.38	0.11	0.80	0.78
	Max	0.33	4.66	0.68	0.41	1.21	0.67	2.42	3.01	1.94	2.50	3.38	8.42
	Stdev	0.07	0.92	0.13	0.11	0.22	0.09	0.31	0.34	0.24	0.38	1.10	2.25
CaO (%)	Mean	34.87	44.19	54.87	54.09	53.40	50.15	52.08	43.29	42.01	48.38	27.72	11.66
	Min	29.78	20.80	53.19	50.48	48.92	45.14	39.62	37.77	35.52	38.46	10.31	0.40
	Max	40.50	55.20	57.01	55.86	56.00	54.86	55.23	52.54	49.20	54.42	39.57	39.15
	Stdev	2.87	7.68	0.63	1.24	1.45	2.14	2.20	2.49	2.35	2.84	12.33	11.66
MgO (%)	Mean	16.34	2.97	0.36	1.23	0.69	5.04	1.01	5.68	2.74	1.44	1.24	1.84
	Min	11.80	0.49	0.05	0.71	0.12	2.03	0.31	4.03	0.59	0.44	0.66	0.93
	Max	20.70	14.20	0.66	1.92	3.85	8.88	3.92	8.97	7.24	3.97	1.78	3.28
	Stdev	2.24	2.59	0.10	0.40	0.80	1.92	0.89	1.21	1.20	0.89	0.43	0.74
LOI (%)	Mean	46.08	37.66	42.33	42.71	41.17	42.81	40.71	39.21	36.15	38.74	22.20	15.16
	Min	44.78	20.40	40.23	41.06	37.86	40.23	38.63	28.40	28.89	35.23	12.26	5.57
	Max	47.28	44.72	44.35	46.20	42.86	44.75	48.50	42.88	41.60	43.00	27.35	31.08
	Stdev	0.78	5.04	0.59	0.90	1.00	0.73	1.26	1.65	1.80	1.32	6.09	7.97
SO_3 (%)	Mean	0.13	0.14	0.06	0.11	0.08	0.14	0.07	0.07	0.10	0.11	0.20	0.58
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.45
	Max	0.67	1.45	0.46	0.59	0.65	0.56	0.48	0.69	0.55	0.70	0.42	0.66
	Stdev	0.21	0.23	0.09	0.15	0.13	0.16	0.09	0.11	0.13	0.13	0.15	0.11
K_2O (%)	Mean	0.11	0.70	0.08	0.05	0.07	0.04	0.08	0.14	0.23	0.12	0.54	2.17
	Min	0.05	0.04	0.03	0.03	0.00	0.01	0.03	0.03	0.01	0.03	0.03	0.56
	Max	0.20	3.26	0.23	0.18	0.40	0.15	0.52	0.82	1.18	0.96	0.84	4.22
	Stdev	0.04	0.62	0.06	0.05	0.09	0.02	0.11	0.23	0.31	0.20	0.33	1.00
Na_2O (%)	Mean	0.32	0.15	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.01	0.16
	Min	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Max	0.69	0.61	0.46	0.15	0.40	0.14	0.43	0.50	0.55	0.20	0.03	1.26
	Stdev	0.17	0.13	0.06	0.03	0.04	0.02	0.04	0.05	0.07	0.02	0.02	0.28

4.3. Chemistry of Rhaetian limestone marl (F_2)

This facies is grouped in a series of limestone benches and dololomie alternating with thinner and discontinuous benches of blackish marl. The dolomitic beds predominate at the base of the series and enrichment limestone gradually to the top of the series where the limestone is becoming more dark gray slate with a side marking the transition to the Hettangian limestone. From the Table 1 it appears that all oxides display greater chemical variations. The Rhaetian limestone marl shows a wide range of variation in SiO_2 (0.44% to 51.70%), Al_2O3 (0.15% to 12.14%), Fe_2O3 (0.09% to 4.66%), CaO (20.80% to 55.20%), MgO (0.49% to 14.20%) and LOI (20.40% to 44.72%).

4.4. Chemistry of Hettangian nodular limestone (F_3)

The nodules are visible only in partly weathered sections or after exploitation and appear darker than the brunatre background sediment. The nodular limestone beds maintain gradational contact with the underlying and overlying facies. This facies (F_3) is organized in a power masse of 4-20 m and is positioned between the Hettangian limestone with low magnesium (F4) in form of beds and Hettangian limestone with silica. As shown from the Table 1, this limestone (F_3) is homogeneous in chemical composition. The average wt% values of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO and LOI of the studied limestone are respectively 1.26%, 0.58%, 0.25%, 54.87%, 0.36% and 42.33%. From the result, we can consider that chemical variations in all the oxides are very little. This facies is rich in CaO and poor in MgO and SiO_2. The excess of lime is present in the form of calcite.

4.5. Chemistry of Hettangian limestone with low magnesium (F_4)

It contains two types of limestone: massive limestone in form of beds creams and the brown dolomites in form of lenticular enclaves in the dominant massive limestones giving the rock a brecciated appearance. The enclaves of dolomites and massive limestones form two distinct materials separated by sharp contacts. Form Table 1, Hettangian limestone with low magnesium (F_4) shows a homogeneous chemical composition in SiO_2 (0% to 1.85% with an average 0,91%), Al_2O_3 (0,23% to 0,75% with an average 0,42), Fe_2O_3 (0,02% to 0,41% with an average 0,21%), CaO (50,48% to 55,86% with an average 54,09%), MgO (0,71% to 1,92% with an average 1,23%) an LOI (41,06% to 46,20% with an average 42,71%). This facies is also rich in CaO, contain low amount of magnesium and poor in SiO_2.

4.6. Chemistry of Hettangian limestone with silica (F_5)

This facies is a hard silicified limestone clear yellow, where quartz is present as grains or small centimetric veins. From the analyses of Hettangian limestone with silica (F_5) presented in Table 1, it appears that SiO_2 ranges from 2.01% to 5.93%, Al_2O_3 from 0.36% to 2.32%, Fe_2O_3 from 0.06% to 1.21%, CaO from 48.92% to 56%, MgO from 0.12% to 3.85% and LOI from 37.86% to 42.86%.

4.7. Chemistry of Hettangian limestone with high magnesium (F_6)

This facies (F_6) gray in color and more compact, it crowns the Hettangian limestone formation. The passage between the limestone with silica (F_5) and this facies is gradual and is not front, as seen from Table 1, geochemical analysis results of samples indicated that this limestone shows also a low range of variation in SiO_2 (0% to 1.97%), Al_2O_3 (0.04% to 0.82%), Fe_2O_3 (0.01% to 0.67%), CaO (45.14% to 54.86%), MgO (2.03% to 8.88%) and LOI (40.23% to 44.75%). This facies is characterized by high content in magnesium compared to others Hettangian limestones.

Although the Hettangian formation in the study area is lithologically homogeneous and typically constituted of high grade limestones. The SiO_2 content is relatively low and variable for each microfacies. This is due to the state of bedrock, which is fractured and affected locally by karst erosion close to the surface, especially near the tectonic discontinuity and the bedding planes. The lithologie, porosity and morphology of these microfacies can also accentuate the karstification in the area. Similarly, the MgO content is variable for each microfacies. It is very low in the nodular limestone (F_3) and limestone with low magnesium (F_5), medium in the limestone with low magnesium (F_4) and higher in the limestone with high magnesium (F_6). This is due to the depositional environment conditions where limestone is sometimes exposed was affected by a secondary dolomisation.

4.8. Chemistry of Sinemurian brecciated limestone (F_7)

Brecciated limestone bar (F_7): Describe in the North of Elmashar foramion (scale of DERSA III to North Col Bab Aonsar in the Haouz Dorsale Calcaire) as tectonic breccias. It is a conglomerate as a big plus frankly discordant flap on the Hettangian dolomitized limestone (F_6) and contact with the lower part of basal Sinemurian limestone (F_8). This conglomerate is to intraformational angular elements made of white limestone massif and rare flint nodules. The contents of oxides show large variations, as the Table 1 below demonstrates . SiO_2 varies from 2.02% to 5.98%, Al_2O_3 from 0.37% to 3.83%, Fe_2O_3 from 0.03% to 2.42%, CaO from 39.62% to 55.23%, MgO from 0.31% to 3.92% and LOI from 38.63% to 48.50%.

4.9. Chemistry of basal Sinemurian limestone (F_8)

Thin micritic limestone benches and thicker compared to the central Sinemurian limestone (F_9). It is of greenish gray color and speckled with rare centimetric benches of flint. These benches are dolomitized and devoid of sedimentary structures. From the Table 1 it is clear that the contents of oxides show large variations whose SiO_2 ranges from 6.10% to 10.99%, Al_2O_3 from 0.94% to 3.45%, Fe_2O_3 from 0.41% to 3.01%, CaO from 37.77% to 52.54%, MgO from 4.03% to 8.97% and LOI from 28.40% to 42.88%.

4.10. Chemistry of central Sinemurian limestone (F_9)

This facies (F_9) is spotted on the surface by depressions having undergone alteration and erosions giving dissolution of limestone. The flint by its hardness has not been completely eroded. These depressions have resulted in the formation of clay containing blocks of limestone and beds of flint. In the lower part after pickling the clay party, this facies is present in form the gray-green benches with centimeter intercalations of dark flint beds up to 20 cm. The central Sinemurian limestone (F_9) is very affected by tectonic manifesting by the dislocation of lamination with disharmonic microfolds. Sometimes these microfolds are affected by fault, these flint benches were awarded to the formation of chert type. Chemical analyses of this facies given in Table 1 display a wide range of variation in all oxides. The SiO_2 ranges from 11% to 19.97, Al_2O_3 varies from 0.98% to 5.21%, Fe_2O_3 varies between 0.38% to 1.94%, the lime content (CaO) in this limestone varies widely, ranging from 35.52% to 49.20%, which is contributed by calcite present in the limestone. MgO ranges from 0.59% to 7.24% and LOI varies also largely from 28.89% to 41.60%).

4.11. Chemistry of sommital Sinemurian limestone (F_{10})

It is in the form of bedded thin limestone benches (10 to 20cm) red with thin greenish levels and reduced extensions (8m in average) and disappears in some level of the quarry. Chemical analyses given in Table 1 revealed that this limestone is almost similar of S basal in SiO_2 (6.01%-10.99%) and Al_2O_3 (0.85%-3.63%). Fe_2O_3 ranges from 0.11% to 2.5% and CaO from 38.46% to 54.42%. But compared to S basal , this limestone shows relatively low contents of MgO (0.44% to 3.97%) and high content of LOI (35.23% to 43%).

Geochemical analysis of Sinemurian limestone showed that the levels of SiO2 and MgO reach important values. The presence of flint kidneys or in the form of narrow parallel stratification bands indicates a heterogeneous distribution of SiO2 in the siliceous limestone. The distribution of MgO in the siliceous limestone also seems to be quite heterogeneous and high levels exist at the contact with the high grade limestone

4.12. Chemistry of Eocene marl (F_{11})

Eocene marl (F_{11}) identified only in one place in the career (East portion of level 2). Succeeding the sommital Sinemurian limestone (F_{10}), this calcareous marl is in form of a delicate matrix, greenish gray color containing a subrounded limestone with pebble of flint and Hettangian limestone. Larger chemical variations in some oxides have been noticed in this facies as shown in Table 1. The SiO_2 content varies widely from 27.30% to 66.92%, Al_2O_3 from 1.95% to 4.68%, Fe_2O_3 from 0.80% to 3.38%, CaO from 10.31% to 39.57%, MgO from 0.66% to 1.78% and LOI from 12.26% to 27.35%.

4.13. Chemistry of Quaternary topsoil (F_{12})

The Quaternary topsoil (F_{12}) is very rich in SiO_2 (51.20%) and Al_2O_3 (3.89%) reflecting their clayey nature overlaying other formations in some parts especially the formations with flint being flush in the top of quarry. Although that this material can be added to raw, the factory in order to protect resources and environment, he preferred to strip and put this vital matter to stockpile for use in the rehabilitation of the quarry.

5. Suitability of limestone of the Elmashar deposit for cement manufacturing

From the chemical composition of different types of limestone in studied area (Table 1), it's evident that for the manufacturing of Portland cement, some quantity of clay, sand and iron must be added to compensate for the percentage of silica, alumina, and iron oxides for the suitable limestones. The content of volatile components (K_2O, Na_2O, and SO_3) is low too in all samples that will not have a meaningful effect on the final quality of the cement produced or on the manufacturing process. Consequently The alkalis in this limestone are in smaller quantities which make it suitable for all types of cements.

Dolomite Triassic limestone (F_1) has low grade lime and very high contents of magnesia, which it's no suitable for cement manufacturing. Rhaetian limestone marl (F_2) contains a comparatively with great content of silica and alumina and a smaller amount of calcium, which makes it more important for making high strength Portland cement. The silica and alumina contents of the Rhaetian limestone marl (F_2) can contribute of reduction of quantity of clay in raw mixture. Hettangian nodular limestone (F_3) and Hettangian limestone with silica (F_5) have very high lime contents and low silica, and magnesium contents, they are very suitable for cement manufacturing. Hettangian limestone with low magnesium (F_4) has very high lime contents, very low silica contents and contents in magnesium. Hettangian nodular limestone (F_3), Hettangian limestone with low magnesium (F_4) and Hettangian limestone with silica (F_5) have suitable for Portland cement manufacturing. Hettangian limestone with high magnesium (F_6) is characterized by high content in magnesium compared to others Hettangian limestones is suitable for cement manufacturing, but the limit of magnesium in preparing high strength Portland cement from this limestone cannot be satisfied by mixing with other high grade limestone in CaO and poor in magnesium. The only solution to this. Sinemurian brecciated limestone (F_7) has high lime contents, medium content of silica and low contents of mangnsium. It is suitable for cement making. Basal Sinemurian limestone (F_8) and sommital Sinemurian limestone (F_{10}) are similar in high contents of but comparatively the basal Sinemurian limestone is rich in magnesium and sommital Sinemurian limestone is rich in CaO. The basal Sinemurian limestone is similar to the Hettangian limestone with high magnesium (F_6) in magnesium contents. its use in cement manufacturing is not possible, except by mixing with the high grade lime from the study area. The sommital Sinemurian limestone show limits admissible in cement making. The central Sinemurian limestone (F_9) is a siliceous limestone have a greater percentage of silica. The siliceous limestone which were considered as waste rock in various limestone mines, can be effectively utilized not only for conservation of mineral resources, but also for sustaining environment [12]. Because of the high silica contents of the sommital Sinemurian limestone (F_9), its use in cement manufacturing is not possible, except by mixing with the high grade lime from the study area. Eocene marl (F_{11}) has very high silica content and low contents of lime. It is no suitable to cement manufacturing, except by mixing with the high grade lime from the study area. Quaternary topsoil (F_{12}) is very rich in silica and alumina contents. It is suitable for cement making to replacing clay but the factory in order to protect resources and environment, he preferred to strip and put this vital matter to stockpile for use in the rehabilitation of the quarry.

These results condition the deposit operating method and the establishment of raw. The contents of the deposit SiO_2 and MgO should be strictly controlled during processing to control variations. In particular, in areas with high concentrations and According to Moroccan standard specifications, simultaneously mixing several quality of limestone especially siliceous limestone, limestone with high magnesium and high grade limestone by exploiting several benches at the same time. All of they need to be mixed between them and with a proportion of clay, and iron oxide to be suitable for cement production.

6. Conclusion

The homogeneity, heterogeneity and quality of the limestone reserves were confirmed by chemical analysis of samples taken from cuttings of drillings in our study. Based mainly on silica contents, magnesium and calcium, the studied limestones are variable in chemical composition which are divided in twelve facies. Because of its chemical composition, Trias limestone (F_1) cannot be used in the raw and must therefore be discarded. However, the topsoil should (F_{12}) be removed and stored in a suitable location in order to be used in the future career rehabilitation plan. The others facies (F_2 to F_{11}) are suitable for the manufacturing of Portland cement. Consequently, some additional studies of raw meal design must be made to complement the information available on the appropriate limestones to maximize the available reserves and protect the resources and environment.

References

[1] Lea FM. The Chemistry of Cement and Concrete. 3rd Edition. London U.K: Edward Arnold Publishers Li-mited; 1970.
[2] Özgüner AM. Prospection of Portland cement raw material: A case study in the Marmara region of Turkey. Journal of African Earth Sciences 2014; 97: 230-243.
[3] Shah MT, Fayez A, Ali L. Chemical Study of the Raw Material in Gandghar Range, District Haripur, NWFP, for Portland Cement Manufacturin. Journal of Chemical Society of Pakistan 2007; 29(2):103-109.
[4] Khurshid A, Noor-ul-Amin, Tahir Shah M. Chemical study of limestone and clay for cement manufacturing in Darukhula Nizampur, Nowshera District, N.W.F.P., Pakistan [J]. Chinese Journal of Geochemistry 2008; 27:242-248.
[5] Aloui T, Ounis A, Chaabani F. Maastritchian Limestones of Feriana Mountain used in White Cement Production (Central West Tunisia). Journal of the American Ceramic Society 2008; 91(11):3704-3713.
[6] Noor-ul-Amin, Tahir S, Khurshid A. Raw mix designing, clinkerization and manufacturing of high-strength Portland cement from the limestone and clay of Darukhula Nizampur, Nowshera District, North-West Frontier Province (N.W.F.P.), Pakistan, Chinese Journal of Geochemistry 2009; 28:279-283.
[7] Moroccan standard NM 10.1.004. Binders Hydraulic-Cement-Composition, specifications and conformity criteria REV. Morocco: Moroccan Industrial Standards Service (SNIMA); 2003.
[8] Chalouan A, Michard A, El Kadiri K, Negro F, Frizon de Lamotte D, Soto JI, Saddiqi O. The Rif. In: Michard A, Saddiqi O, Chalouan A, Frizon deLamotte D, editors. Continental Evolution: The Geology of Morocco – Structure,Stratigraphy, and Tectonics of the Africa–Atlantic–Mediterranean Triple Junction. Springer; 2008. p. 203-302.
[9] Vitale S, Zaghloul MN, Tramparulo FDA, El Ouaragli B, Ciarcia S. From Jurassic extension to Miocene short-ening: An example of polyphasic deformation in the Exter-nal Dorsale Calcaire Unit (Chefchaouen, Morocco). Tecto-nophysics 2014; 633:63-76.
[10] Vitale S, Zaghloul MN, Tramparulo FDA, El Ouaragli B. Deformation characterization of a regional thrust zone in the northernRif (Chefchaouen, Morocco). Journal of Geodynamics 2014; 77:22-38.
[11] El Talibi H, Zaghloul MN, Perri F, Aboumaria K, Rossi A, El Moussaoui S. Sedimentary evolution of the siliciclastic Aptian–Albian Massylian flysch of the Chouamat Nappe (central Rif, Morocco). Journal of African Earth Sciences 2014; 100:554-568.
[12] Rao DS, Vijayakumar TV, Prabhakar S, Bhaskar Raju G. Geochemical assessment of a siliceous limestone sample for cement making. Chinese Journal of Geochemistry 2011; 30:33-39.